

Crop Yields During Ten Years of Organic and Conventional Cropping Systems

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Problem

- Organic agriculture is increasing in popularity in the United States, yet there are few comparisons of crop yields in organic and conventional cropping systems.
- Crop yields, especially in dryland agriculture, vary considerably from year to year in response to variability in weather and to management considerations.
- Long-term comparisons of crop yields in organic and conventional cropping systems are not well characterized.

Objective

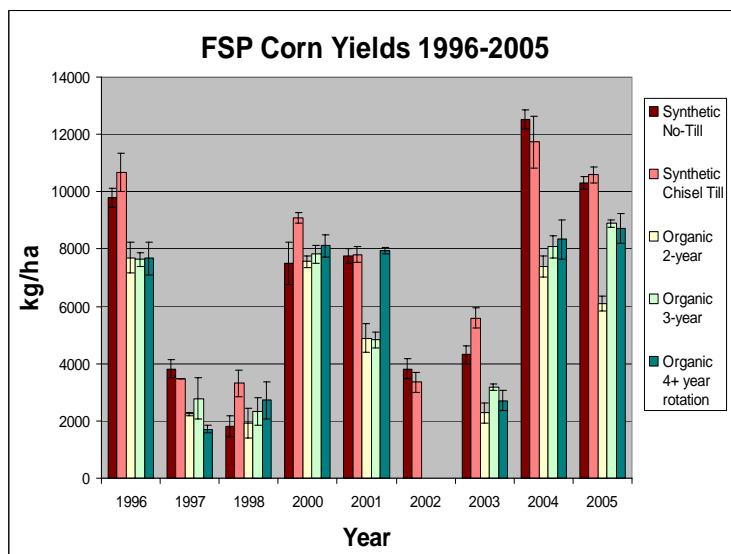
- Compare crop yields (corn, soybean, wheat) among no till, chisel till, and organic cropping systems.

Approach

- Crops in conventional systems are managed in accordance with prevailing practices with input from University of Maryland specialists.
- Crops in organic systems are managed in consultation with local organic farmers.
- Row crop yield data are taken from the center rows of each plot each year using commercial size combines with weighing scales. Hay yields are taken from the entire plot area using commercial size hay-harvesting equipment. Hay bales and haylage are weighed on a farm scale at the nearby dairy.

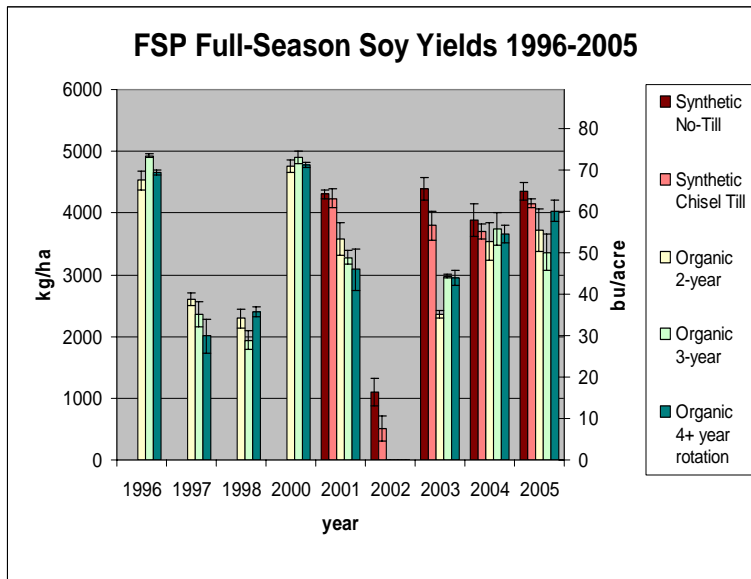


Results



- Corn yields vary considerably by year; 1997, 1998, 1999 (no grain harvested in 1999) and 2002 yields reflect drought years; 2003 yields reflect the second wettest year on record.
- Organic corn yields are generally lower than conventional corn yields due to challenges with cover crop and weed management in organic systems.
- Increasing crop rotation length among organic systems seems to result in a slight increase in corn yields.

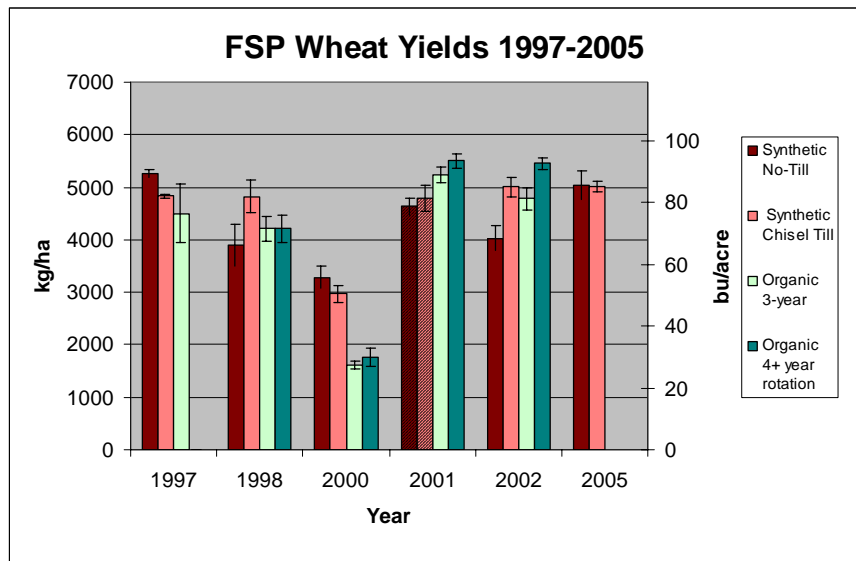
- Soybean yields vary considerably by year reflecting dry and wet years as for corn, but variability is not as great as for corn.



- Organic soybean yields are lower or equal to conventional soybean yields. Lower yields are due to challenges with weed management in organic systems.
- The smaller differences in yields between organic and conventional crops for soybeans compared to corn may be due to not needing to provide an external source of nitrogen for soybeans.

- Increasing crop rotation length among organic systems does not seem to have a consistent effect on soybean yields.

- Due to wet fall weather, wheat was not planted in 2002 and 2003 in all systems and in 2004 in the organic systems (soybean planting, and therefore harvest, in organic systems is often later than in conventional systems).



- Wheat yields vary less by year than do corn and soybean yields.
- Conventional and organic wheat yields are generally similar.
- Increasing crop rotation length between organic systems seems to have a slight positive effect on wheat yields.

Future Research

- Continue taking crop yield measurements, including SPAD measurements of corn and wheat to monitor crop N status.
- Summarize and publish 10-year yield results in 2006.

An Economic Comparison of Cropping Rotations in the Beltsville Farming Systems Project

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Problem

- Information on costs and returns of alternative cropping systems are necessary for producers to make decisions on adoption.
- There are a limited number of economic comparisons of organic and conventional cropping systems, especially in the mid-Atlantic region.

Objectives

- Develop an analytical framework for comparing costs and returns among cropping systems in the Farming Systems Project.
- Compare costs and returns among FSP cropping systems for initial cropping years.

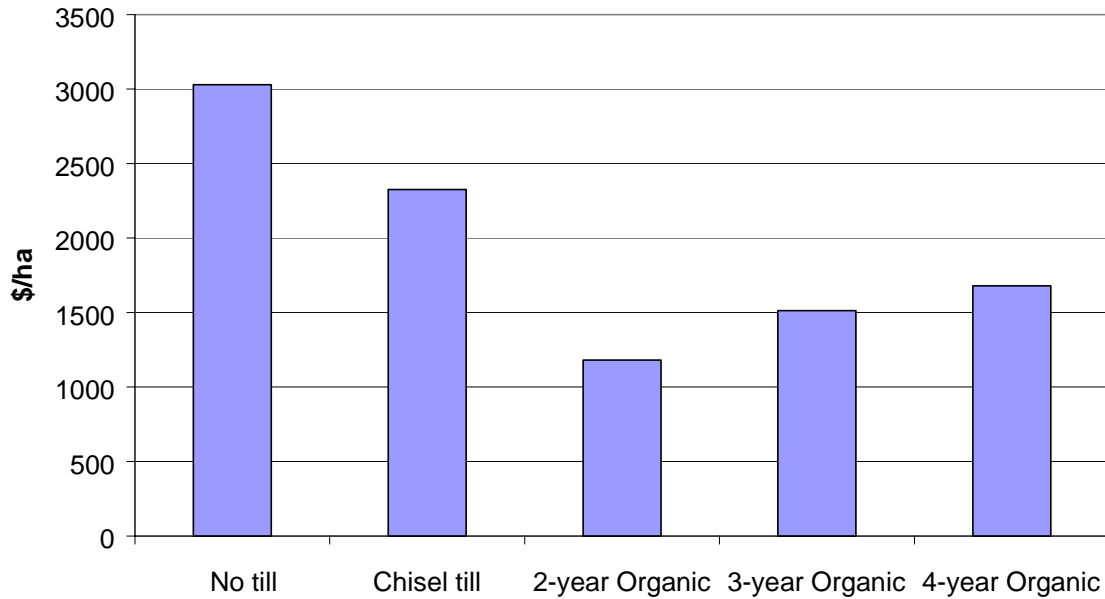
Approach

- Obtain records of field activities for cropping systems, 1996, 1997, 2000 and 2001.
- Using market information, assign costs for farm inputs and activities and prices for farm products.
- Create enterprise budgets for marketable crops.
- Calculate net returns by crop and by system.
- Make comparisons on annual and long-term bases.

Initial Results

- Conventional no till cropping system consistently shows greatest returns among cropping systems, on a crop-by-crop or a whole system basis. Since the FSP site had been under no till management for at least 11 years prior to plot establishment, all plots but the no till plots were in a transition period during the initial years of the study.
- While some systems had negative returns for individual crops in some years, all systems had positive returns in all years on a whole system basis.
- Organic systems tend to show a positive relationship between rotation length and economic returns.
- Returns for 3- and 4-year organic systems were greater than for conventional no till in some years and some crops.

Net Present Value of Returns (Cumulative over 4 years)



Future Research

- Conduct similar analyses for cropping systems from 2001 to 2005.
- Incorporate organic price premiums into the analysis.
- Impose agricultural conservation policy scenarios that may affect comparative economic results.
- Include environmental costs and benefits that are not accounted for in traditional economic analysis, in order to make a more accurate comparison of alternative cropping systems.

Publications and Presentations

- 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.
- Hima, B. L., M. A. Cavigelli, Y-C. Lu, and J. Teasdale. 2005. A comparative economic analysis of the Farming Systems Project, Beltsville, MD. American Society of Agronomy Annual Meeting, Salt Lake City, UT, 2005.

Weed Abundance, Community Structure, and Crop Yield Loss Relationships

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Problem

- Weeds represent a significant threat to all cropping systems and have been identified as the most important management issue of organic farmers.
- The species composition of a weed community changes in response to management, soil, and weather conditions.
- It has been hypothesized that crop yield loss due to weeds is lower in organic than in conventional systems because of less accessible soil resources early in the season in organic systems.

Objectives

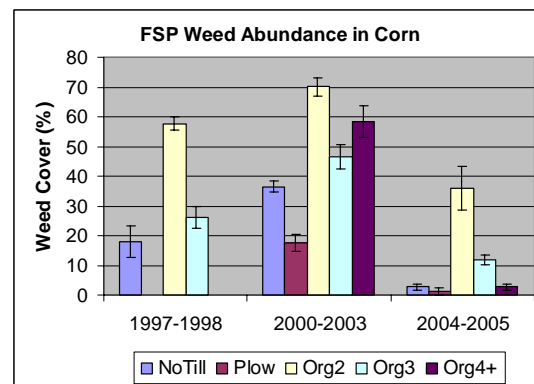
- Document the abundance and species distribution of weeds in the major crops present in all FSP cropping systems: corn and full-season soybeans.
- Estimate crop yield losses due to weeds in these FSP cropping systems.

