Organic Matter and Soil Structure in the Everglades Agricultural Area[1]

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Introduction

This publication pertains to management of organic soils (Histosols) in the Everglades Agricultural Area (EAA). These former wetland soils are a major resource for efficient agricultural production and are important globally for their high organic matter content. Recognition of global warming has led to considerable interest in soils as a repository for carbon. Soils rich in organic matter essentially sequester or retain carbon in the profile and can contribute directly to keeping that sequestered carbon from entering the atmosphere. Identification and utilization of management practices that minimize the loss of carbon from organic soils to the atmosphere can minimize effects on global warming and increase the longevity of subsiding Histosols for agricultural use. Understanding and predicting how these muck soils will respond to current and changing land uses will help to manage soil carbon.

The objectives of this document are to:

a. Discuss organic soil oxidation relative to storing or releasing carbon and nitrogen

b. Evaluate effects of cultivation (compare structure for sugarcane vs. uncultivated soil)

The intended audience for this publication includes growers within the EAA, state and federal personnel dealing with organic soils in southern Florida, researchers working in soils and reclamation, and Certified Crop Advisers or other consultants making agricultural or environmental recommendations.

Organic Matter in Histosols: Origins and Fate

The muck soils found throughout the EAA and southward through the Everglades formed under flooded conditions, primarily as wetlands dominated by sawgrass (*Cladium* sp.). These wet conditions preclude the decomposition of organic material, allowing those materials to form the organic soils we see today. More than 100 years ago, farmers recognized the potential of these soils to produce vegetables and row crops. The natural benefits of these organic soils, such as the supply of nutrients from decomposition of the organic matter, were enhanced by the subtropical climate, allowing fruit, vegetables, and row crops to satisfy market demand when competition from other production areas in the United States was at a minimum.

Soils in the EAA vary greatly and should not be considered as a single type. For example, the depth of the organic material generally decreases with distance from Lake Okeechobee. Likewise, the organic soils are shallower at the edges of the EAA, transitioning into mineral, sandy soils typical of the coastal areas.

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The major soils found in the EAA progress from one series to the next based upon their depth to the underlying mineral material (Table 1). As subsidence (soil oxidation and loss of depth) progresses, the soil organic layer decreases, ultimately changing to the next shallower soil series. For example, Lauderhill would be expected to become Dania with time (Table 1).

Because EAA soils are drained for at least part of the year for farming operations, the organic materials exposed at the surface continue to decay, but at a more rapid pace than when flooded. This decay process is known as *subsidence*. During the process of subsidence, nutrients within the soil are released as the organic materials decay. Growers often adjust their fertilizer recommendations to take advantage of this natural supply of nutrients.

When considering crops grown in the EAA, sugarcane decreases soil temperatures and substantially slows subsidence compared to vegetables. In addition, sugarcane is likely one of the best crops for the EAA to minimize subsidence because of its tolerance to short-term flooding. Many sugarcane cultivars currently planted within the EAA have the ability to maintain root functionality for short periods of time when experiencing flooded conditions. Efforts are underway to breed more flood-tolerant sugarcane varieties. However, these new cultivars must not only deliver flooding tolerance but also produce commercially viable quantities of sugar to be widely accepted.

Raising the water table has been shown to decrease subsidence and therefore increase the longevity of muck soils (Snyder 2005). Best management practices (BMPs) for organic soils include maintaining a higher water table throughout the production area to reduce subsidence. It is evident that this BMP and others relating to soil loss have been employed extensively because the subsidence rate has decreased from the traditional rate of 1 inch of soil loss per year to less than 0.6 inch per year with BMPs.

Crop diversification is another option to manage subsidence. For example, sugarcane grown in rotation with a useful cover crop to be used as a green manure crop (the cover crop is not harvested, but tilled into the soil for its nutrient and organic contributions) is both a means of retaining soil nutrients in the field while returning organic matter to the soil to offset subsidence losses.

Harvesting of green sugarcane without the traditional field burning just before harvest will return considerable organic matter back to the soil. Additional consideration must be given to crop residue management since the fresh weight of this material can be several tons/acre. When considering the next ratoon, plant residues covering the rows can result in cool soil and direct plant shading that potentially decrease the sugarcane growth rate.

The process of tillage mechanically stirs the surface layer of soil. This process loosens the soil and prepares it for additional farming operations. With respect to subsidence, tillage operations aerate that tilled soil zone, and in turn, this aeration promotes microbial growth and enhances subsidence. For this reason, reduced or no-till operations can be used to reduce subsidence.

A second and important effect that tillage causes is the loss of soil structure (Figure 1). During natural soil forming processes, soil particles are often attached to each other creating aggregates. Any soil structure that might have been present before tillage will be destroyed. Loss of soil structure affects a number of physical properties, including ease of drainage or other water movement within the profile. Once aggregates have been destroyed, the associated particles that originally made up the aggregate now have considerably more surface area and are more susceptible to microbial degradation, enhancing subsidence and carbon loss.

Figure 1. Good structure (left) is illustrated by the presence of many aggregates that allow for water infiltration and good plant rooting, and is often indicative of high organic matter concentrations. Poor structure (right) results in soil that clumps together but breaks apart readily with tillage, does not hold water well, and is an impediment to rooting.

