

CONSIDERATIONS ON SOIL CARBON MANAGEMENT

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Abstract. Soil organic carbon is important for the functioning of ecosystems and agro-ecosystems, having a major influence on the physical structure of the soil and its ability to store water. Loss of soil organic carbon can therefore lead to a reduction in soil fertility and land degradation. The content of organic carbon in a soil is determined by losses of organic carbon (through decomposition, erosion of particles and losses through dissolved organic matter and inputs of organic carbon). Thus, worldwide, soil management to increase the content of soil organic carbon involves measures that reduce losses and/or measures that increase inputs. Carbon management is important for many problems that involve soils.

Introduction

Globally, the quantity of carbon stored in soil is second only to that in the ocean and represents the largest store of terrestrial organic carbon. We know broadly that plant production and patterns of allocation determine the relative distribution of carbon with soil depth (Jobbagy and Jackson, 2000). It is believed that older organic matter materials are stored deeper in the soil profile.

Soils without organic matter are more compact. Soil aggregation is better when soil organic matter content is higher. Compaction reduces water infiltration, nutrient solubility, productivity and so is reducing the retention capacity of soil carbon. Soil conservation is represented by the management of carbon. Carbon management is important and necessary for many problems including soil, water management, land productivity and climate change. The concentration of oxygen and carbon dioxide in the soil can be continuously monitored because of existing sensors. Gas measurement systems in the soil provide important information on consumption, production and transport, with major implications in the estimation of qualitative and quantitative soil respiration and aeration status.

Soil organic matter is one of the most important carbon sinks, which in turn, under certain conditions, is transformed into atmospheric carbon dioxide, being a potential source for development of the greenhouse effect. One of the most

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important terrestrial pools for carbon (C) storage and exchange with atmospheric CO₂ is soil organic carbon. (SOC). If we adopt the recommended management practices, agriculture contributes not only to soil conservation and water quality goals, but also for enhancing the amount of soil organic carbon in the soil and to mitigating carbon dioxide (CO₂) emission effects on climate change.

1. Forms and sources of carbon in soils

There are 3 basic forms of carbon that may be present in soils. They are: elemental carbon, inorganic carbon and organic carbon.

Elemental carbon forms include charcoal and coal. Inorganic carbon forms are derived from geologic sources. Inorganic carbon forms are present in soils typically as carbonates. The most common carbonate minerals that are found in soils are calcite (CaCO₃) and dolomite [Ca Mg (CO₃)₂].

Organic carbon forms are derived from the decomposition of plants and animals. Organic carbon is the most important component because it's the key for all energy transformation of nature and directly influences all properties of the soil quality. Photosynthesis transforms CO₂ into vegetable material and some remains in soil as organic carbon. This is the process of carbon sequestration. (Moraru Paula Ioana, T. Rusu, Mara Lucia Sopterean, 2010).

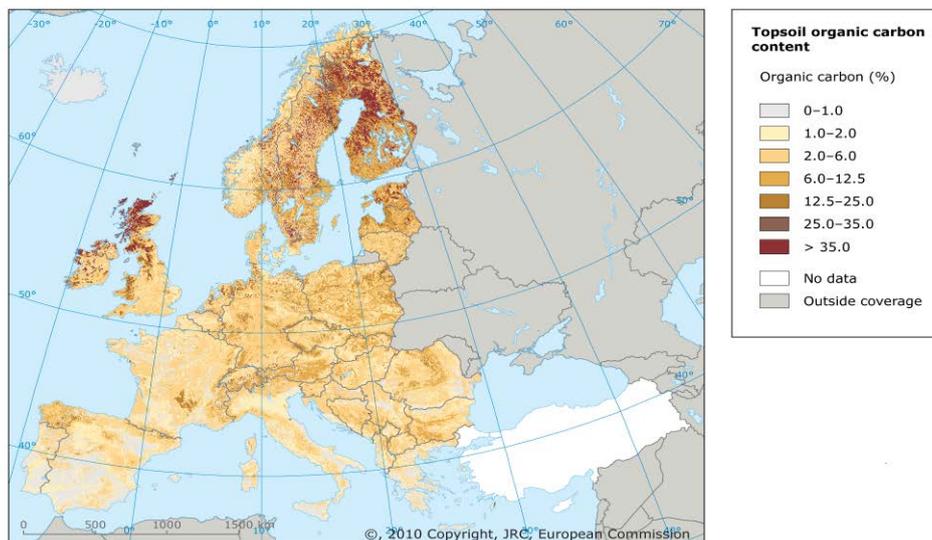


Fig. 1 - Topsoil organic carbon content (Source: JRC: Jones et al., 2005)

Around 45 % of the mineral soils in Europe have low or very low organic carbon content (0–2 %) and 45% have a medium content (2–6 %) (Rusco et al.,

2001). Low levels exist in particular in the southern countries of Europe: 74% of the land in Southern Europe is covered by soils that have less than 2% organic carbon in the topsoil (0–30cm) (Zdruli et al., 2004).