Approaches

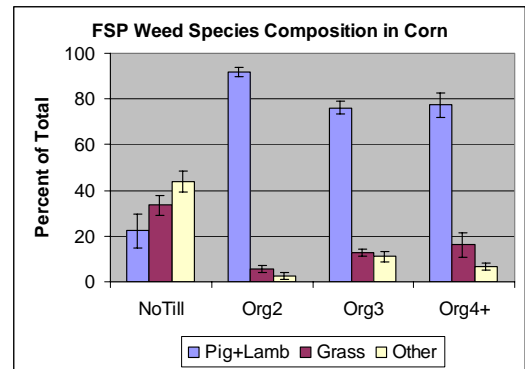
- Visual ratings of the percent soil covered by weeds and the percent weed biomass by species were made in each quadrant of each plot in corn and full-season soybeans at weed maturity (September).
- Adjacent weedy and weed-free subplots (four rows by 20 ft) were established in spring in plots with significant weed populations in areas with uniform crop stands. The middle two rows of the weedy subplot were visually rated in the same way as the whole plots. Weed biomass and crop yield were determined from the middle two rows of each subplot. From these data, relationships between cover ratings and weed biomass and between weed biomass and crop yield loss were established. Using these relationships, yield losses for the whole plots were estimated from cover ratings.
- In 2001 and 2002, subplots with uniformly seeded populations of smooth pigweed were established in all systems to attempt a more precise estimation of corn yield loss in organic and conventional systems.

Results

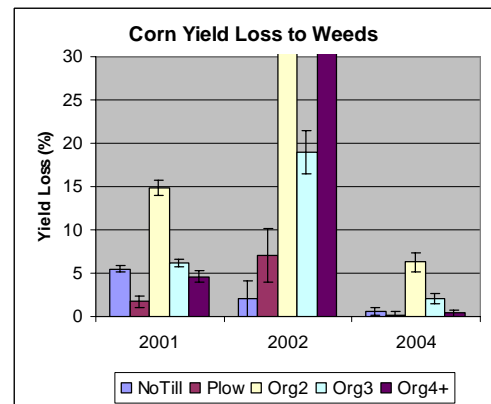
- Weed percent cover in corn was highly variable depending on cropping system and year. Weed control failures reflected changes in system management and weather variability over the course of the study. Failures of weed control in the organic systems during 2000-2003 resulted from use of a reduced till system and wet spring weather. Management changes in all systems led to improved weed control that is more representative of these systems in 2004-2005. Results for soybean plots were similar.



- Weed control in corn and soybean in the organic system with the longer hay rotation was usually better than that in the shorter organic rotations, and was comparable to that in herbicide based systems in corn in 2004-2005. A lower weed seedbank in the longer rotation is discussed in the seedbank presentation.
- Averaged over all years, the organic systems were dominated by pigweed and lambsquarters whereas the no till system was dominated by grasses and miscellaneous other species, primarily perennials (dandelion, mulberry, horsenettle, etc.). The relative numbers of the warm-soil favoring species (pigweed) and the cool-soil favoring species (lambsquarters) in the organic systems fluctuated depending on spring weather relative to the time of soil disturbance.



- A multiple regression analysis of covariance showed a linear relationship between weed biomass and percent cover rating as well as significant responses to the interaction between percent cover and crop, year, and percent of total cover as pigweed plus lambsquarters (results not shown).
- A multiple regression analysis of covariance showed a negative linear relationship between crop yield loss and weed biomass that was affected only by year. This analysis showed that yield loss was greatest in dry years (e.g. 20% per 100 g m⁻² of weeds in 2002) and least in years with adequate rainfall (e.g. 5% per 100 g m⁻² of weeds in 2004).
- Yield loss was not significantly influenced by system in this analysis suggesting that the rate of yield loss per unit of weed biomass was similar in all systems. Since there was a disproportionately higher range of weed biomass values in the organic than in the conventional systems this may not be a definitive analysis. Studies to address this disproportionality by establishing similar weed populations in all systems in 2001 and 2002 led to inconclusive results because of the high heterogeneity of subplot sites.
- Yield losses in conventional no till and chisel till systems were less than 5% in most years in corn and soybeans. Yield losses varied in organic systems depending on management and weather. High levels of yield loss were sustained in 2002 when weed control was poor and per unit yield losses were high. On the other hand, corn yield losses were less than 5% in the long rotation organic system in corn in 2001 and 2004 suggesting that, with good management, this system can function comparably to conventional systems.



Presentations

- Teasdale, J.R., and M.A. Cavigelli. 2003. Long-term organic farming systems research. ASA Organic Agriculture Symposium, Annual Meeting Abstracts CD-ROM, A08-teasdale370880-oral.

Soil and Nutrient Erosion Potential of Organic and Conventional Cropping Systems

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Problem

- While organic agriculture is increasing in popularity in the mid-Atlantic region and the rest of the United States, there are few data available to assess the environmental sustainability of organic cropping systems.
- A key measure of agricultural sustainability is soil and nutrient loss by erosion.
- Some researchers suggest that organic cropping systems have lower soil and nutrient erosion than do conventional cropping systems because organic systems rely heavily on organic matter inputs and cover crops. Others claim that organic systems have greater soil and nutrient erosion than conventional systems since they also rely heavily on tillage to control weeds.

Objectives

- Compare nutrient erosion risk using aggregate nutrient distribution data and the Water Erosion Prediction Project (WEPP) model in FSP 3-year crop rotations: organic (ORG), no till (NT) and chisel till (CT) systems.
- Compare soil data in cropping systems to that for a hardwood forest on the same soil type.

Approach

- Sample soil (0-5 cm depth) in the fall in FSP ORG, NT and CT cropping systems; and in a hardwood forest.
- Separate soil samples into five aggregate size classes (2-6, 0.5-2.0, 0.2-0.5, 0.05-0.2, and <0.05 mm) using wet sieving.
- Measure total carbon (C), nitrogen (N), and phosphorus (P) of each aggregate size class.
- Calculate aggregate nutrient distributions to estimate nutrient erosion risk.
- Use the WEPP model to predict soil erosion in each of the three cropping systems.
- Combine WEPP erosion predictions with aggregate associated nutrient concentrations to estimate nutrient erosion risk from the three systems.



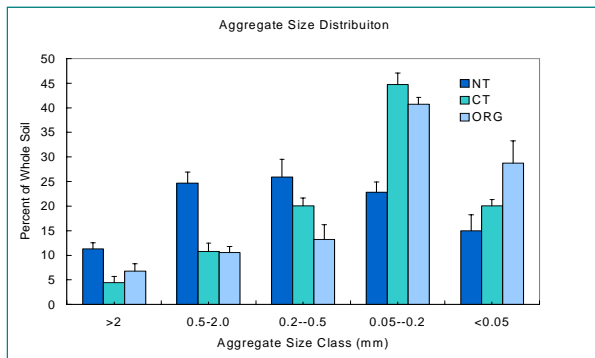
Results

Measured soil properties.

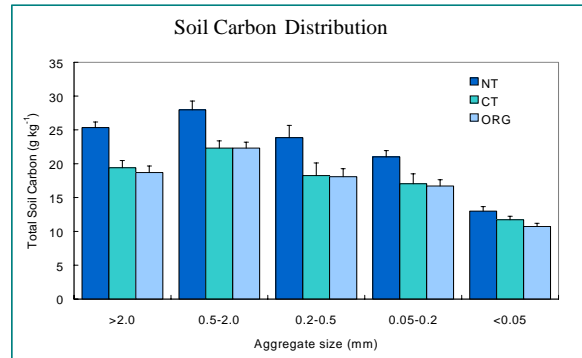
Cropping system	Total C	Total N	Total P	BD†	AS (MWD)	Macro-aggregates
	g kg ⁻¹	g kg ⁻¹	mg kg ⁻¹	Mg m ⁻³	mm	g g ⁻¹
No Till	23.6 a*§	1.8 a*	769 a*	1.37 b	0.74 a	0.62 a*
Chisel Till	16.7 b	1.5 b*	703 a*	1.53 a*	0.40 b*	0.35 b
Organic	16.5 b	1.5 b*	690 a*	1.53 a*	0.40 b*	0.31 b
Forest	18.0	0.66	196	1.30	0.74	0.45

† BD, bulk density; AS, aggregate stability; MWD, mean weight diameter.

§ Means followed by the same letter within a column are not significantly different at the $P < 0.05$ significance level. Means followed by an asterisk indicate that treatment is significantly different from the Forest treatment at the $P < 0.05$ level, according to separate t-tests.



A greater proportion of soil is in the micro-aggregate size range (≤ 0.2 mm) in CT and ORG soils than in NT soil. Microaggregates are more susceptible to erosion than are larger aggregates; thus, soil erosion risk is higher in CT and ORG than in NT.



Distributions of C, N and P among aggregate size classes were very similar; C data are shown above. Although nutrient concentrations are greater in macroaggregates than in microaggregates, nutrient erosion in these soils is influenced more by the size distribution of aggregates (left panel) than by their nutrient contents.

Soil and nutrient losses predicted by the WEPP model.

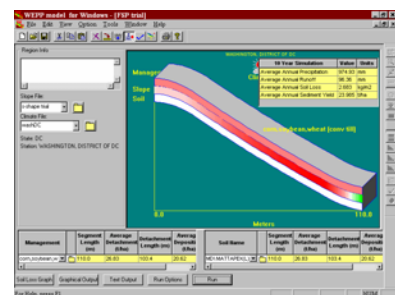
System	Runoff	Predicted soil erosion	Micro sediment	C	N	P
	mm y ⁻¹	Mg ha ⁻¹ y ⁻¹	%	kg ha ⁻¹ y ⁻¹		
NT	107	8.5	64	170	15	6
CT	116	64	65	1074	94	43
ORG	108	43	65	679	62	29

Tillage greatly increases soil erosion, resulting in increased aggregate associated nutrient erosion. Although soil physical properties were similar in CT and ORG, ORG makes use of cover crops during a greater portion of the rotation than CT, giving it much needed erosion control cover.

- No till cropping has lower soil and nutrient erosion potential than do either chisel till or organic systems.
- Predicted soil and nutrient erosion are lower in tilled organic cropping systems than in conventional chisel till systems.

Future Research

- Refine WEPP database to include cover crops and practices common to organic farming.
- Conduct soil erosion experiments on-site using rainfall simulators to evaluate WEPP soil erosion predictions and our nutrient erosion estimations.



WEPP model interface

Papers and Presentations

- Green, V.S., M.A. Cavigelli, T.H. Dao, and D.C. Flanagan. 2005. Total carbon, nitrogen, and phosphorus in soil aggregate size classes of organic and conventional cropping systems. *Soil Sci.* xxx:xx-xx (in press).
- Green, V.S., M.A. Cavigelli, T.H. Dao, and D.C. Flanagan. 2003. Cropping system effect on distribution of C, N, and P among aggregate size classes. ASA, CSSA, SSSA, annual Meeting Abstracts (CD-ROM), November 2-6, 2003, Denver, CO.

