

Study on the Effects of Different Factors on Carbon Pools in Terrestrial Ecosystems

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Abstract

Soil is the largest carbon pool in terrestrial ecosystems, and it is particularly important to study soil carbon pools. In this study, we investigated the effects of intensive agriculture, plant inputs and organic matter inputs on the soil organic carbon pool, and the results showed that intensive agriculture increased the soil carbon pool and soil organic matter content to a certain extent, and increased the rate of carbon sequestration in the soil, but intensive agriculture made the soil more prone to erosion, resulting in the loss of soil nutrients; the plant inputs were mainly in the form of root secretion, fine roots and coarse heeled debris, resulting in the increase of carbon stock in the soil; the organic matter inputs increased the carbon stock and the rate of carbon sequestration in the soil, and the organic matter inputs increased the carbon stock and the rate of carbon sequestration in the soil. Plant inputs are mainly in the form of root secretions, fine roots and coarse heeled debris, resulting in an increase in soil carbon stocks; organic material inputs increase soil carbon stocks and sequestration rates, while organic materials can increase the stability of soil aggregates, which can better realize the transfer of nutrients, retain water, and promote the growth of the crop root system, but organic material inputs will increase soil porosity and accelerate the loss of soil nutrients.

Keywords

Intensive Agriculture; Plant Inputs; Organic Matter Inputs.

1. Introduction

Soil is the largest and most active carbon reservoir in terrestrial ecosystems [1]. Soil organic matter (SOM) can be defined as the decaying biological debris that lives on or collects in the soil. Soil organic matter is heterogeneous and multiphase, ranging from the latest root secretions to difficult-to-decompose humic substances [2]. At a soil horizon of 1 m, soil organic matter contains approximately 1500×10^{15} g of carbon and acts as a major terrestrial carbon reservoir regulating soil biochemical processes. In terms of carbon stocks, soil carbon stocks are three times higher than in the atmosphere and four times higher than in all terrestrial plants and marine organisms (especially corals), respectively [3-4]. Atmospheric CO₂ concentrations have increased from 280 ppm in 1750 to 397 ppm in 2014. without appropriate action, based on current projections, atmospheric CO₂ concentrations will continue to rise to 500-1000 ppm by 2100. in addition, during the same period, atmospheric CH₄ and N₂O concentrations have

increased from 700, 270 ppb, respectively, to 1745, 314 ppb. to 1745, 314 ppb [5]. Currently, the average annual increase in atmospheric carbon is 4 Pg (1 Pg = 10¹⁵), and the global average temperature is rising by 0.1°C per century, which exceeds the critical rate at which the Earth's system can adjust. At the same time, in the central Northern Hemisphere and at high latitudes, precipitation at the surface is increasing at a rate of 0.5-1% per decade, while in the subtropics it is decreasing at a rate of 0.3% per decade [6], an anomaly that has also led to a decline in soil organic carbon pools. Abrupt changes in precipitation characteristics make soils more susceptible to water erosion, thereby disrupting the biogeochemical cycle of water and other components (carbon, nitrogen, phosphorus and sulfur). The organic carbon pool in soils is mainly influenced by intensive agriculture, plant inputs and inputs of exogenous organic materials. This paper will focus on the above aspects to specify their effects on soil organic carbon pools.

2. Intensive Agriculture

Lal et al [7] showed that the world's arable land accounts for 35% of the global land area, but holds 12% of the soil carbon stock. Therefore, increasing soil carbon sequestration is an important soil management approach used to mitigate climate change. Intensive agriculture relies heavily on agrochemicals, conventional tillage, agricultural machinery and land-use change to maximize crop yields as much as possible in a monoculture model. When crops are grown, the tillage process redistributes the soil, which is considered to be one of the main processes leading to significant soil erosion [8-9]. Differences in tillage practices result in different rates of soil erosion and carbon movement [10]. More than 80% of soil redistribution on agricultural land is due to tillage erosion [11]. The tillage process affects all aspects of the soil organic carbon pool differently. On the one hand, it brings soil organic carbon to the surface layer, thus providing favorable conditions for decomposition and leading to increased mineralization, but on the other hand, soil organic carbon is diluted in the surface layer due to mixing of subsoil and surface soil [12]. Monoculture systems can negatively affect soil function and sustainability [13]. Deep soil organic matter and soil bioactivity are reduced due to continuous growth of wheat, maize and soybean. Liu et al [14] concluded that accumulation of certain acidic compounds in deep soils has caused severe damage to soil bioactivity and microbial carbon. Therefore, selection of appropriate crop types is an important control measure that can influence soil organic carbon content in long-term monoculture systems.

