Impacts of Organic Farming on Soil Organic Matter

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Key words: farm soil comparisons, soil organic matter sequestration, soil fulvic and humic acids contents

Abstract

Soil health is a critical component for developing Organic 3.0, which strives to place organic as a model sustainable food systems. However, the extent to which organic can contribute to maintaining and improving humic substances (HS) across the United States has not been investigated. It is especially important to take HS and its components into account when examining soil parameters, because humic substances is closely associated with soil health attributes. We measured the percent total soil organic matter (%SOM) and the percentages of sequestered SOM in the form of long-lived humic acids (%HA) and fulvic acids (%FA) in 1040 conventional farm soils from 48 United States and 683 organic farm soils from 38 United States to determine if and quantify how much organic farming leads to more SOM sequestration in comparison with conventional farming practices. The average %SOM is 7.37 for conventional and 8.33 for organic samples. %FA ranges are 0.08 to 2.20 and 0.04 to 14.8 for conventional and organic farm soils with mean values of 0.26 and 0.65, respectively. The %HA ranges are 0.17 to 23.0 (mean 2.85) for conventional and 0.25 to 48.9 (mean 4.1 for organic samples). The mean %humification (i.e. sequestration) is 45.6 for conventional soils and 57.3 for organic. Except for water retention, which is statistically better in conventional soils, all other comparisons show improved levels in organic farm soil samples. This information is critical for the development of Organic 3.0, because it provides clear information for in tracking the effects of changes in farm soil management practices over space and time, which can aid us in moving our current agricultural system toward sustainability.

Acknowledgments

We thank the V K Rasmussen Foundation and the Farmers Advocating for Organics Fund for financial support of the NSP. We express our deepest gratitude to the hundreds of soil sample donors across the nation who made this work possible.

Introduction

Over the last century, agricultural systems have increased in productivity dramatically due to the intensification of agricultural practices. However, in the face of this increased yield, there is a growing concern over the declining fertility of soils, especially reduced humic substances (HS) which is closely associated with the soil health attributes. Humic acids (HA) and fulvic acids (FA) are main components of HS in most soils. Lower than optimum levels of HA and FA depress a soil's productivity. Thus, the HS level reflects the long term ability of the soil to remain healthy and productive and, as such, HS are the baseline measure of any soil organic matter. HS, and HA in particular are better water retainers than SOM on an equal mass basis and thus help to combat drought.

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This will be especially important in the face of climate change, because higher HS will mitigate some of the environmental consequences of climactic shifts.

Soil nutrient amendments can impact SOM levels. The use of synthetic fertilizers, for example, has the potential to increase SOM, but there is still debate about the effects of synthetic fertilizer on building or degrading SOM and, synthetic fertilizers are also linked to environmental degradation and soil tradeoffs. However, few, if any studies have conducted a wide-spread, thorough comparison of organically managed soils to conventionally managed soils across the United States to determine the impacts of management system on SOM levels (Gattinger *et al* 2012).

Additionally, while total SOM measurements are frequently used in studies of soil health, global carbon cycling, the effects of landscape and climate on soil properties and the effects of land management on soil health and fertility, fewer studies have examined the levels of SOM components (HA and FA), especially in the context of organically managed soils in comparison with conventional soils. It is critical to include these measurements in analyses of SOM levels, because while fulvic acids are water soluble and fluctuate from year to year, humic acid represents the long-term storage of carbon in the soil. It also is a much more accurate measure of soil health, because it is more closely related with beneficial soil properties such as water retention, nutrient storage, and improved texture and permeability.

This study uses novel analytical methods to examine not only the total SOM content of conventional and organic soils, but also the levels of HA and FA in the soil. We examine hundreds of conventional and organic soil samples from across the United States to answer the question: How does organic management affect the levels of SOM component sequestration in soils?

Material and methods

Samples were collected from surface (0-30 cm) agricultural top soil in 50g measurements by local farmers. Leaves, sticks, rocks, pebbles and trash were removed from the samples. Samples were then air-dried and sent via USPS Parcel Post to the National Soil Project laboratory in Boston, MA. Farmers also included information about geographical location of soil collection, soil texture and classification. Samples were then stored at room temperature in sealed containers until processing.

Soil samples were requested through online, telephone, in-person, and paper communication. The goals of this study are to look at a large cross-section of organic and conventional farms to determine the average impact of organic farming as a tool for improving soil health, so we included farms with a range of crops, organic farming duration, soils and locations. Future analyses can examine specific crop types, duration of organic production, and other variables, but for this study our aim was to examine the overall impact of organic across the United States.

This study used an optimized loss-on-ignition (LOI) method to examine levels of total Soil Organic Matter (SOM) and Humic Substances (HS), including fulvic acids (FA) and humic acids (HA) in the soil (Ghabbour et al., 2014). Soil samples were also analysed for percent water retention and humicication (H) (Ghabbour et al. 2012).

All statistical data analyses were performed in R. Because the soil variables could be correlated, we used a Multivariate ANOVA (MANOVA) to determine whether there were significant differences between variable means due to organic vs. conventional soil management. We used a multifactorial model that also included the U.S. State that the sample was taken from as a cofactor, because location can have an impact on soil properties (e.g. Wardle et al., 2004). We also performed Pearson's correlation analysis on all soil variables to determine correlation coefficients. To determine which variables contributed to significant differences between soil management, we followed the MANOVA with univariate ANOVAs on each soil variable (%FA and %HA contents, %water retention, %SOM and %H). All significance levels were corrected for multiple tests using Bonferroni corrections.