Soil Bioactive Phosphorus Dynamics in Aggregates: Implications for Eroded Sediments

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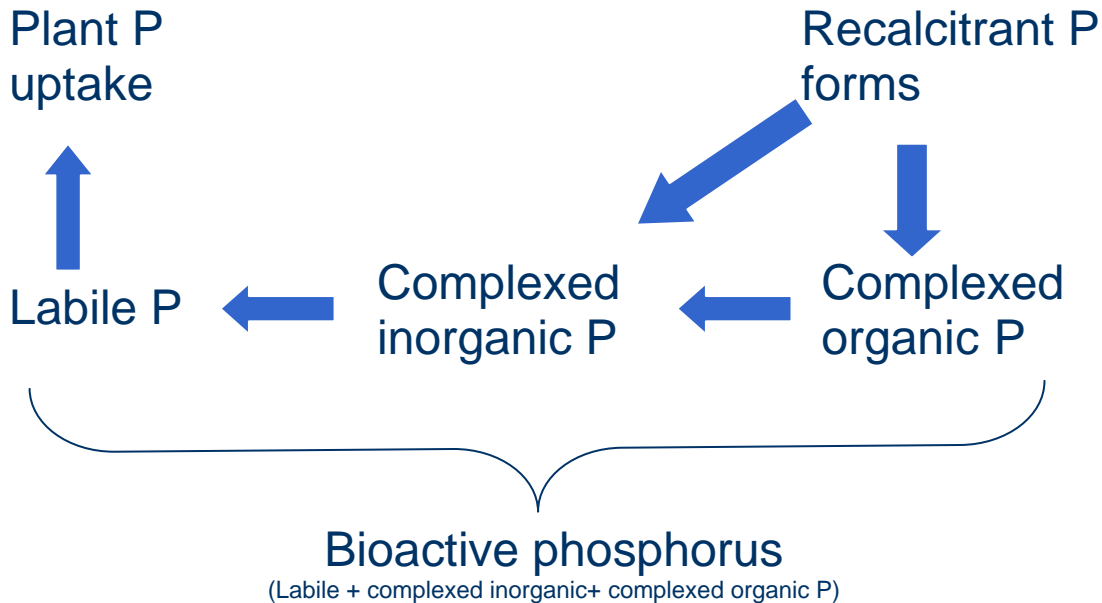
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Problem

- Particulate nutrient transport from agricultural fields contributes to water quality degradation.
- Traditional measures of soil phosphorus (P) such as total P or soil test P (STP) do not adequately predict the contribution of soil P to water quality degradation because these measures do not necessarily reflect soil P bioavailability.
- Measures of bioactive soil P may also not adequately predict the contribution of soil P to water quality degradation without accounting for the likely dynamic nature of these pools.

Soil P dynamics



Objectives

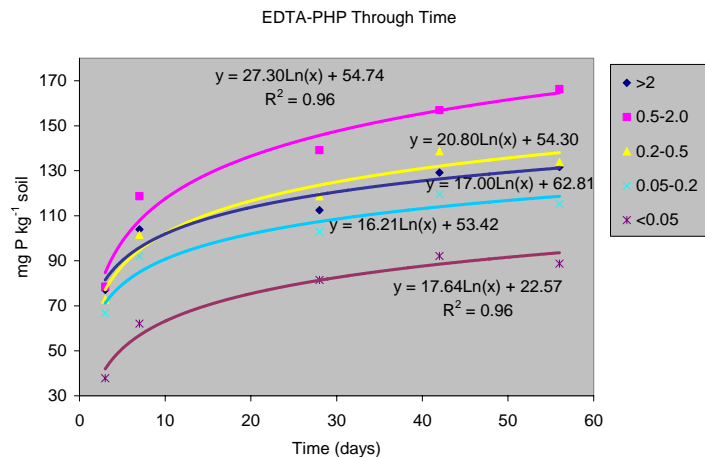
- To better understand P dynamics in soil and in potentially eroded sediments by characterizing soil bioactive P pool dynamics in five aggregate size classes.

Approach

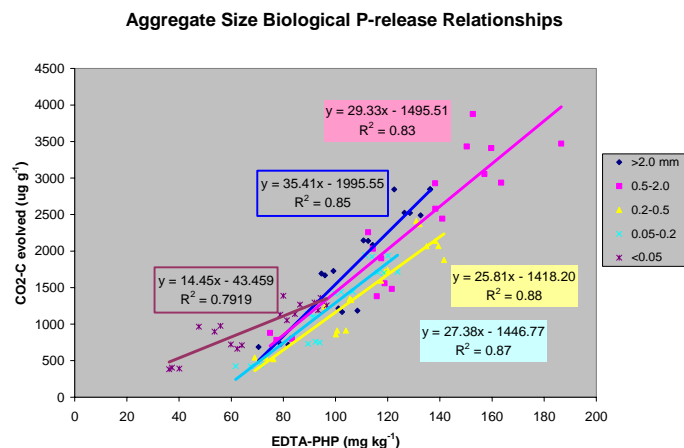
- Separate no till soil (0-5 cm depth) into five aggregate size classes (2-6, 0.5-2.0, 0.2-0.5, 0.05-0.2, and <0.05 mm) by wet sieving.
- Incubate 5 g sub sample of each aggregate size class in 1 L jars at 60% water filled pore space, 25 C in the dark for 56 d (3 replicates).
- Periodically sample jar headspace for CO₂ analysis to monitor biological activity.
- Periodically sample soil for bioactive P analysis:
 - water extractable P (WEP) represents labile P
 - EDTA extractable P (EDTA-P) represents complexed inorganic P
 - EDTA extractable, phytase hydrolysable P (EDTA-PHP) represents complexed organic P

Results

- Bioactive P represents 25 to 40% of total P.



While labile P and complexed inorganic P remained relatively unchanged during 8 weeks incubation (data not shown), complexed organic P increased substantially in all 5 aggregate size classes. This result indicates that recalcitrant P forms are being converted to complexed organic P, which is subject to release as labile P over time. Thus, EDTA-PHP measured in the field or in recently eroded sediments may underestimate bioactive P that may be released after soil aggregates are lost via erosion.



Strong correlation ($r^2=0.78$) between CO₂ evolution and EDTA-PHP accumulation through time (all aggregate sizes combined) indicates that changes in EDTA-PHP during incubations are the result of biological processes. Correlations by aggregate size reveal potential differences in biologically mediated P release dynamics among aggregate size classes, suggesting that P dynamics differ by aggregate size class.

Future Research

- Design studies to determine the parameters that affect organic P dynamics (temperature, soil moisture, texture, organic carbon) and quantify these effects.
- Conduct similar incubations on eroded sediments to quantify the water quality impact of soil erosion.

Papers and Presentations

- Green, V.S., T.H. Dao, M.A. Cavigelli, and D.C. Flanagan. 2006. Dynamics of soil bioactive P pools in aggregates of various sizes. *Soil Sci.* xxx:xx-xx (in preparation).
- Green, V.S., T.H. Dao, M.A. Cavigelli. 2005. Characterizing bioactive phosphorus of soil aggregates in conventional and manure-based cropping systems. In: C.J. Li et al (Eds), *Plant Nutrition for Food Security, Human Health and Environmental Protection*. Tsinghua University Press, Beijing, China. p. 1166-1167.
- Green, V.S., T.H. Dao, M.A. Cavigelli, and D.C. Flanagan. 2005. Aggregate associated C, N, and P dynamics. ASA, CSSA, SSSA, annual Meeting Abstracts (CD-ROM), November 6-10, Salt Lake City, UT.

Nitrogen Balance in Organic and Conventional Cropping Systems in the mid-Atlantic

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Problem

- A fundamental goal of sustainable agriculture is to minimize nutrient losses and increase internal nutrient cycling.
- The relative nutrient balance of organic and conventional cropping systems is not well documented.

Objectives

- Determine nitrogen (N) balance (N inputs-N outputs) for organic, low-input and conventional cropping systems during the first five years of the FSP.

Approach

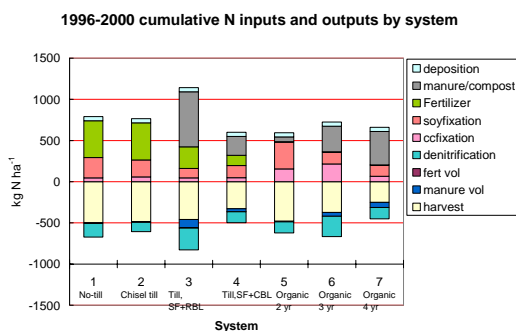
- Measure (M) or estimate (E; based on Meisinger and Randall, 1991) N inputs and outputs in six FSP cropping systems:
 - Inputs
 - Atmospheric deposition (M)
 - Manure and Compost N (M)
 - Fertilizer N (M)
 - Legume (soybean, cover crops) N fixation (E)
 - Outputs
 - Harvested N (M)
 - Fertilizer volatilization (E)
 - Manure volatilization (E)
 - Denitrification (E)

Systems:

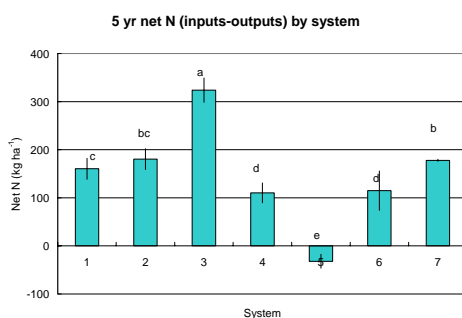
X- tillage type, N source

- 1- No-till, mineral fertilizer
- 2- Chisel till, mineral fertilizer
- 3- Tilled, mineral fertilizer & raw broiler litter
- 4- Tilled, mineral fertilizer & composted broiler litter
- 5- Tilled, legume & organic fertilizer, 2 yr organic rotation
- 6- Tilled, legume & raw broiler litter, 3 yr organic rot.
- 7- Tilled, legume & broiler litter, 4 yr organic rot.

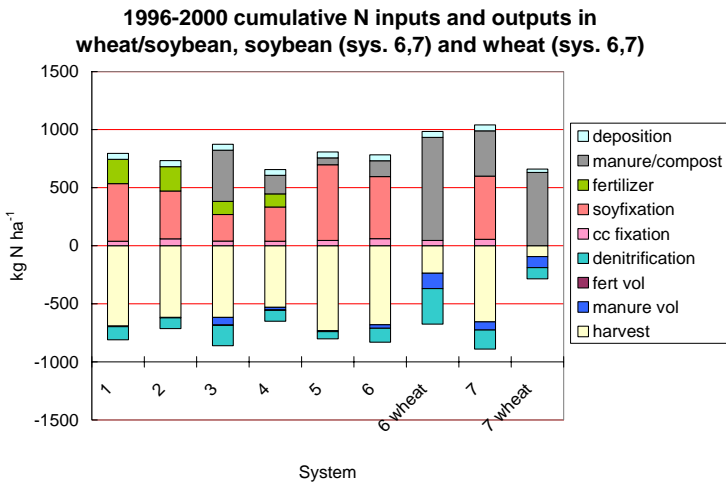
Results



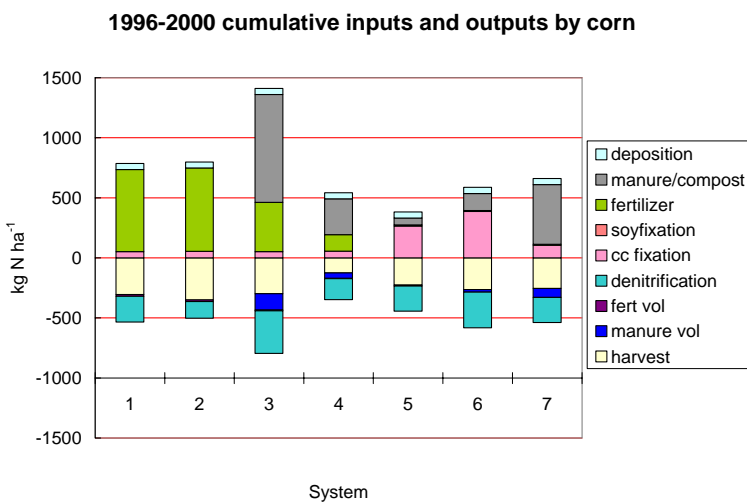
Atmospheric N losses were high when large amounts of raw broiler litter were applied.



