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Regenerative organic farm management practices mitigate agro-ecosystem vulnerability to climate change by sequestering carbon and building resilience

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Abstract

Rodale Institute, a solutions-based non-profit U.S. research, outreach and education institution, has been conducting side-by-side research trials comparing organic or conventional management practices since 1981. The grain production system, Farming Systems Trial (FST), was started in 1981 while the Vegetable Systems Trial (VST) was initiated in 2016. The primary goal of both FST and VST is to quantify the impacts of farm management practices on the linkages between soil health and human health. Measurements of soil biological, chemical, and physical parameters have been and are continuing to be made in conventional and organic plots. Over the 34 years of management history in FST, soil organic carbon (SOC) levels have increased from 2.0% to 2.5% and the depth of the A horizon has increased by 2 to 10 inches in the organic systems compared to the conventional systems. In addition, the organic plots are more resilient to climatic uncertainty and have higher yields during drought years. Finally, organic systems are less energy intensive and emit lower amounts of greenhouse gases. Hence regenerative organic systems are productive systems providing nutrient dense grains and vegetables and mitigating agro-ecosystem vulnerability to climate change by sequestering carbon and building resilience.

Keywords: Carbon sequestration, Farming Systems Trial, Organic, Regenerative, Resilience, Vegetable Systems Trial

Introduction, scope and main objectives

For many generations, conventional, agro-chemical-intensive farming practices were responsible for feeding global populations. However, today, farmers not only need to meet the demand for increased production but also to improve the soil health in order to sustain those yields for generations and to ensure that the food they grow is nutrient dense. The extensive use of agro-chemicals and GMO varieties in conventional farming has degraded soils reducing productivity, water quality, the plants' ability to extract the nutrients needed to maintain personal health, and ecosystem services. Conventional farming systems increase nitrate leaching, phosphorus run-off and pesticide exposure. Biologically-based alternatives to synthetic chemical pesticides will be used for weed and insect pest management and thereby improve farm worker safety by eliminating toxic pesticide exposure. Ultimately reductions in soil health have contributed to a decline in the nutrient density of the soil, which decreases nutrient bioavailability to grain and vegetable crops (Ikemura and Shukla, 2009). Unlike conventional, agro-chemical intensive farming, organic farming practices regenerate soil by reducing tillage, increasing crop diversity through long crop rotations and the extensive use of cover crops, and fertilizing with manure and compost. These practices elevate soil organic matter levels and enhance soil biological activities.

In response to these issues, Rodale Institute designed two long-term research studies comparing organic and conventional systems side-by-side. Since 1981 this comparison has been conducted in a grain cropping systems trial (FST) while last year the VST began. The goals for both these studies were to:

1. Improve the nutrient density (or increase the amount of nutrients per calorie) of crops, hence food quality;

2. Reduce environmental and health risks in agriculture particularly through the use of pesticides;
3. Improve productivity, soil health, water quality, protection of natural resources, and the quality of life for farmers, their employees, and the farm community;
4. Adapt to and mitigate climate change;
5. Reduce fertility and pest management costs; and
6. Increase net farm income.

Project objectives were to:

1. Compare the effect of organic and conventional farming systems on crop nutrient profiles, including minerals, crude protein, beta-glucans, lipid-soluble and water-soluble vitamins as well as soil quality.
2. Measure the pesticide contamination levels in leachate and crops in organic and conventional systems.
3. Quantify carbon storage levels, greenhouse gas emissions, and adaptability to climatic uncertainty.

Methodology

Experimental Design:
Farming Systems Trial: Three grain cropping systems - manure organic, legume organic, and synthetic agro-chemical conventional system – have been compared in FST since 1981. The **Manure Organic** system represents an organic dairy or beef operation. It features a long rotation including both annual feed grain crops and perennial forage crops with fertility provided by leguminous cover crops and periodic applications of composted cow manure. The diversity of the rotation and stimulation of the soil biological community through the use of compost are the primary lines of defense against pests. The **Legume Organic** system represents an organic cash grain system. It features a mid-length rotation consisting of annual grain crops and cover crops, and its fertility is leguminous cover crops with the rotation diversity and enhancement of soil biology through the use of legume cover crops providing the primary lines of defense against pests. This system will be used as a check to compare a standard organic system using only cover crop-based soil additions to the manure-based organic systems. The **Synthetic Conventional** system represents the majority of grain farms in the U.S. It has a short rotation of corn and soybeans and relies on synthetic nitrogen for fertility, and weeds are controlled by synthetic herbicides selected by and applied at rates recommended by Penn State University Extension. In 2008, each of the three systems was modified to include tilled and rotational no-till systems to conform to the current global trend of reducing tillage in agricultural systems. The no-till organic systems utilize cover crops and our innovative no-till roller/crimper to manage weeds while conventional system utilizes synthetic herbicides. GMO varieties of corn and soybean were also introduced in the conventional systems to emulate the majority of conventional farmers.