Because most soils within the EAA have been farmed, some for as long as 100 years, they have undergone considerable changes. As mentioned above, subsidence due to water and tillage has continued to affect these soils, as have land-use changes. Vegetable production has changed with time, the acreage of sod and turf has increased, and cyclic changes in sugarcane acreage have also affected these soils. Lately, land use has changed again, as reclamation efforts by state and federal agencies for environmental purposes have resulted in conversion of agricultural lands to wetlands. However, the combined legacy of previous land uses can affect the reclamation process. The soil structure, as originally present in native soils, has been altered to some extent with each subsequent land use.

Soil Structure in Sugarcane and Uncultivated Fields (Dania Soil)

To study the value of soil structure and aggregates in muck soils and the effects of different land uses, two sites were compared. One was in continuous sugarcane production for many years while the other was never farmed or tilled. Soils at both sites were classified as a Dania series (Table 1). Note that Dania soils are shallow organic soils and currently represent one of the more common soil series within the EAA. Deeper muck soils, such as the Pahokee or Lauderhill, can be expected to respond similarly, especially as subsidence progresses. For both land uses, aggregates size increases with depth. Compared to the soil used for sugarcane production, aggregate size is larger in the uncultivated soil, which would be expected since this land was never tilled. Few large aggregates are found in the 6- to 12-inch depth used for sugarcane due to the relatively frequent tillage operations. Large aggregates are much more common closer to the surface in the uncultivated soil.

Carbon and Nitrogen in Aggregates

As subsidence proceeds in organic soils, quantities of nitrogen are released along with carbon. When this nitrogen occurs in plant-available form, the nitrogen can be used by crops to enhance production. For sugarcane, this source supplies most of the nitrogen required during the growing season.

As the size of aggregates increases, so does the organic carbon and nitrogen content within the aggregates. In the soil used for sugarcane, both smaller aggregates and reduced organic nitrogen concentrations were found, indicating that mineralized nitrogen was likely taken up by the sugarcane. In the uncultivated Dania soil, more organic carbon and nitrogen were found in larger aggregates compared to aggregates in the sugarcane sites. Thus, tillage was negatively affecting the number and size of aggregates, as well as the organic carbon and nitrogen contained within those aggregates.

Overall Soil Changes between Uncultivated and Sugarcane Dania Soils

Despite the changes in aggregate size and organic carbon and nitrogen concentrations between the sugarcane and uncultivated soils, soil bulk density was essentially unchanged (0.47 g cm^{-3}). This finding means that tillage operations, while changing the soil structure, had no apparent change in the weight of the soil per unit volume. While there were no differences between the two land uses in organic carbon content in the 0- to 6-inch depth, higher organic carbon was found below the 6-inch depth in the cultivated soil. The much more prolific production of sugarcane roots compared to native pasture plants on the uncultivated site is likely the reason for this difference.

Differences in organic nitrogen concentrations were evident with both soils showing increasing nitrogen with depth. Compared to the soil in sugarcane production, the uncultivated soil had higher organic nitrogen in the surface soil layer (0- to 6-inch depth). If the entire soil profiles are considered, the difference between the sugarcane and uncultivated soils was not dramatic, but the use of nitrogen by sugarcane was measurable.

Conclusions for Florida's Histosols in the Everglades Agricultural Area

Based upon the findings from the land-use comparison (sugarcane or uncultivated), organic carbon was higher with cultivation in the lower depths. There is considerable potential for minimum tillage and residue management to further enhance carbon sequestration in the sugarcane system. Carbon sequestration is improved and soil subsidence is slowed with sugarcane production, and both of these are positive outcomes. Taking action to increase or maintain carbon sequestration appears to be appropriate but may introduce some risk to farming operations. Additional management methods are needed to reduce this risk. For both the longevity of these organic soils and from a global perspective, slowing subsidence through BMP implementation makes sense. Since these BMPs also have considerable societal benefit, it remains to be seen if society will help to offset a part or all of the additional risk through some form of cost-sharing program or carbon credits trading.

In general, the subsidence throughout the EAA has been slowed because of higher water table management and implementation of other selected BMPs. Additionally, the comparison of soil with different land uses shows that the humification rate, conversion of organic matter from peat to humus, has changed. Another likely factor is a relative increase in the mineral content of soil as the organic constituents are lost through subsidence (Snyder 2005).

For More Information

Snyder, G. H. 2005. "Everglades Agricultural Area Soil Subsidence and Land Use Projections." *Soil Crop Sci. Soc. Fl. Proc.* 64:44–51.

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Table 1. Summary of characteristics of EAA Histosols (Snyder 2005).

Soil Series	Mineral Content (%)	Thickness of organic layer (inches)	Underlying material
Torry	> 35	> 51	Limestone
Terra Ceia	< 35	> 51	Limestone
Pahokee	< 35	36-51	Limestone
Lauderhill	< 35	20-36	Limestone
Dania	< 35	< 20	Limestone
Okeechobee	< 35	> 51	Limestone
Okeelanta	< 35	16-40	Sand