N inputs were greater than N outputs in all systems except for the 2-year organic system. Net N in the low-input system with raw broiler litter was two to three times greater than in other systems. Positive N balance in cropping systems may lead to soil N retention and/or to nitrate loss by leaching, which is not included in this analysis.



N inputs tended to be similar to N outputs during the wheat/soybean and soybean phases of the rotations. N inputs were greater than N outputs during the wheat phase of the 3- and 4-year organic rotations due to relatively large manure inputs.



N inputs were greater than N outputs during the corn phase of the rotation for conventional and low-input systems. N inputs were similar to N outputs during the corn phase of the rotation for the organic systems.

Future Research

- Expand analysis to include all 10 years of FSP plot data.
- Analyze soil samples collected to 1 m depth in 1996, 2000 and 2005 for total soil N to help assess fate of net positive N balance.
- Analyze fall deep soil (1 m depth) nitrate data collected from 1996 to 2001 to estimate nitrate leaching potential in these cropping systems.
- Use measured soybean N fixation estimates to improve values for this parameter.
- Expand analysis to include C and P balance.

Papers and Presentations

- Cavigelli, M.A., V.S. Green, and J.J. Meisinger. 2004. Nitrogen balance in organic and conventional cropping systems. ASA, CSSA, SSSA, Annual Meeting Abstracts (CD-ROM), Seattle, WA.
- Green, V.S., M.A. Cavigelli, and J.J. Meisinger. 2004. Nitrogen balance in organic and conventional cropping systems in the mid-Atlantic region. Mid-Atlantic Ecological Society of America, Lancaster, PA.

Nitrogen Fixation of Soybeans in Organic and Conventional Cropping Systems

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Problem

- Sustainable agricultural production relies upon effective management of internal resources.
- Soybeans are capable of fixing greater than 300 kg ha⁻¹ y⁻¹ nitrogen, however, there is a substantial range in actual nitrogen fixation rates.
- It is not well understood how cropping systems affect N fixation and whether conventional and organic cropping practices result in different soybean N fixation.
- Measured N fixation estimates should increase the reliability of cropping system N balance estimates.

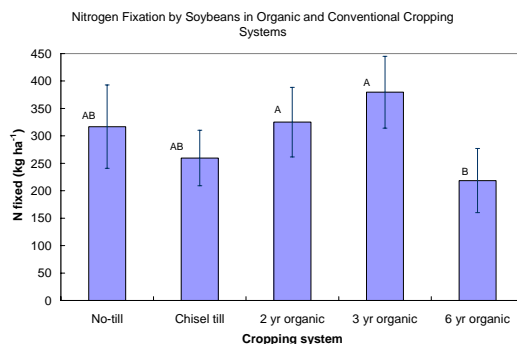
Objectives

- To determine the effect of organic and conventional cropping systems on the amount of nitrogen fixed by soybeans.

Approach

- N fixation estimated using nitrogen difference method
 - Nodulating (Williams 82) and non-nodulating (mutant, near isoline of Williams 82) soybeans were grown in adjacent microplots (4 rows x 5 m for each variety) in each of four replicates of five cropping systems (No till, Chisel till, 2-year Organic, 3-year Organic, 6-year Organic).
 - In 2004, a weedy and a weed free set of microplots were maintained in all plots. In 2005, only weed free microplots were established. Weeds were removed by hand in weed free microplots.
 - Just prior to leaf senescence, the above ground portion of the soybean plants was sampled (1 m section of row) for each variety in each plot.
 - Soybean plant sub-samples were ground and analyzed for total N.
 - Total above ground soybean plant N was calculated.
 - N fixed by the nodulating soybeans was calculated as the difference in aboveground plant N between nodulating and non-nodulating soybeans, with a correction made for the difference in soil N content between soybean planting and harvest.

Results 2004



- ◆ Nitrogen fixation ranged from 218 to 380 kg N ha⁻¹ in the FSP cropping systems in 2004.
- ◆ Nitrogen fixation was less in the 6 yr organic rotation than in the 2- or 3- yr organic rotations.
- ◆ Biomass N concentration averaged 3.7% for the nodulating soybean variety and 2.2% for the non-nodulating variety.

2005

No till plot



6-year organic plot



Non-Nodulating

Nodulating

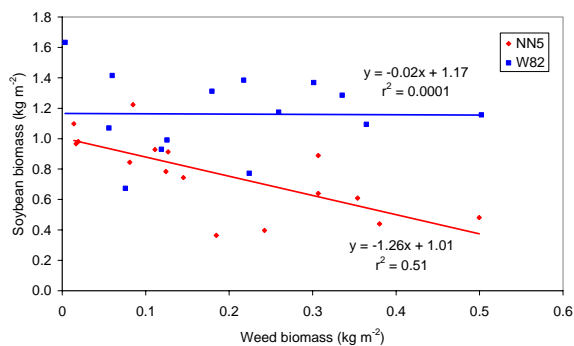
- ◆ Non-nodulating soybeans (left side of picture) do not fix nitrogen. The only nitrogen available to them is the nitrogen in the soil.
- ◆ The right side of the picture shows a near iso-line of the non-nodulating variety. It is a nodulating variety and fixes its own nitrogen as well as getting nitrogen from the soil.
- ◆ Note the color and biomass differences, which indicate that a large portion of the N utilization in soybeans in the no till plots is from N fixation.

Nodulating

Non-nodulating

- ◆ Non-nodulating soybeans, right side of picture, nodulating soybeans left side.
- ◆ These non-nodulating beans have greater biomass than the non-nodulating beans in the no till plots seen to the far left. This difference may be due to nitrogen enrichment of the soil due to three years of alfalfa in the organic rotation.
- ◆ The smaller difference in size between the two soybean isolines in the organic plot compared to the two isolines in the no till plot indicates that nitrogen fixation by soybean is much greater in the no till plot than in the organic plot in 2005.
- ◆ Treatment differences seem to be much greater in 2005 than in 2004.

Weed biomass vs. soybean biomass



- ◆ In 2004, weed biomass had no influence on biomass of the nodulating soybean (W-82); there was a relationship between weed biomass and biomass of the non-nodulating soybean isolate (NN5).
- ◆ These results show that soybean N fixation can help alleviate the competitive effect of weeds in soybean (at least during a year with adequate rainfall).

Future Research

- Complete 2005 data analysis.
- Investigate the cause of N fixation differences among cropping systems.

Papers and Presentations

- Green, V.S., M.A. Cavigelli, and J.J. Meisinger. 2006. Soybean nitrogen fixation in organic and conventional cropping systems in the mid-Atlantic. *Journal of Sustainable Agriculture* xx:xx-xx (in preparation).

Global Warming Potential of Organic, No Till, and Chisel Till Cropping Systems

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Problem

- Atmospheric concentrations of carbon dioxide (CO₂) and nitrous oxide (N₂O) are increasing and are implicated in global warming scenarios. N₂O is also a catalyst of stratospheric ozone degradation.
- Agriculture may help mitigate increases in atmospheric concentrations of CO₂ and N₂O by sequestering C in soil and by reducing soil N₂O fluxes.
- Organic farming may help mitigate global warming potential (GWP) since organic farming does not allow use of synthetic N fertilizers and since management of soil C is a central tenet of organic farming. However, there are few long-term cropping systems that include organic, no till and chisel till cropping systems where this hypothesis can be tested.

Research Objectives

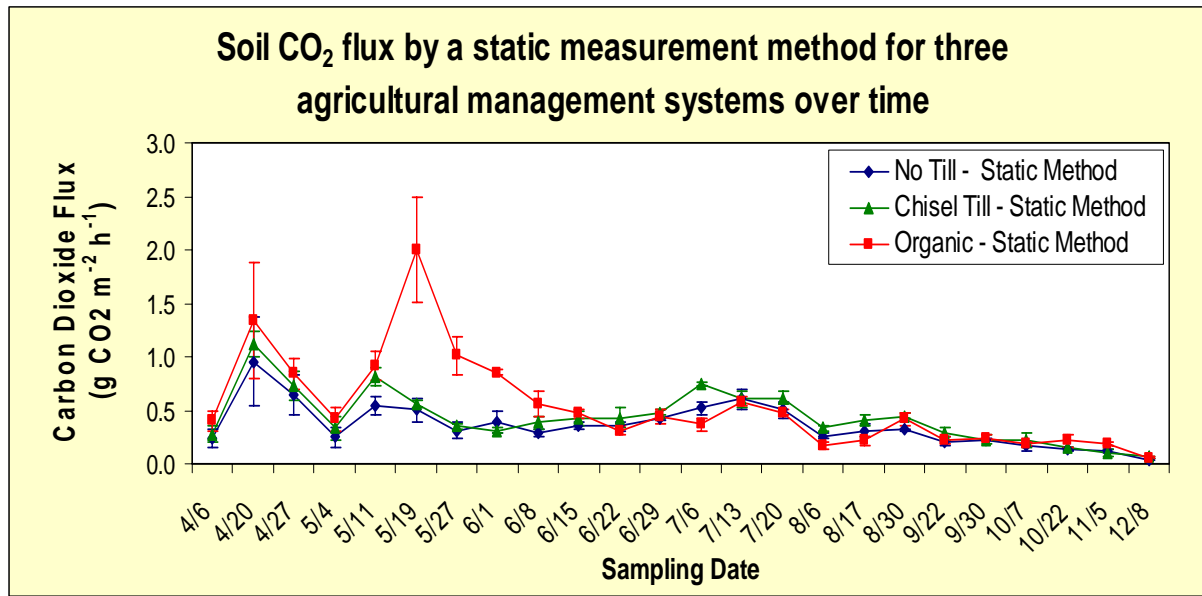
- To compare the global warming potential of no till, chisel till and organic cropping systems.

Approach

- Make approximately weekly measurements of CO₂ and N₂O flux, while simultaneously measuring soil moisture and temperature, from corn plots in three-year rotations under organic, no till and chisel till management.
- Four 30 cm diameter chambers per plot, 2 in traffic+fertilizer row, 2 in adjacent row that receives no fertilizer and little tractor traffic.
- Data collection is part of a national ARS network, GRACEnet.
- Soil samples are collected to 1 m depth at least every 5 years in all plots to assess total soil C and N.
- All sources of C returned to the soil (except plant roots) are measured.
- Measurements made in forest site periodically.



Initial Results



- Cumulative CO₂ flux was greater in the organic system (12.88 g CO₂ m⁻¹ h⁻¹) than in the no till (8.62 g CO₂ m⁻¹ h⁻¹) and chisel till (10.38 g CO₂ m⁻¹ h⁻¹) systems ($P < 0.05$).
- Differences among systems were due mostly to large CO₂ fluxes in spring in the organic system, especially following moldboard plow incorporation of hairy vetch (5 May) and disk incorporation of poultry litter (25 May). Rotary hoeing (2 and 9 June) and cultivation (21 and 28 June) in the organic system did not appear to have an effect on CO₂ flux. The readily available soil and vetch C had probably been released during the earlier plowing, and little new C was available to soil microorganisms following rotary hoeing and cultivation.
- N₂O flux data are being analyzed.
- Measurement of soil C in samples collected in spring 1996, fall 2000 and fall 2005 will allow an assessment of changes in soil C between 1996 and 2005.

Future Research

- Expand gas flux measurements to other crops in 3-year crop rotations.
- Expand gas flux measurements to 6-year organic cropping system.
- Complete GWP calculations.