In addition to the naturally-occurring organic carbon sources are sources that are derived as a result of contamination through anthropogenic activities. The total carbon content present in the soil increases when contaminants are released in the environment. However, the total carbon contribution from contaminants, to the total organic carbon content of the soil is relatively small to negligible. Soil air and atmosphere contain the same gas, but in different proportion shown in table 1. (Gus P., T. Rusu, Ileana Bogdan, 2004).

Tab. 1 - Atmospheric air and soil composition

Compounds	Atmospheric air (%)	Soil air (%)
Oxygen	20,87	11,5
Nitrogen	78,31	79
Carbon dioxide	0,03	0,3-3
Argon	0,76	0,76
Other gases	0,03	traces (0,1)
Water vapor	1-2	1,5-2

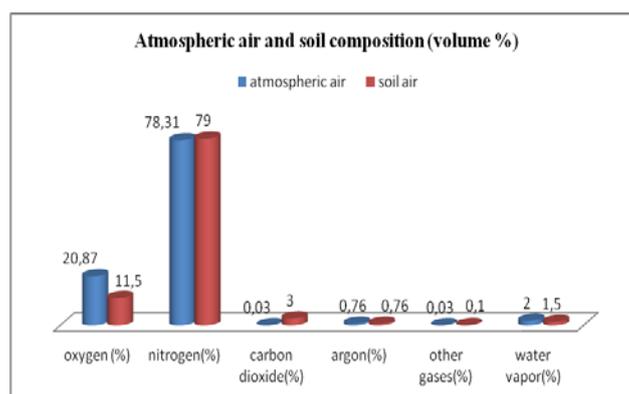


Fig. 2 - The amount of atmospheric air and soil air

The amount of soil organic carbon depends on soil texture, climate, vegetation and current land management. Soil texture affects soil organic carbon, because of the stabilizing properties that clay has on organic matter. Soils that have high clay content tend to have higher soil organic carbon than soils with low clay content under similar climate condition and land use.

Factors affecting organic carbon in soil:

- soil management;
- plant species/crop selection – continuous pasture builds organic carbon quicker than other rotations;
- residue management – residue is a source of organic material and removing it means less input;
- soil and nutrient losses – erosion events remove topsoil which contains the bulk of a soil's organic matter;
- plant production restraints (poor management) - affect plant root growth, available water and nutrient absorption, restricting plant growth and biomass above and below the soil surface, reducing organic inputs;
- climatic conditions, such as rainfall and temperature, are rate determining factors for organic matter decomposition;
- agricultural practices influence both the quantity and quality of soil organic carbon, which has directly impact on soil productivity, soil resilience and soil sustainability.

2. Carbon(C) sequestration in soils

Carbon sequestration is the long-term storage of carbon in oceans, soils, vegetation (especially forests), and geologic formations. Although oceans store most of the Earth's carbon, soils contain approximately 75% of the carbon pool on land — three times more than the amount stored in living plants and animals. Therefore, soils play a major role in maintaining a balanced global carbon cycle.

In agricultural systems, the amount and length of time carbon is stored is determined predominately by how the soil resource is managed. A variety of agricultural practices that can enhance carbon storage have been proposed. The benefits of these various practices as well as their potential hidden costs must be considered when management decisions are made.

Organic carbon levels in soils reflect the balance between additions and losses of organic carbon. Carbon sequestration refers to the storage of carbon in a stable solid form. It occurs through direct and indirect fixation of atmospheric CO₂. Direct soil carbon sequestration occurs by inorganic chemical reactions that convert CO₂ into soil inorganic carbon compounds such as calcium and magnesium carbonates. Direct plant carbon sequestration occurs as plants photosynthesize atmospheric CO₂ into plant biomass.

Fluxes between terrestrial or soil organic carbon and the atmosphere are important and can be positive (sequestration) or negative (emission of CO₂).

The different C pools existing in the soil have different mean residence times, ranging from one year to a few years depending on the biochemical composition to decades or more than 1000 years. There is also some connection with the composition, but mainly with the kind of protection or the type of bonds. Carbon sequestration and an increase on soil organic matter will have a direct positive impact on soil quality and fertility.