Vegetable Systems Trial: Four vegetable cropping systems – organic reduced tillage, conventional reduced tillage, organic black plastic mulch, and conventional black plastic mulch – are being established in this trial. The **Organic Reduced Tillage** system will utilize a rolled down cover crop as a green manure and a weed barrier as surrogate to herbicide application. Crops in the organic and conventional reduced tillage system will be planted using a no-till planter or transplanter. The **Conventional Reduced Tillage** system will have a cover crop burned down with herbicides in spring. Some crops, such as potatoes, may require tillage for planting and harvesting and therefore the reduced tillage systems will not be completely no-till. The **Organic Black Plastic Mulch** system will consist of a plowed down cover crop in the spring with black plastic mulch laid shortly after plow down. Harvest will be followed by removal of black plastic and cover crop establishment. The **Conventional Black Plastic Mulch** system will consist of a plowed down cover crop in the spring with biodegradable black plastic mulch laid shortly after plow down and incorporated into the soil following harvest. Within the organic and conventional plasticulture system, the goal is season extension or double cropping within a single growing season for maximum profitability.

Soil Sampling Protocol: In both FST and VST, chemical, physical and biological soil quality parameters were measured on surface and deep core soil samples. These parameters include soil pH, soil organic matter percentages, total carbon and nitrogen levels, macro- and micronutrients, cation exchange capacity, bulk density, aggregate stability, microbial biomass, microbial community structure, water infiltration rates, and compaction.

Results

In FST, combined grain yields of corn, soybean, wheat, and oats, averaged between 1986 and 2014, between the three cropping systems show no significant difference in combined. Organic systems perform especially well during years of drought. During a 5-year period between 1988 and 1998 when total rainfall from April to August was less than 14 inches (compared to 20 inches in normal years), average corn yields were 31% (115 bushels per acre) greater than conventional system (86 bushels per acre). In both 2015 (Fig. 1) and 2016, the organic systems were more productive than the conventional system. This performance may be attributed to greater soil organic matter (SOM) in organic systems. Soil organic matter in tilled manure organic systems increased from 3.3% in 1981 to about 4.5% in 2014 representing a net increase of 27%. In the conventional system, SOM changed from 3.3% to 3.6% – a net increase of only 8%. In addition to increases in SOC with organic management, the depth of the A horizon increased by 2 to 10 inches compared to the conventional system (Fig. 2). Soil samples in 2015 from the organic treatments had higher soil carbon and nitrogen concentrations while 2014 oat grain samples had higher B vitamin levels, micronutrient content and crude and total proteins.

Fig. 1: In 2015, organic corn in the Farming Systems Trial was resilient against drought and yielded 18.6% more than corn in adjacent conventional plots.

Discussion

Increases in soil organic matter make agro-ecosystems more resilient against climatic variability because SOM holds water (Hudson, 1994; Johnson et al., 2005) and stimulates biological activity to form soil aggregates which keep water in the root zone. During drought years in the 1990's and 2015-2016, the impact of higher than normal precipitation in spring followed by a long dry spell in late summer and fall was seen in corn plants from an organic legume treatment and an adjacent conventional treatment. Because of this precipitation pattern, it is likely that nitrate and phosphate fertilizers applied in the spring to the conventional treatment ran off the field and low soil moisture

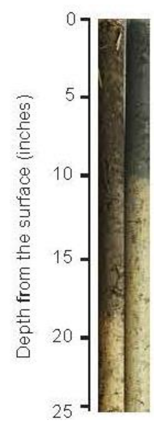

Fig. 2: The A horizon in the manure organic system (left-hand core) in FST extended about 9 inches deeper than the conventional system.

content later in season reduced nutrient flow which contributed to drought stress. Soil healthy was also linked to the nutritive quality grains illustrating that organic systems produce healthier soil and food.

Conclusions

Healthy soils created by biologically-based, regenerative organic management practices sequester more carbon to deeper depths than chemically managed soils. By stimulating higher levels of activity in the soil microbiome, soil organic matter becomes biologically, chemically and physically occluded increasing soil organic carbon concentrations in surface soils increasing the depth of the A horizon. These processes enhance soil aggregation leading to improved soil structure, tilth, and productivity. Biologically active soils provide nutrients to plants on demand making them more resilient and to resist pests, so farmers can reduce pesticide applications. This combined with reducing the cost of fertilizers while maintaining or even increasing yields offers huge economic gains for the producer. The organisms present in healthy soil live in synergy with each other, creating a soil food web that breaks down residue, fixes nitrogen, metabolizes phosphorous into plant-available forms, strikes a balance between beneficial and predatory insects, builds soil organic matter – or carbon – and even filters water and neutralizes pollutants.

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