Papers and Presentations

- Cavigelli, M.A. and G. McCarty. 2005. Sustainable Agricultural Systems Laboratory GRACEnet research. GRACEnet National Workshop, Fort Collins, CO, Oct. 4-6.

Relationship of Carbon Dioxide Flux in No till and Organic Cropping Systems with Soil Moisture, and Comparison of Measurement Methods

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Problem

- Soil moisture exerts an effect on carbon dioxide flux from soils but the effect of moisture under different cropping systems has not been modeled.
- No standard flux measurement technique has currently been accepted; various techniques are employed, resulting in diverse estimates of flux among researchers.

Objectives

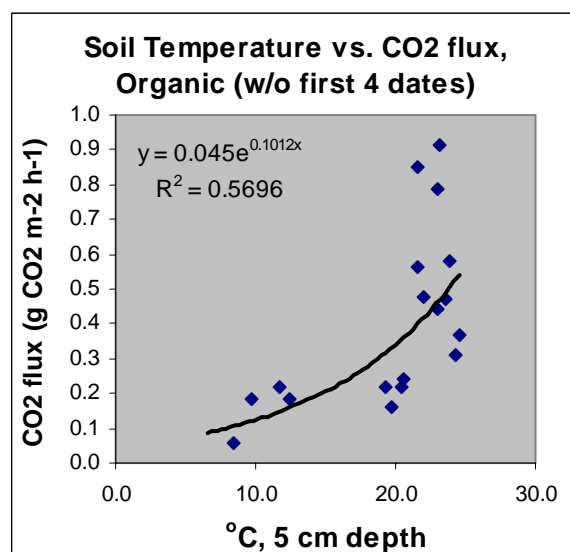
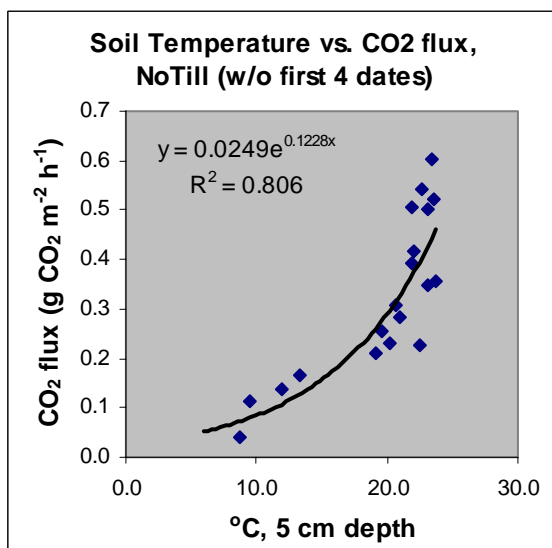
- To explore the relationship between soil moisture and carbon dioxide flux under no till and organic management.
- To compare static vs. dynamic flux measurement methods under field conditions.

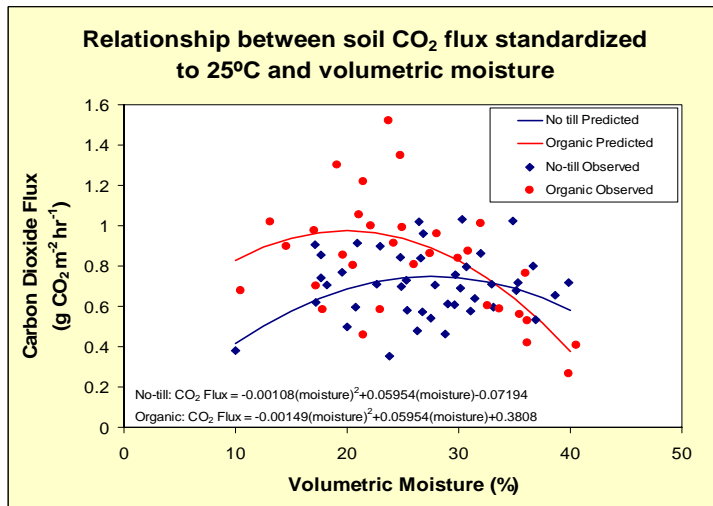
Approach

- Make approximately weekly measurements of carbon dioxide flux, while simultaneously measuring soil moisture and temperature, from soils under conventional no till and organic management using both static and dynamic measurement methods.
- Measure soil bulk density to assess the effects of tillage practices on soil porosity.
- Measure soil dissolved organic carbon for each management system.
- Conduct a repeated measures ANCOVA on dynamic method flux data (standardized to 25°C) with the linear and quadratic effects of volumetric water content as covariates.
- Fit curves to model the relationship between soil moisture and carbon dioxide flux under each cropping system.

Initial Results

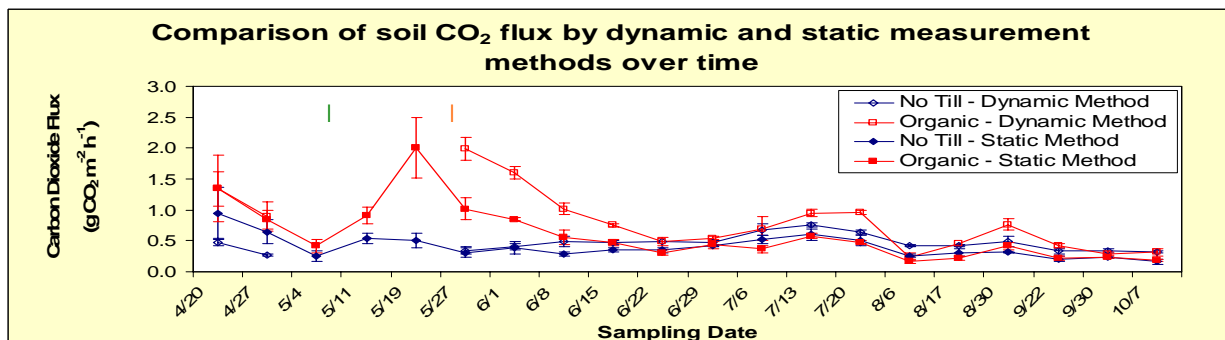
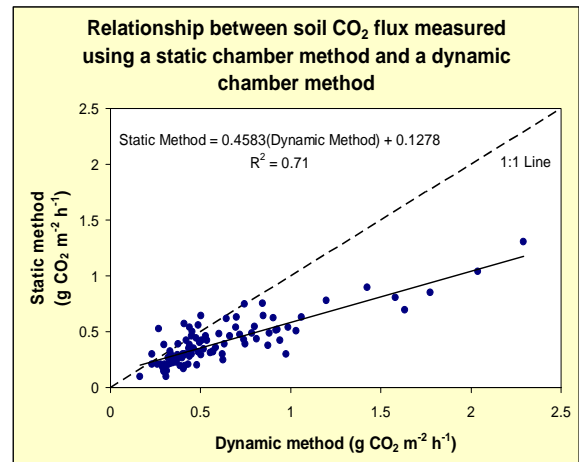
- Soil CO₂ flux measured by static and dynamic methods responded exponentially to increases in soil temperature in both systems. The weaker relationship between soil temperature and CO₂ flux in the organic system compared to the no till system reflects the additional impact of tillage and organic matter incorporation in the organic system.





- Quadratic relationships between soil CO₂ flux and soil moisture were different in organic and no till systems.
 - Maximum CO₂ flux occurred at 20.0% VWC in the organic system soils and at 27.6% VWC in the no till system soils.
- Flux was greater in the organic system below 29.1% VWC (P<0.05) but greater in the no till system above 39.8% VWC (P<0.05).
 - There was no difference in flux between systems between 29.2% and 39.7% VWC (P<0.05).

- There was a linear relationship between CO₂ fluxes measured using the static and dynamic methods.
- CO₂ flux was greater when measured by the dynamic method than by the static method, possibly due to the fan in the dynamic chamber disturbing the boundary layer between the soil and the atmosphere.
- Cumulative mean flux using the dynamic method was 35% and 11% greater than using the static method for the organic (13.31 vs. 8.71 g CO₂ m⁻¹ h⁻¹) and no till (7.68 vs. 6.82 g CO₂ m⁻¹ h⁻¹) systems, respectively.



Future Research

- Gather CO₂ flux data under drier soil conditions to better model the effect of moisture on flux from dry soils.
- Develop a model for the relationship between moisture and CO₂ flux using static method measurements.

Papers and Presentations

- Cavigelli, M.A., J.W. White, L.J. Sikora. 2005. Soil CO₂ flux in conventional and organic cropping systems: comparison of measurement methods and relationship with soil moisture. USDA Greenhouse Gas Symposium, Baltimore, MD, March 22.

Effects of Cropping Systems on Assemblages of Ground Beetles (Coleoptera: Carabidae)

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Problem

- Ground beetles (Coleoptera: Carabidae) represent one of the largest families of insects and are commonly found living on the soil surface in temperate ecosystems, including annual cropping systems.
- Numerous studies have demonstrated that ground beetles play an important role in insect pest suppression in annual cropping systems.
- Some ground beetles may have an important influence on weed population and community dynamics by consuming weed seeds
- Ground-beetle assemblages are influenced by ecosystem-management practices (nutrient and pesticide inputs, tillage, crop or cover crop type, etc.)



Objectives

- Document the ground-beetle species that occur at the FSP site and their relative abundance.
- Determine the effects of cropping systems on the relative abundance of individual species and the species composition of the entire ground-beetle assemblage.

Approach

- Ground beetles were sampled in the no till, chisel till and organic treatments of the FSP during the 2001 and 2002 growing seasons using pitfall traps. The same plots were sampled each year; in 2001 plots were in corn; in 2002 they were in soybean.
- Six pitfall traps per plot were set and maintained for 9-14 days during each of three sampling periods: Spring (May); Summer (July); Fall (October).
- The contents of the traps were preserved in alcohol, sorted, and identified.
- Canonical variates analysis (CVA) was conducted on the ten most common ground-beetle species to determine if differences existed in the species assemblages in the three cropping systems.

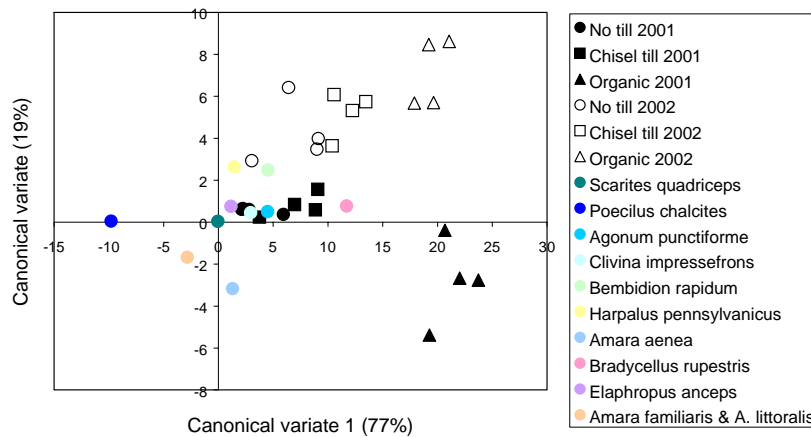
Initial Results

- Thirty-one ground-beetle species were represented in the approximately 2300 specimens that were collected from the site over the two years of pitfall trapping.
- The 5 most abundant species accounted for about 75% of the total collected; the 10 most abundant taxa, about 90%.

The ten most common ground-beetle taxa collected from the FSP site, 2001-2002.