Fertilizer application is a major soil management measure that largely influences soil organic carbon content and the effectiveness of other nutrients. The increase in soil organic carbon can be attributed to the return of crop residues to the field [15]. Soil carbon pools accumulate gradually due to fertilization, tillage, crop rotation and soil and water conservation agriculture [16]. Yang et al [17] showed that nitrogen fertilizer with organic manure significantly increased soil organic carbon content in a long term orientation trial of wheat-maize rotation. Successive applications of chemical fertilizers and farmyard manure resulted in significant increases in organic carbon and total nitrogen [18]. Zhou et al [19] collected data from 106 pairs of treatments in 28 long-term orientation trials on subtropical rice soils and found that NPK with straw was able to sequester a higher rate of carbon sequestration than NPK with organic fertilizers, and that the rate of carbon sequestration in the soil had a decreasing tendency with the number of years of fertilizer application. Guo et al [20] showed that long-term application of nitrogen fertilizer could significantly increase the organic carbon content in 0-20 cm of soil and increase the carbon stock in soil after 25 years of different nitrogen fertilizer application. However, Fan et al [21] showed that long-term application of inorganic fertilizers may lead to significant reduction in soil quality and loss of soil organic carbon. Therefore, Saiki et al [22]

proposed the use of organic fertilizers as an alternative to chemical fertilizers as a better and safer way to maintain soil health.

Intensive agriculturalization increases crop yields to a certain extent, but it also adversely affects the soil, and intensive agriculture poses a potential threat to soil organic carbon to a certain extent, such as the rapid mineralization of soil organic carbon, which leads to a large amount of carbon being converted to carbon dioxide in the soil air, increasing the concentration of carbon dioxide in the air, and at the same time leading to a decrease in the amount of carbon stored in the soil. In particular, large amounts of photosynthetically sequestered carbon are taken away with crop harvesting, leading to carbon depletion in arable agricultural soils, although the crops also return very small amounts of plant residues in the process. Intensive agriculture accelerates the process of biological decay of soil organic matter through the destruction of soil aggregates and the application of fresh organic material, which in turn accelerates soil erosion, removes carbon-rich topsoil and reduces soil organic carbon content.

3. Plant Input

As an important component of the global carbon cycle, the characteristics of the carbon cycle in farmland under the influence of anthropogenic management measures are of great significance to global climate change. Carbon and nitrogen metabolism, as the most basic metabolic pathways in crops in farmland systems, not only affect the growth and development of crops, but also have a close relationship with the global carbon and nitrogen cycles. Carbon metabolism has an important impact on crop growth, development and yield, which makes the study of crop carbon metabolism very necessary. Crop carbon metabolism is a very complex process, which can be divided into carbon dioxide into organic carbon through photosynthesis, carbohydrate accumulation, decomposition, and carbohydrate transportation and conversion of several major processes, of which photosynthesis is particularly important part, it is affected by light, carbon dioxide concentration, mineral elements, crop characteristics and many other factors[23]. Shang Hui et al[24] showed that, with the reduction of fertilizer application, maize yield and aboveground carbon storage decreased significantly, and appropriate application of nitrogen and phosphorus fertilizers on maize carbon assimilation and soil carbon sequestration has a significant increase in the role of a win-win initiative to improve and stabilize maize yield and increase soil carbon sequestration. Miao Huitian et al. [25] showed that NPK and organic-inorganic fertilizer can effectively increase the carbon sequestration of maize plants, increase the distribution ratio of carbon assimilates in kernels and rachis of maize plants, and thus reduce the distribution ratio of carbon assimilates in stems, leaves and stubble as well as its C/N, which has a dual effect on soil fertilization and carbon fixation.

Plant inputs drive decomposition and soil organic matter formation and can be viewed as the controlling pump in the carbon cycle. It has been shown that native biota adapted to a particular site are more able to decompose dead leaves at that site more rapidly than if they were placed at another site, i.e., they have a native advantage [26]. Root matter is in the form of secretions, fine and coarse root debris as the main inputs of organic matter [27-28]. Cereals choose to grow more above ground due to genetic selection, transferring 20-30% of their assimilated carbon to roots. Root respiration accounts for 6-17% of the photosynthetic products of different plants, and 3-6% of the assimilated carbon is transferred to the soil [29]. According to Jones et al [30], 20-40% of the photosynthetic carbon is transferred to the ground, of which 5-55% remains in the roots, 2-18% forms organic matter, and 12±5% undergoes soil respiration.