Results

Our MANOVA analysis (Table 1) showed that soil management is significant, as is the State that samples were collected from. Additionally, there was a significant management by State interaction, showing that the effects of soil management differ by the State a soil is collected from.

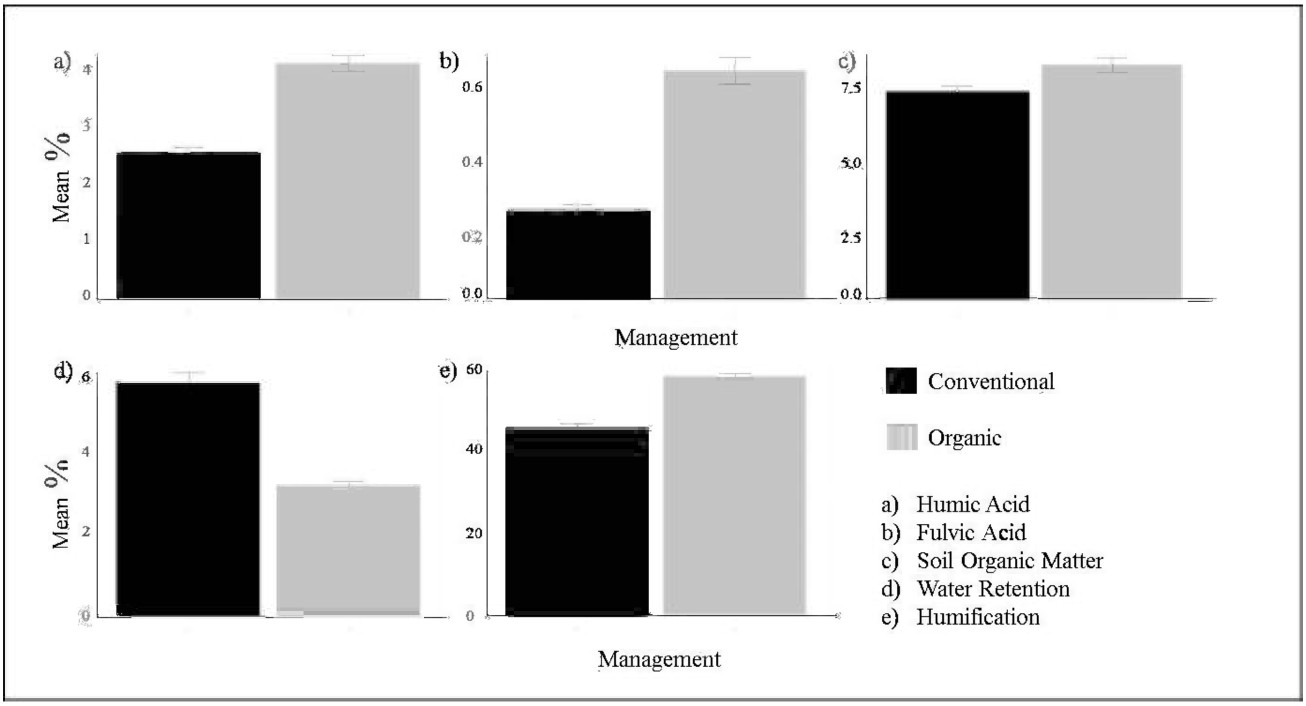
Table 1: The MANOVA Analysis showed that soil management and state were highly significant, as was the interaction between the two factors.

	DF	Pillai	F Value	Num DF	Den DF	Pr (>F)
Management	1	0.39	181.8	4	1138	<0.001 ***
State	55	1.17	8.24	220	4564	<0.001 ***
Management x State	35	0.29	2.58	140	4564	<0.001 ***
Residuals	1141					

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Because the MANOVA showed significant differences between both soil management and States, we also conducted univariate ANOVAs on each soil variable (%HA and %FA contents, %water retention, %SOM, and %H) to determine which variables contribute to these differences. All variables except % water retention showed significantly higher levels in organic as compared to conventional (Figure 1).

Figure 1: Mean levels of a) Humic Acid, b) Fulvic Acid, c) Soil Organic Matter, d) Water Retention, e) Humification



Discussion

Soil degradation is a serious threat to our ecosystems and food security. The need to optimize and foster soil health is critical for developing a future system of Organic 3.0, as it it supports nutrient retention and storage (Russell, 1973; Woomer and Ingram, 1990) and promotes soil aggregation (Oades, 1984), which leads to reduced erosion (Lal, 1956) and greater moisture infiltration (Lavelle, 1988).

The excessive use of synthetic fertilizers, and lack of recycled material soil amendments such as manure and compost have contributed to soil degradation, but many organic methods can counter these impacts. This study shows that all soil organic matter components are improved by organic management.

Further research is needed to determine specific practices used in organic contributing to these improvements. Additionally, research is needed to examine the lower levels of water retention found in organic soils as compared to conventional.

This study clearly shows that organic farming leads to more SOM sequestration, and SOM components than conventional farm management. Several studies have shown that organic soil has a healthier profile than soils that are conventionally managed, but this is the first time that research has investigated the components of SOM and done a broad analysis of samples from around the country. The findings support that not only is organic management, on average, healthier for soil health, it also suggests that organic is a critical tool for sequestering carbon in the soil, thus mitigating climate change through long-term greenhouse gas reduction.

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