Species	Number	Percent of total
<i>Scarites quadriceps</i> Chaudoir	655	28
<i>Elaphropus anceps</i> (LeConte)	409	18
<i>Bembidion rapidum</i> (LeConte)	318	14
<i>Harpalus pensylvanicus</i> (DeGeer)	185	8
<i>Poecilus chalcites</i> (Say)	136	6
<i>Clivina impressifrons</i> LeConte	111	5
<i>Agonum punctiforme</i> Say	86	4
<i>Amara aenea</i> (DeGeer)	83	4
<i>Amara familiaris</i> (Duftschmid) & <i>A. littoralis</i> Mannerheim	52	2
Total	2035	89

Canonical variates analysis of 10 most common carabid species by system and year (number of individuals cup⁻¹ day⁻¹)



- CVA indicated a significant treatment effect (Wilks' Lambda, $P < 0.0001$), with canonical variates 1 and 2 explaining 77 and 19% of total variability, respectively.
- While almost all treatments differed from each other to some extent, the two conventional systems were more similar to each other than either was to the organic system in either year.

Future Research

- Generating possible explanations (hypotheses) for the initial results based on biological attributes of the species.
- Explore opportunities to relate these results to those for other soil invertebrates and weed seedbanks.

Papers and Presentations

- Clark, S., K. Szlavecz, and M. Cavigelli. 2004. Ground beetle communities in conventional, no-till, and organic farming systems of the mid-Atlantic region. Research Symposium in Ecology, Evolution, and Behavior, University of Kentucky, College of Agriculture, Lexington, KY.

Soil arthropods in organic and conventional cropping systems:

Isopoda and Diplopoda

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Problem

- Isopoda (isopods) and Diplopoda (millipedes) are in the macrodecomposer functional guild.
- They can be very abundant in forests, grasslands, and even urban areas.
- They are not commonly found in traditionally managed agricultural fields, probably due to soil disturbance, pesticide use and/or lack of detritus.

Objectives

- To determine if organic farming systems provide adequate habitats for these macrodecomposers, thus harboring higher soil biodiversity.
- To compare Isopoda and Diplopoda assemblages in no till, chisel till and organic cropping systems.

Approach

- Isopoda and Diplopoda were sampled in the no till, chisel till and organic cropping systems of the FSP during the 2001 and 2002 growing seasons using pitfall traps. The same plots were sampled each year; in 2001 plots were in corn; in 2002 they were in soybean.
- Six pitfall traps per plot were set and maintained for 9-14 days during each of three sampling periods: Spring (May); Summer (July); Fall (October).
- The contents of the traps were preserved in alcohol, sorted, and identified to species level.
- For isopods, we also collected population data

Results

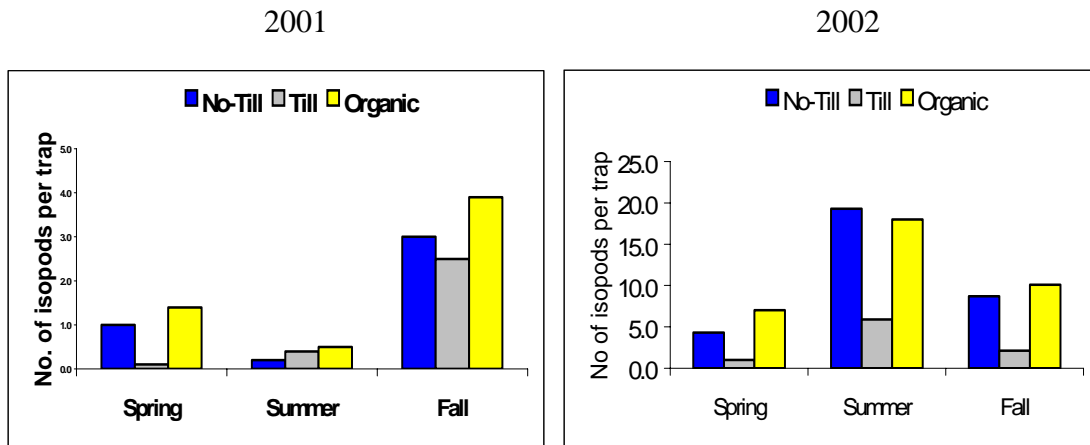
- Three isopoda species were found: *Armadillidium nasatum*, *Trachelipus rathkei* and *Philoscia muscorum*. All are non-native species of European origin. *P. muscorum*, which is very common in the Mid-Atlantic region, was only sporadically present.
- Diplopoda were dominated by two non-native species: *Ophiulus pilosus* and *Brachyiulus pusillus*. Few individuals of the native *Choneiulus palmatus* and a female Aniulini (Julida: Parajulidae) were also found. There were more isopods than millipedes. Millipedes were present in large numbers in spring only.

Trachelipus rathkei



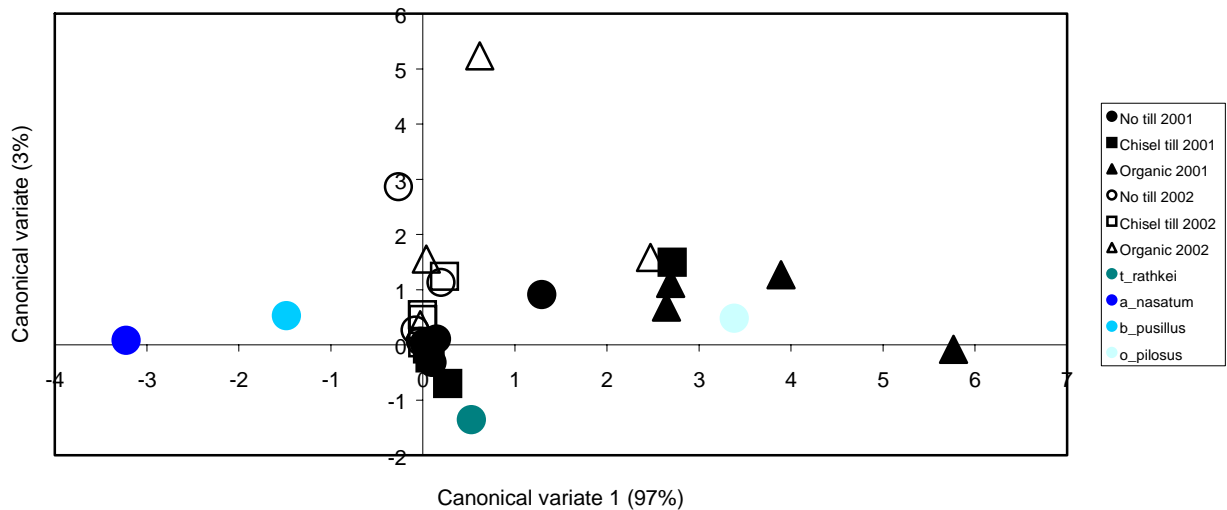
Armadillidium nasatum

- Chisel tilled plots had the lowest numbers of isopod individuals.



- CVA results show that the organic plots in 2001 were the most unique. Some, but not all organic plots in 2002 were also different from most other plots but so was one of the chisel till plots in 2001.

Canonical variates analysis of 2 isopod and 2 diplopod species by system and year (number of individuals cup⁻¹ day⁻¹)



Future Research

- Generating possible explanations (hypotheses) for the initial results based on biological attributes of the species.
- Explore opportunities to relate these results to those for other soil invertebrates and weed seedbanks.

Abundance and Species Composition of Earthworms in Organic and Conventional Cropping Systems

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Problem

- Crop type and management are known to affect soil invertebrate communities.
- Earthworms are especially affected by tillage practices, since many species build horizontal or vertical semi-permanent burrows.
- While data on earthworm abundance in chisel till and no till fields are abundant, few studies include organic farming as an alternative.

Objective

- To compare earthworm communities among organic and conventional cropping systems.

Approach

- Assess earthworm density, biomass and species composition in no till, chisel till and organic cropping systems
- Take samples for two years in the spring, summer and fall.
- Compare data to samples collected in nearby forest plots.

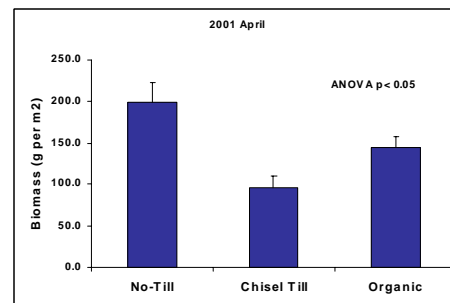


Results

- Four species were found on the agricultural fields: *Lumbricus friendi*, *Aporrectodea caliginosa*, *Allolobophora chlorotica*, and *A. rosea*. Two morphotypes of *Aporrectodea caliginosa* were found. All are non-native members of the Lumbricidae family. This is the first report of *Lumbricus friendi* dominating agricultural fields. This is also the first study describing *L. friendi* as a new species for the fauna of North America.
- In the forest, one native Lumbricid, *Eisenoides loennbergi* was found. In one patch this was the only earthworm species. Non-native earthworms had not invaded the forest.
- Tillage had a greater effect on earthworms than did pesticides. Results for other sampling dates were similar to those shown.



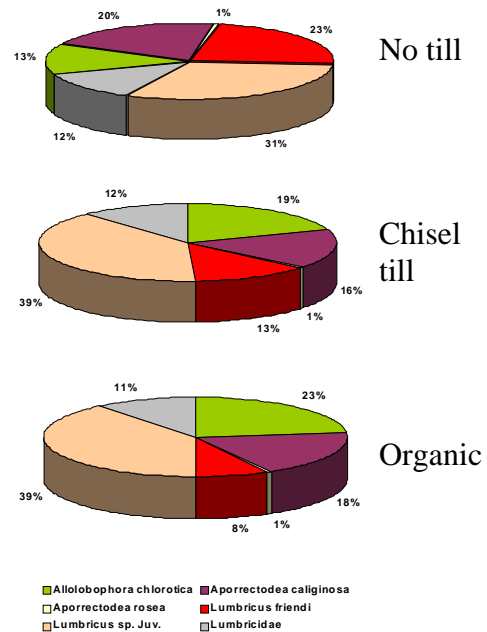
Lumbricus friendi



- The difference in earthworm biomass among systems was due mostly to differences in the proportion of the anecic *Lumbricus friendi*. We speculate that there was lower *L. friendi* biomass in tilled systems due to the destruction of the vertical burrows of this species by tillage. This speculation is supported by that fact that many specimens had regenerated tails.



A. chlorotica with regenerated tail



Future studies

- Determine the effect of earthworms on soil biogeochemical processes (e.g. soil respiration, trace gas fluxes, N mineralization). Compare these effects among the cropping systems.
- Repeat sampling five years later to see if patterns hold up in the long term.
- Carry out DNA analyses of the *A. caliginosa* morphotypes. This analysis (currently ongoing in collaboration with the Eotvos University, Budapest, Hungary) will contribute to a general taxonomic revision of the Lumbricidae family.

Papers and Presentations

- Placella, S. and K. Szlavecz and C. Csuzdi. 2001. Sustainable agroecosystems: alternative farming methods and soil fauna. Baltimore Ecosystem Study 4th Annual Meeting.
- Placella, S.A., K. Szlavecz and M. Cavigelli. 2003. Sustainable agroecosystems: alternative farming methods and soil fauna. Council for Undergraduate Research: Posters on the Hill, Washington, D.C. (one of 60 projects selected nationally for presentation at Senate Office Building).
- Csuzdi C., K. Szlavecz and M. Cavigelli. 2003. Effects of crop management systems on species composition and abundance of earthworm communities (Oligochaeta). 5th Ecological Congress of Hungary, Budapest, Hungary, August.
- Csuzdi, C. and K. Szlavecz. 2003. *Lumbricus friendi* Cognetti, 1904 a new exotic earthworm from North America. Northeastern Naturalist 10 (1): 77-82.

Effects of earthworms on water infiltration rates

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Problem

- Earthworms are known to greatly influence the hydrology of soils by creating macropores and burrows.
- Infiltration rates are likely to be influenced by earthworm burrow morphology.
- The dominant anecic earthworm at the FSP is *Lumbricus friendi*.
- There are no data on the effect of *L. friendi* activity on water infiltration in soils.