The importance of C sequestration to manage soil fertility has been recognized for millennia since the dawn of settled agriculture. However, its impact on the atmospheric chemistry as a source of atmospheric CO₂ and its role in stabilizing atmospheric chemistry as a natural C sink gained attention during the 1970s. As the third largest global pool, the soil/ pedological C pool plays an important role in the global C cycle through natural and anthropogenic changes in both organic and inorganic components.

In soil carbon management, increasing the soil C pool has been substituted with the term of soil carbon sequestration (Paustian et al., 2000). Current research and knowledge suggests that in particular agricultural soils can sequester significant amounts of carbon since agricultural practices in the past have depleted soil carbon stocks worldwide. Intensive tillage practices have been recognized as the major factor of causing the loss of soil organic carbon in agricultural soils.

Agricultural soil carbon sequestration depends on a variety of factors like existing soil C levels, soil type, climate and management practices (Smith et al., 2007). In theory, the size of the potential soil organic carbon sink should be equal to the historical amount of C loss.

3. Methods for determining soil organic carbon

There are numerous methods and variations of the methods for the identification of total organic carbon. These methods may be qualitative, semi-quantitative, or quantitative depending upon the technique used. Quantitative techniques range from simple gravimetric determinations through volumetric and manometric measurements through the more complex spectrophotometric and chromatographic methods.

There are two qualitative methods in the literature for the structural characterization of organic carbon forms in soils. One of these qualitative methods is based on nuclear magnetic resonance (NMR) spectroscopy and the other one diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy (Brian A. Schumacher, 2002).

NMR is an important for the characterization of soil organic matter and humification processes in soils. (Kogel – Knaber, 1997). The NMR techniques is

very convenient because the extraction of organic matter is not needed, but this methods are expensive and time-consuming (Rumpel et al., 2001).

Diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy, when used in conjunction with multivariate data analysis, provides a rapid and inexpensive means of differentiating carbon forms in soils. Both, inorganic and organic forms of organic compounds may be identified using this technique (Nguyen et al., 1991).

Numerous comparative studies have been performed examining the efficiency of total organic carbon (TOC) methods (Nelson and Sommers, 1996). In nearly all of these studies, the standard method to be compared against was the Walkley-Black dichromate extraction with titrimetric quantitative method. In generally, nearly all of the newer methods having comparable or greater total organic carbon recoveries and greater precision than the Walkley - Black method.

The most accurate standard laboratory test for soil carbon is dry combustion using an elemental analyzer. These instruments heat a small sample (usually a fraction of a gram) of dry pulverized soil to around 1000°C and measure the CO₂ gas that is a combustion product. The results are expressed as the percentage of carbon in the sample. The dry combustion test oxidizes and measures total soil carbon: organic matter, charcoal, and carbonates.

Less accurate are the more traditional loss on ignition (LOI) and Walkley - Black tests. Loss on ignition measures the weight loss of a dry soil sample after it is heated in an oven to 360–450°C for a couple of hours. Walkley - Black is a wet chemistry method using potassium dichromate.

The Walkley - Black test does not usually give a full accounting of charcoal, and may miss some types of organic matter. Neither measures inorganic carbon. Because the interest in soil carbon from the perspective of biosphere function or climate change is relatively recent, many labs are accustomed to testing for soil organic matter for the purposes of calculating effective rates of herbicide application. For this purpose, soil organic matter is a liability because it lessens the effectiveness of herbicides on living vegetation, and loss on ignition or Walkley - Black tests are typically used.

Conclusion

Carbon is sequestered in soil when organic matter accumulates faster than it is respired as CO₂ by soil. Soil C storage helps to stabilize atmospheric CO₂ concentrations and promotes improved drainage, soil structure, water holding capacity, and other important soil properties that improve agricultural productivity (Lal et al., 2004).

The development of agriculture during centuries and in the recent decades has led to consumption of soil carbon stocks, which were created over a long period of time.

Soil carbon sequestration is a strategy to achieve food security through improvement in soil quality. While reducing the rate of enrichment of atmospheric concentration of CO₂, soil C sequestration improves and sustains biomass/agronomic productivity.

Soil organic carbon is an extremely valuable natural resource. Irrespective of the climate debate, the SOC stock must be restored, enhanced, and improved. A carbon management policy that includes regulation, based trading soil carbon must be developed.

Yet, the close link between soil carbon sequestration and world food security on the one hand and climate change on the other can neither be overemphasized nor ignored.

We need policies to encourage the maintenance or increases in soil C stocks for a variety of societal benefits, including improved soil quality, reductions in both wind and water erosion, and the mitigation of economic impacts of natural events, such as hurricanes and droughts.

Agricultural soils are particularly important for C storage because of their potential for C sequestration both now and in the future (Schlesinger, 1995).

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