Organic Farming Practices for Improving Soil Health

THE ORGANIC CENTER

Jessica Shade, PhD
THE ORGANIC CENTER

Kate Tully, PhD
UNIVERSITY OF MARYLAND

Introduction

Healthy soils are essential for resilient crop production and supporting our ecosystem. They positively contribute to soil water retention, support a diversity of organisms vital to decomposition and nutrient cycling, provide crops with essential nutrients and can maintain carbon stores, contributing to global climate change mitigation. Simply put, there is no way for us to meet the growing demands for food, feed, fiber, and fuel if we do not maintain soil health.

Unfortunately, soils in the United States are being degraded by unsustainable agricultural practices. Techniques used by organic farmers can help stop soil health degradation, or even restore soil health in previously degraded soils, because they replenish soil organic carbon and preserve underground biodiversity.

However, the specific impacts of organic practices on soil health are not well understood. Broad surveys of soil health comparing organic and conventional systems consistently show the benefits of organic farming, but rarely compare strategies within organic systems to understand where these benefits arise, or how they can be maximized.

This report looks at past research on the benefits of organic farming to soil health and climate change mitigation, and details a new study published in the scientific journal, *Organic Agriculture*, that surveys organic soil-building practices to illuminate specific strategies that have the biggest impacts on soil health.

Soil Health on Organic Farms

Multiple research studies have shown that organic soils tend to score higher when it comes to soil health metrics than conventional soils. For example, organic soils have greater biological activity, greater soil stability, more biomass and higher diversity than conventionally managed soils. Organically managed soils also tend to have higher water-holding capacity, porosity, and aggregate stability than conventionally managed soils, which can lead to yield advantages in extreme weather events such as droughts and flooding, meaning that organic may fare better as our planet continues to experience climate change.

Organic Soils and Climate Change Mitigation

Eighty percent of the Earth's terrestrial carbon is stored in soils, and other than the ocean, it is the largest pool of carbon on earth. Humans manage the majority of the Earth's soils, and research shows that our management practices can deplete the soil's carbon stores – releasing it back into the atmosphere – contributing to global climate change. Agriculture, in particular, has been linked to large losses of soil organic carbon worldwide. In fact, an article published in the Proceedings of the National Academy of Sciences shows that over the history of farming, human agricultural practices world-wide have resulted in a loss of 133 billion metric tons of carbon from the soil. It also points out the rate of carbon loss from agricultural soils has increased dramatically over the last 200 years as more land is converted to crop and rangeland.

Fortunately, a number of studies show that with proper management, some agricultural practices can actually increase the carbon pool in our soils – making healthy soils part of the climate change solution. A study conducted by The Organic Center, in collaboration with Northeastern University, quantified the non-labile stable portion of carbon in over a thousand samples of organic and conventional soils in the United States, and found that organic soils had significantly higher levels of sequestered carbon than their conventional counterparts. These results build on past research showing higher levels of total carbon in organic soils, highlighting the potential of organic agriculture to increase the amount of carbon sequestration in the soil, contributing to climate change mitigation.

New Research within Organic Systems

While a growing body of scientific literature suggests that soil management strategies commonly used in organic systems improves overall soil health, there is little research on specific practices within organic systems that have the greatest potential to build healthy soils. Additionally, measurements of soil health across research studies can differ drastically because of a lack of agreement on how best to measure soil health. Significant variations in in characteristics assessed and the methods used to gauge soil health mean that results across different studies are difficult to compare.

Newly published research by Tully and McAskill examines over 150 published studies to take an inventory of current knowledge on best practices within organic management for enhancing soil health, and provide a roadmap for current management opportunities and future research directions to support long-term sustainability. We look at all the data that have been collected on organic soil building strategies from around the world to pull out general themes of organic practices so that we can get a big picture understanding of the trends around which strategies have the biggest impacts on soil, and how we can be strategic in filling gaps in our knowledge to advancing ecological organic practices.

STUDY HIGHLIGHTS

- Soil health is defined as the soil's capacity to function.
- The maintenance of soil health is a cornerstone of the organic agriculture movement.
- Many studies compare organic to conventional systems, but few compare organic systems to one another.
- This project conducted a literature review to compare soil health outcomes among organic systems.

FOUR KEY PRACTICES EMERGED TO IMPROVE SOIL HEALTH OUTCOMES:

1. cover crops
2. organic amendments
3. rotation diversity and length
4. tillage

What is soil health?