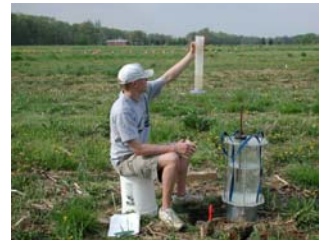


Objective

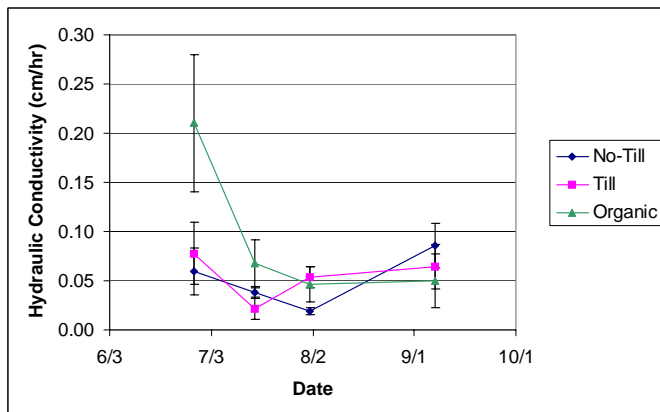
- To understand the relationship between earthworm activity and water movement in agricultural soils.

Approach

- Measure infiltration rates in no till, chisel till and organic cropping systems using two techniques.
 - Cornell sprinkle infiltrometer is a portable infiltrometer that measures infiltration rate, hydraulic conductivity, and sorptivity under simulated rainfall conditions. Apparatus measures infiltration across an area of 0.046 m². Used to compare infiltration among systems.
 - Turf-tek ponded infiltrometer is also portable but measures only infiltration rate and only under ponded conditions. Apparatus measures infiltration across a much smaller area. Used to sample areas with and without *L. friendi* burrows separately in the no till system.



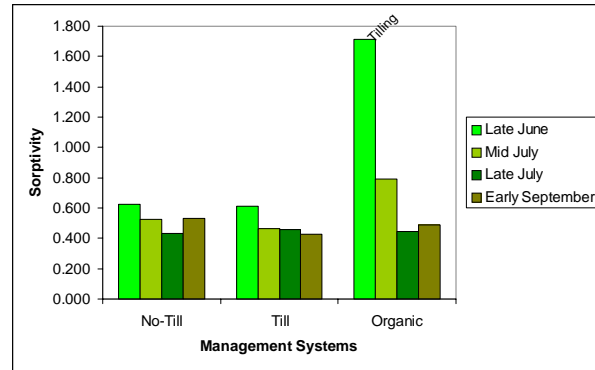
Results



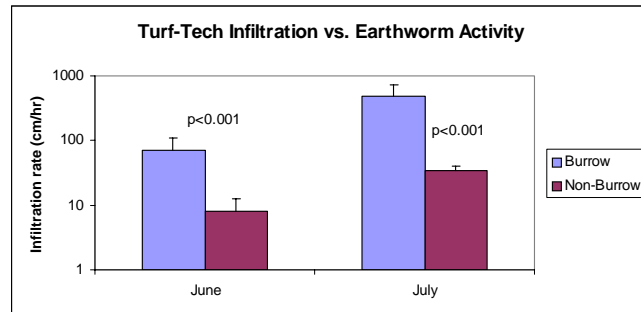
- Tillage had a greater effect on hydraulic conductivity than did earthworms.

- Differences in hydrology among cropping systems disappeared with time.

$$[\text{Sorptivity} = (\text{Rainfall Rate}) * (2 * \text{Time to Runoff})^{0.5}]$$



- Pondered infiltration showed a huge earthworm effect (note logarithmic scale on y-axis).



Future studies

- Relate infiltration rates in areas with burrows to burrow morphology.
- Repeat measurements in other crops (e.g. soybean).
- Determine if there is a seasonal effect of earthworm influence on infiltration.

Papers and Presentations

- Pitz, S.L., K. Szlavecz, and M.A. Cavigelli. 2004. Hydrology and earthworms in agroecosystems. ESA Mid-Atlantic Ecology Conference, Lancaster, PA.

Weed Seedbank Dynamics

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Problem

- Weed seed can remain dormant and persist in the soil for many years as a “seedbank” that defines the potential for future weed populations.
- Long-term experiments offer an opportunity to determine interactions between aboveground weed control and belowground weed seed bank dynamics.
- It was hypothesized that weed seed mortality would be higher in organic than in conventional systems because of the higher biological activity in organic systems.

Objectives

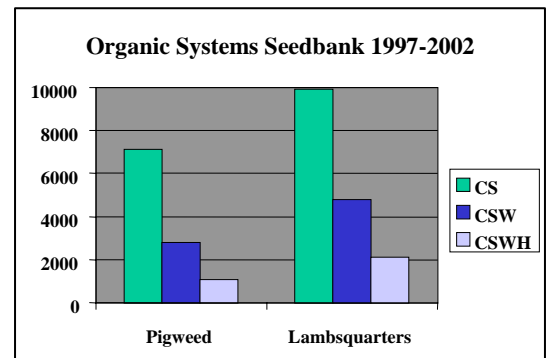
- To document annual changes in the weed seedbank in FSP cropping systems.
- To determine the relation between aboveground weed abundance and belowground seedbank.
- To determine the mortality rate of weed seed in organic and conventional systems.

Approach

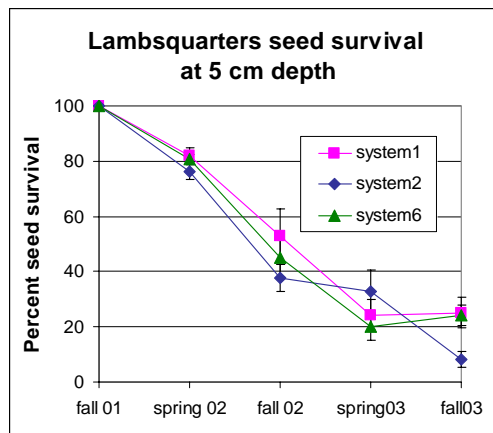
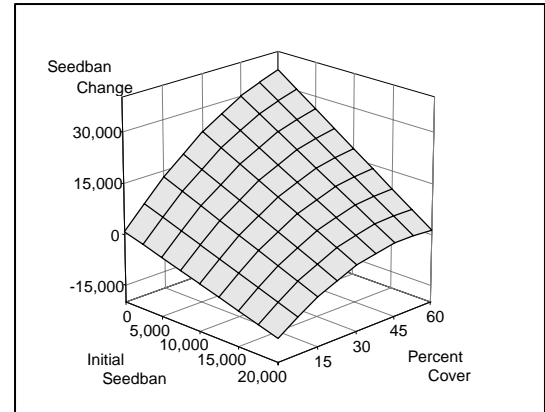
- The soil weed seed population for major species was determined using a greenhouse emergence assay of composite soil samples collected from the top 10 cm of each plot in early spring of each year from 1996 to 2002.
- Analyses were conducted relating seedbank population changes to the initial seedbank and the aboveground weed abundance in the previous year.
- Experiments were conducted to determine the mortality of known quantities of pigweed and lambsquarters seed inserted and removed from plots over two two-year periods, 2001-2003 and 2002-2004.

Results

- The seedbank of the summer annual species, smooth pigweed and common lambsquarters, were highest in the two-year organic corn-soybean (CS) rotation, which includes only summer annual crops. The seedbank was reduced as the rotation length increased to include phenologically more diverse species (winter annual wheat in the three-year CSW rotation and both wheat and a perennial hay crop in the CSWH rotation).
- There was often a significant correlation between the weed seedbank in spring and weed cover ratings in corn and soybean at maturity the same year, demonstrating that maintaining a low seedbank through more diverse rotations can lead to improved weed control in organic crops. This is a fundamental requirement for organic farming since postemergence weed management is not always reliable.



- Weed seedbank populations had highly fluctuating annual levels depending on weather and management. These fluctuations could be modeled by a simple quadratic response surface with two parameters 1) initial seedbank (which is proportional to seed losses) and 2) weed cover ratings at maturity (a surrogate for seed production). This model shows the dynamic nature of weed seedbanks, which can undergo large seedbank increases when weed control is poor and large seedbank decreases when weed control is good.



- Mortality rates of the major species in the organic systems, pigweed and lambsquarters, were relatively high, approximating 50% annually. There were no consistent system or depth effects. These results confirm that seed losses in the absence of seed inputs can be high and that seedbanks can be returned to relatively low equilibrium levels after a couple of years of good weed control. This pattern explains the effectiveness of including two or more years of hay in organic rotations.

Future Research

- This large dataset will be integrated with comparable datasets from long-term research at the BARC Sustainable Agriculture Demonstration Site and the Rodale Farming Systems Trial in cooperation with Penn State and Rodale researchers to conduct a comprehensive analysis of weed population dynamics in conventional and organic systems.

Publications and Presentations

- Teasdale, J.R., R.W. Mangum, J.R. Radhakrishnan, and M.A. Cavigelli. 2003. Factors influencing annual fluctuations of the weed seedbank at the long-term Beltsville Farming Systems Project. *Aspects Appl. Biol.* 69:93-99. An associated presentation was made at the international conference "SeedBanks: Determination, Dynamics & Management" at the University of Reading, UK, 2003.
- Teasdale, J.R., R.W. Mangum, J. Radhakrishnan, and M.A. Cavigelli. 2004. Weed seedbank dynamics in three organic farming crop rotations. *Agron. J.* 96:1429-1435.
- S.D. Ullrich, J.R. Teasdale, and M.A. Cavigelli. 2003. Weed seedbank dynamics in organic and conventional long-term cropping systems. *ASA Organic Agriculture Symposium, Annual Meeting Abstracts CD-ROM*, A08-ullrich412133-oral.
- Material from this research has been presented at several talks on weed management for organic farming made to organic and sustainable audiences, 2004-2005.

Vitamin E in Soybean Seeds From Conventional and Organic Farming Systems

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Problem

- Do organic production methods affect the nutrient composition of foods?
- High temperatures and/or drought during seed maturation increase the proportion of α -tocopherol in soybean seeds. Are any effects of farming system modified by environment?

Objective

- Measure phytochemicals with known or putative significance for human nutrition in a crop raised using conventional and organic farming methods; relate results to weather.

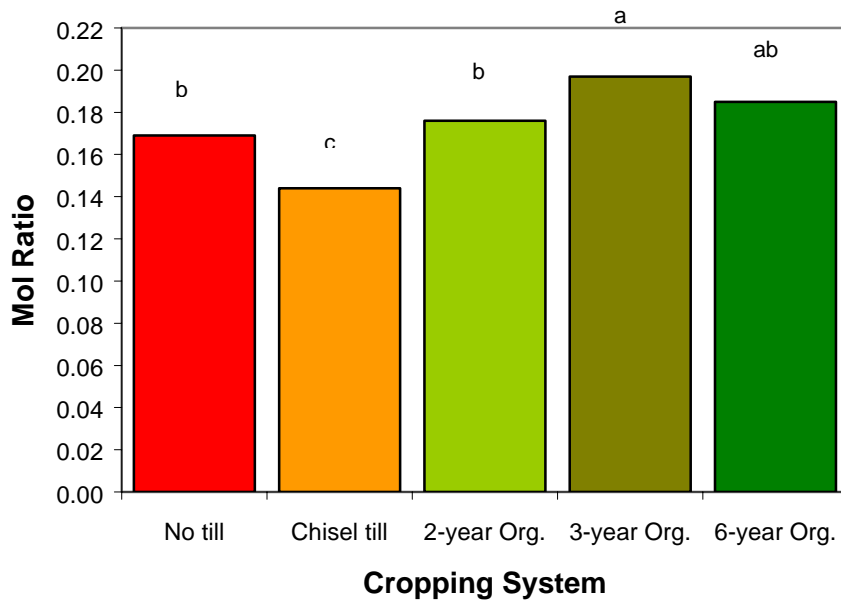
Approach

- Soybean seed oil is a major source of vitamin E (α -tocopherol) in American diets, but α -tocopherol is a relatively small proportion of total tocopherols in soybean seeds.
- Measure α -, γ -, and δ -tocopherols, a family of fat-soluble antioxidants, in soybean seeds from the two conventional (no till, chisel till) and three organic (2-, 3-, 6-year rotations) cropping systems of the FSP. Compare both full season and double crop beans.
- Four replicate samples from geographically distinct sites within each of four replicate blocks for each farming system were harvested in 2002 and analyzed. 2002 was characterized by warm temperatures and extreme drought.
- The measurements were repeated in 2004, a year with average temperatures and rainfall. In 2004, Williams 82, a nodulating variety, and a non-nodulating near isoline were grown in microplots within each cropping system. The microplots were further subdivided into weeded and non-weeded sections.