Forest ecosystems store more than 80% of aboveground carbon sequestration by plants and more than 50% of soil organic carbon [31]. Forest types can be categorized based on the combined effects of climate, inherent soil properties and topography. These factors are probably the main contributors to our inability so far to make appropriate choices for managing

forests on a global scale. According to the latest IPCC report on climate change (AR5), the annual equivalent of about 30 ± 4.5 Pg C loss due to reduced vegetation cover. However, rising atmospheric temperatures and CO₂ concentrations will in turn stimulate forest growth. Poudel et al [32] projected a 33% increase in total forest biomass in Sweden over the next 100 years based on current global climate change trends.

4. Inputs of Organic Materials

Inputs of organic matter play an important role in managing soil carbon pools, replenishing organic carbon stocks depleted through unfavorable agricultural practices. At the same time the restoration of grassland and forest ecosystems can significantly increase the soil organic carbon pool, thus compensating for carbon losses due to mineralization. However, some agricultural activities can have a negative impact on soil quality. In addition, some complex technologies (e.g. crop residue management, conservation tillage methods and legume cropping systems) are effective strategies for increasing carbon stocks in arable land.

The deterioration of soil quality is a major constraint to sustainable food production worldwide [33]. Many studies have shown that the application of organic matter inputs can improve soil quality, increase agricultural stability and improve soil structure [34-35]. Chen Xiaofen et al [36] showed that water-stable macroaggregates were the main carriers of soil organic carbon in the study of different fertilization treatments on the organic carbon of red soil rice soil agglomerates, and the application of organic fertilizers significantly increased the water-stable macroaggregates and the content of organic carbon in them, which was an effective measure to improve the soil agglomerates structure and to increase the biological function and productivity of red soil. Chen Xuanjing et al. [37] showed that long-term fertilization of organic carbon in purple rice soil aggregates showed that >0.25 mm water-stable aggregates were the main carriers of soil organic carbon, and long-term nitrogen, phosphorus, and potassium fertilization combined with rice straw returning to the field significantly increased the water-stability of purple rice soil aggregates and the content of organic carbon in the aggregates, which was an effective measure to improve the granular structure of purple rice soil.

The slow decomposition kinetics of exogenous organic matter, and the input of anthropogenic organic matter in the form of organic conditioners continuously provide a variety of essential nutrients to the microbial community [38-39]; this input is superior to chemical fertilizers in many ways. Through soil amendments, inputs of organic materials greatly increase cation exchange capacity and improve negative charge due to organic carbon [40-41]. These properties have a very important role in retaining nutrients from various sources of organic inputs and nourishing agricultural crops. Finally, the input of organic matter also ensures agglomerate stability as high stability of agglomerates provides favorable conditions for large-scale nutrient transfer, water retention time, root growth and microbial activity [42-43]. In addition, organic matter such as compost and vermicompost enhance organic carbon content.

Soil organic matter is a crucial factor for soil fertility, crop production and protection of land from various environmental threats [44]. However, excessive use of mineral fertilizers without alkaline fertilizers (e.g. lime) tends to acidify the soil and reduces water in the soil through excessive transpiration by plants. On the other hand, in addition to biological activities, exogenous organic matter input improves soil porosity and aggregate stability as compared to the application of mineral fertilizers only. Lima et al [45], on the other hand, advocated that the long-term use of farmyard manure enhances carbohydrates, as well as lignin and lignin-like products. Bhattacharya et al [46] demonstrated that a mixture of fly ash and vermicompost was found to increase the organic carbon content of the soil in the applied to the soil resulted in a significant increase in organic carbon content. Zhao et al [47] showed that long-term nitrogen, phosphorus, and potassium rationing of straw in a rice-wheat rotation system on a neutral

purple soil increased carbon inputs, which in turn increased soil carbon stocks. However, improvements to soil properties are not always beneficial to agricultural production, as increased porosity may accelerate nutrient loss [48]. Consequently, as chemical oxygen demand (COD) increases, this nutrient loss may lead to poor water conditions [49].

Green manure (GMs) can be defined as a plant that provides nutrients for plant growth and improves the quality of the soil by changing its properties [33]. The use of crop residues as green manure can improve the overall soil environment and maintain crop yields [50]. Lin et al [51] found that soil organic carbon increased by 59-63% after combining green manure with industrial wastewater. Mandal et al [52] showed that there was a general trend of relative increase in the organic carbon content of the soil by planting green plants such as sesame, sesame, and cycad in the cultivation of paddy fields Yang et al [53] found that green manure planted during long term winter season greatly increased the soil organic carbon content and C/N and redistributed the large clusters into small clusters.

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