Soil health is defined as the capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans. Because soil health has a qualitative nature, farmers and scientists across the world have developed their own set of indicators of soil health such as color, tilth, drainage, presence and diversity of macrofauna and weeds, and crop yield. Unfortunately, without a unified definition of soil health, it can be difficult to coalesce soil health trends from disparate soil studies. However, in 2017, the Soil Health Institute announced Tier 1 soil health indicators in an effort to give scientists and farmers a common set of metrics to measure and monitor soil health through time. Those indicators included a combination of chemical, physical, and biological metrics.

Soil health indicators used in this study

PHYSICAL SOIL HEALTH INDICATORS	**CHEMICAL** SOIL HEALTH INDICATORS	**BIOLOGICAL** SOIL HEALTH INDICATORS
• Aggregate stability (how the soil sticks together)	• Nitrogen	• Organic matter
• Water-holding capacity	• Phosphorus	• Microbial biomass
• Infiltration and porosity	• Potassium	• Earthworm abundance
• Susceptibility to runoff and erosion		• Weed pressure and diversity

Methods

Researchers conducted a global systematic review of the literature, including all studies that compared practices within organic farming systems to report soil health indicators. The review yielded 153 articles that met the screening criteria.

Study Findings

Four key practices emerged as being the most critical for impacting soil health, including:


Cover crops


Rotation diversity and length


Organic amendments


Tillage

Cover crops

Cover crops are plants that are grown to benefit the soil rather than harvest income. They provide protection from soil erosion, nutrient losses, along with many other agroecosystem benefits. In organic systems, they can be used for weed suppression and are often a critical source of nutrients for cash crops through nitrogen fixation and green manure.

There is an abundance of studies showing that cover crops enhance soil health overall, but there is sparse research comparing how cover crops affected soil health in organic systems. While this paucity of data clouded trends that may be apparent, it was clear that roll-killed cover crops suppressed weeds better than disking. Additional research should focus on the impacts of cover crop species, termination methods, and amendment combinations on soil health outcomes. Research should also focus on the timing of nitrogen release from cover crops during decomposition. If nutrients are available too soon, they can lead to nitrogen leaching. If available too late, they can lead to nitrogen deficiency stress.

Organic amendments

The use of synthetic nutrients is banned on organic farms, so organic farmers must rely on naturally-occurring fertilizers such as compost and manure for enhancing nutrient content in soils. The use of organic amendments has been shown to increase soil carbon sequestration, which may help to mitigate climate change by locking away carbon that could otherwise act as a greenhouse gas in the atmosphere. However, organic soil amendments can vary dramatically in nutrient content, carbon to nitrogen ratios, and timing of nutrient release, which has led to variability in the impacts of organic soil amendments on soil health.

The variability in organic amendment type and treatment also makes it difficult to compare studies, but this project was able to uncover some general themes. Specifically, combining different organic amendments (such as vermicomposts in combination with manure) is better for soil health than using one type of organic fertilizer alone.

Future research should focus on specific regional effects of fertilizer types and rates, and how timing of nutrient release can be synchronized with crop need.

Rotation diversity and length

Crop rotations—the sequence of crops grown on the same land in succession— are a critical component of maintaining healthy soils. They break pest and weed cycles, help cycle nutrients, and reduce economic risks associated with single cropping strategies. Organic farms tend to have longer crop rotations than their conventional counterparts, which leads to higher on-farm diversity.

This study found that most research on crop rotations focuses on the effect of rotation length, rotation complexity and grain versus forage rotations. Diversity in rotations was key to enhancing soil health, especially when it comes to including perennials, such as alfalfa, into the systems to improve soil health indicators including soil carbon, nitrogen and aggregate stability.

Tillage

Tillage on organic farms is sometimes used as a form of weed control, but frequent tillage can destroy soil structure and lead to soil organic carbon loss. However, there is growing interest in organic strategies that reduce tillage.

Studies on organic systems show that reducing tillage can increase soil carbon, but the variable definition of "reduced tillage" makes it difficult to identify other potential trends. Unfortunately, organic no-till methods can decrease yields, so future research should focus on ways to reduce tillage without having a negative impact on yield. Alternately, shallow non-inversion tillage (also called "vertical tillage" or "strip-tillage") can optimize both yields and soil carbon storage.

Additional research comparing different methods of tillage (such as a gradient between chisel ploughing to shallow inversion tillage) would help optimize strategies that promote multiple parameters of soil health while not suppressing crop yields on organic farms.

Thank you to our funders

This report and the research published by Tully and McAskill in Organic Agriculture would not be possible without generous support from:

- GRO Organic
- Annie's Homegrown (General Mills)
- Patagonia