Results

- In 2002, seeds from the two longer organic rotations had about 30% more α -tocopherol (vitamin E) than seeds from the two conventional systems ($p < 0.001$) without differing in total tocopherols.
- Among the organic systems, α -tocopherol as a proportion of total tocopherols was lower in the 2-year than in the 3-year organic rotation.
- Among the conventional systems, α -tocopherol as a proportion of total tocopherols was lower in the chisel till than in the no till system.
- In 2004, no significant differences in tocopherols were observed based on farming system or weediness.
- The 2002 results may reflect an increased impact of environmental stress (temperature, drought) on organically-raised soybeans compared to conventional soybeans.

α -Tocopherol/Total - 2002



Future Research

- Analyze seed collected in 2005 (replicating the 2004 study) and continue observations in future years to evaluate interactions between weather and farming systems.
- Expand the pallet of analytes to include isoflavones, fatty acids, oil and protein and analyze existing samples retrospectively.

Presentations/Papers

- S. Britz. 2005. Phytonutrients and global change. Seminar at USDA, ARS, Eastern Regional Research Center, Wyndmor, PA, March.

Evaluation of Digital Photography from Model Aircraft for Remote Sensing of Crop Biomass and Nitrogen Status

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Problem

- Remote sensing is a key technology for precision agriculture to assess actual crop conditions, but commercial, high-spatial resolution imagery from aircraft and satellites are expensive and the costs may outweigh the benefits of the information.
- Adoption of remote sensing by farmers is also limited by the time required to deliver the imagery. Aerial photography from radio-controlled model aircraft can provide high-resolution imagery and can deliver the data to the user on the same day. Furthermore, imagery acquired from model-aircraft platforms have substantially lower cost for a given spatial resolution compared with airborne and satellite sensors.

Objective

- To evaluate low-cost, high-resolution digital photography acquired by remote controlled model aircraft for use in estimating nutrient status of corn, and crop biomass of corn, alfalfa, and soybean.

Approach

- Based on conclusions from previous work, we optimized an aerobatic model aircraft (Fig. 1) for acquiring pictures using a consumer-oriented digital camera (Fig. 2).

Fig. 1. Radio-controlled model aircraft.



Fig. 2. Commercial digital camera mounted on plane.



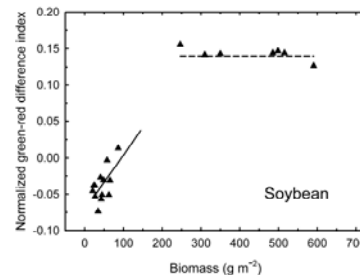
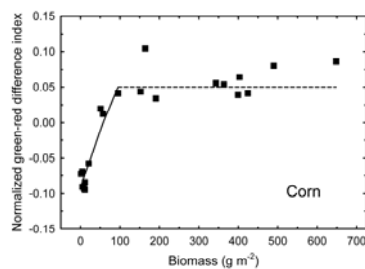
- Because of the spectral differences between vegetation and soil at green and red wavelengths, we hypothesized color imagery would also be useful for determining both biomass and nutrient status, allowing the use of lightweight digital cameras.
- Colored tarpaulins were used to calibrate images; there were large differences in digital number (DN) for the same reflectance because of differences in the exposure settings selected by the digital camera. To account for differences in exposure, a normalized green-red difference index [$NGRDI = (DN \text{ green} - DN \text{ red}) / (DN \text{ green} + DN \text{ red})$] was used; this

index was linearly related to the normalized difference of the green and red reflectances, respectively.

- FSP is uniquely suited to this work because of the large range of crop biomass and corn nutrient status present during particular portions of the growing season, because the same crop is often planted at different times and under different soil nutrient conditions in the various cropping systems.
- Crop biomass was collected by hand from georeferenced areas within a few days of airplane flights.

Results

- Dry biomass for corn and soybean from zero to 120 g m⁻² was linearly correlated to NGRDI, but for biomass greater than 150 g m⁻², NGRDI did not increase further.



- In a separate fertilization experiment with corn, NGRDI did not show differences in nitrogen status, even though areas of low nitrogen status were clearly visible on mid-season digital photographs.
- Simulations from the SAIL (Scattering of Arbitrarily Inclined Leaves) canopy radiative transfer model verified that NGRDI would be sensitive to biomass before canopy closure and that variations in leaf chlorophyll concentration would not be detectable. With true color photography, nitrogen deficiency is detected primarily by brightness differences, not by spectral differences.

Future Research

- Research continues with a commercial research and development agreement (CRADA) between BARC and IntelliTech Microsystems, Inc. (Bowie, Maryland) to develop unmanned airborne vehicles for crop nutrient management and precision agriculture.

Papers and Presentations

- Hunt, E.R., Jr., M. Cavigelli, C.S.T. Daughtry, J.E. McMurtrey, III, C.L. Walthall. 2005. Evaluation of digital photography from model aircraft for remote sensing of crop biomass and nitrogen status. *Precision Agriculture* 6:359-378.
- Hunt, E.R., Jr., C.L. Walthall, C.S.T. Daughtry, M. Cavigelli, S.J. Fujikawa, D.W. Yoel, T.L. Ng, and M.C. Tranchitella. 2005. High-resolution multispectral digital photography using unmanned airborne vehicles. 20th Biennial Workshop on Aerial Photography, Videography, and High Resolution Digital Imagery Resource Assessment, Oct., 4-6, Weslaco, TX.

Landscape Level Variation in Soil Resources and Microbial Properties in a No-till Corn Field

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Problem

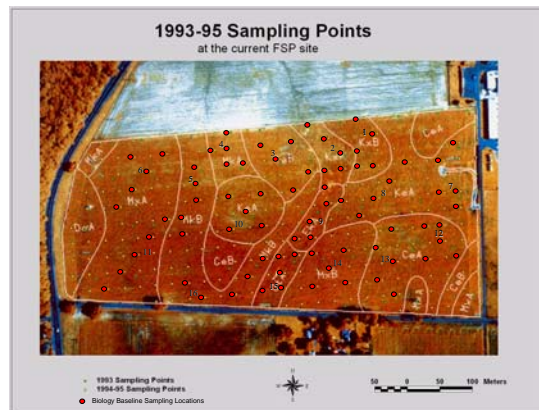
- Soil microorganisms are fundamental to crop production in that they are involved in many carbon and nutrient transformations, in soil aggregate formation and stabilization, in crop disease creation, and crop disease prevention.
- Soil microbial properties are known to exhibit high spatial and temporal variability, which can hinder our understanding of the effects of agricultural management on soil microbial activities, populations and communities.
- If this variability is explicitly considered in soil sampling schemes, experimental results can help us better understand soil microbial properties and the factors regulating them.

Objectives

- To quantify soil microbial properties by soil type and determine if soil type delineations commonly available to farmers from soils maps can help explain variability in soil microbial properties across a landscape.

Approach

- Soil type was defined four different ways: 1) by drainage class, 2) by series, 3) by map unit (series plus slope) and 4) by texture of the Ap horizon.
- Soil samples were taken from 16 map units in April, June, August, and October at the FSP site in 1995, prior to the establishment of FSP plots.
- 12 physical and chemical properties and 27 microbial properties were sampled at all locations on most sampling dates.
- Soil properties by soil type were compared using univariate and multivariate methods.



Results

- Soil physical and chemical properties generally varied with soil type and canonical discriminant analyses showed that soil drainage classes, series, and map units were delineated by a similar set of soil properties (total C, total N, moisture, pH, equivalent CEC, and soil test P).
- Ap texture classes were delineated by a different set of soil properties (available K, Mg and Ca, and equivalent CEC).
- A number of soil microbial properties varied by soil type, but, in general, a smaller proportion of measured soil microbial properties showed soil type effects compared to the proportion of soil physical and chemical properties that showed soil type effects.
- Method of soil classification strongly influenced which soil microbial properties varied by soil type.

- Soil microbial activities, population sizes, and community structures were generally greater or most unique in mid-range soils regardless of how soils were classified, possibly because soil moisture was optimal for microbiological activity and growth in these soils.

Means of soil properties that were significantly different among Ap textural classes according to one-way (bulk density and canonical variates) or two-way analyses of variance. Means within a row followed by a different letter are significantly different according to $LSD_{0.05}$.

Soil properties	Ap texture class		
	Low sand, high silt	Medium sand, medium silt	High sand, low silt
Physical and chemical properties			
Bulk density ($Mg\ m^{-3}$)	1.21 b	1.30 b	1.44 a
Available K ($cmol\ kg^{-1}$)	0.32 ab	0.33 a	0.22 b
Available Mg ($cmol\ kg^{-1}$)	1.01 b	1.28 a	1.09 b
Active C/Total C ($mg\ g^{-1}$)	6.05 ab	5.23 b	6.95 a
Canonical variate 1	-2.28 b	-0.88 a	-3.13 c
Canonical variate 2	-12.1 b	-10.2 a	-9.8 a
Microbial activities			
Alkaline phosphatase/Active C ($g\ PNP\ g^{-1}\ h^{-1}$)	1.78 b	2.90 a	2.45 ab
β -glucosidase/Active C ($g\ PNP\ g^{-1}\ h^{-1}$)	0.99 b	1.48 a	1.36 ab
MBC_{fc} /Active C ($g\ g^{-1}$)	3.07 b	4.49 a	4.20 ab
Microbial populations			
AMF spore incidence	0.6b	5.2a	3.0ab
Microbial communities			
FAME canonical variate 1	3.10 a	2.04 b	3.67 a
FAME canonical variate 2	-0.55 a	-1.46 b	-2.38 c

^aNA = not applicable.

^ans = not significant at $P < 0.05$.

- To improve upon results presented here, future efforts to quantify landscape level variation of soil properties should probably be sampled at a finer scale that explicitly accounts for soil properties that vary at the sub-map unit level, including terrain attributes, microtopography, soil texture, soil bulk density, and other factors that impact soil temperature and moisture dynamics that influence microbial populations.

Future Research

- Relationships between soil physical+chemical properties and microbial properties will be explored by conducting correlation analyses among the data.
- Spatial variability of these data will also be investigated using multivariate analyses without constraining results to soil type categories defined a priori.

Papers and Presentations

- 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.
- Cavigelli, M.A., L.L. Lengnick, J.S. Buyer, P. Millner, D. Fravel, Z. Handoo, S. Wright, and G. McCarty. 2002. Spatiotemporal distributions of soil resources and microorganisms in a no-till corn field. ASA/CSSA/SSSA Annual Meetings, Indianapolis, IN, Nov. 10-14.