Impact of agronomic practices on soil organic carbon dynamics: A review

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Abstract
Climate change is one of the important factors for growing concern over food security, since accelerated increase in green house gas concentration especially carbon dioxide in the atmosphere by manmade activities, resulted in global warming. In this context, soil, considered to be the largest terrestrial sink for organic carbon through carbon dioxide sequestration from the atmosphere and simultaneously it also acts as a source of organic carbon through decomposition of organic residues. Consequently, even minor changes in soil organic carbon have a significant impact on global warming. To mitigate the global warming, it is essential to focus on increasing carbon sequestration and to reduce carbon dioxide emission into the atmosphere. Soil organic carbon cannot be dealt as a single entity it is usually composed of different fractions with varying degrees of rate of decomposition and stability. Further, each of which is influenced by different management practices. Hence, clear understanding of these fractions as influenced by different agronomic interventions became more crucial to recommend the most appropriate agronomic intervention to maintain the carbon equilibrium in any ecosystem.

Keywords: Soil organic carbon (SOC), carbon dynamics, particulate organic carbon (POC), dissolved organic carbon (DOC), microbial biomass carbon (MBC)

Introduction
Climate change is becoming a serious global environmental concern. It is evident that accelerated increase in GHG concentration in the atmosphere due to manmade activities ignited the issues of global warming (Ahmed et al., 2018) [1]. Among GHG, carbon dioxide concentration plays a major role in influencing the climatic system, in turn raising the concerns of the global world (Kumar et al., 2019) [2]. Soil simultaneously acts as a major terrestrial sink and source to atmospheric carbon content (Gross and Harrison, 2019) [3]. Soils play a key role in storing large amounts of atmospheric carbon as SOC. Consequently, even minor changes in soil organic carbon have a significant impact on global warming (Nunes, et al., 2020) [4].

SOC is a dynamic component and an important indicator of soil quality and health (Gurmu, 2019) [5]. Carbon is continually being fixed into organic form by photosynthetic organisms under the influence of light and simultaneously carbonaceous materials being stored in soil is decomposed and returned to the atmosphere for survival of higher organisms (Thompson and Kolka, 2005) [6]. Therefore, an equilibrium between amount of OC stored and amount leaving the soil at that particular point is essential to determine the amount of carbon actually stored in the soil (Lv and Liang, 2012) [7].

SOC plays a key role in improving the soil aggregate stability and in turn prevents soil degradation and enhances physical, chemical and biological properties of soil (Liu et al., 2019) [8]. SOC is a common constituent of SOM which is considered as a reservoir of nutrients to crops, improves nutrient availability, retains moisture, reduces soil crusting, thus ultimately influencing the productive capacity of soil (Canqui and Lal, 2009) [9]. There are several fractions with varying degree of decomposition and stability which are very essential to understand the influence of management practices on SOC dynamics (Yadav and George, 2007) [10]. These fractions are gaining importance because the total organic carbon in soil is composed of labile and non-labile forms and wherein labile forms reported to have comparatively more oxidizable nature (Juan, et al., 2018) [11]. Further, labile fractions are also sensitive to different agronomic interventions (Yang, et al., 2003) [12].
The soil organic carbon stored in the soil is controlled by several other factors like climate, physical properties of soil, Soil depth, Soil microorganisms and Topography/relief (Oliveira, et al., 2018) [13] and (Esmaeilzadeh and Ahangar, 2014) [14]. Several studies reported that the modification of these factors through agronomic interventions have marked influence on carbon dynamics.

To mitigate the carbon losses and to address the issues of climate change proper understanding of carbon dynamics in soil is essential. Keeping this in view, this present article reviewing the importance of different organic fractions and factors influencing the carbon dynamics in the soil followed by a discussion on the effect of different management practices on the soil organic carbon was made considering this as a need of an hour. Sound knowledge of which is important to recommend suitable agronomic intervention to maintain the carbon equilibrium in that concerned ecosystem.

Soil Organic Carbon Fractions

Total organic carbon

The carbon fraction stored in soil organic matter, that which is composed of dead and living organic components represents Total organic carbon (TOC). Generally, SOM consists of around 58 % TOC (Canqui et al., 2015) [15]. Even marginal increase in TOC in soil found to have significant reduction in atmospheric carbon dioxide concentration (Srivastava et al., 2012) [16]. The carbon materials in the soil are grouped into three pools active, slow and passive (Sahoo et al., 2019) [17]. The active pool being subjected to rapid oxidation hence, prone to rapid decomposition contributing carbon dioxide to the atmosphere (Dumale et al., 2011) [18]. Slow pools of SOC are comparatively resistant to decomposition. While, the stabilized pool of SOC is highly resistant to decomposition and thereby could not serve as an immediate nutrient source (Lorenz et al., 2011) [19].

Particulate organic carbon

SOM is classified based on size of the components as POM which is conventionally divided into two main groups coarse particulate organic matter (cPOM) and fine particulate organic matter (fPOM). The cPOM fraction mainly consists of partially decomposed organic materials representing labile carbon pools while fPOM consists of well decomposed or amorphous organic matter constituting less labile carbon pools (Lamberti and Gregory, 2007) [20]. POM plays a very important role as a food source and substrate for heterotrophic microorganisms acts as a prime site for biological activity (Michand et al., 2011) [21]. The carbon constituent in POM is known as particulate organic carbon (POC) which is comparatively more in topsoil (Zeller et al., 2011) [22]. POC components are preferred by many microbes and due to its C/N ratio influencing the microbial communities in that region (Guo et al., 2014) [23].

Dissolved organic carbon

DOC is a one of the potential fraction of SOC pools which that part of soil solids that can readily pass into soil solution (Rizinjirabakea et al., 2019) [24]. It is of two types autochthonous DOC (originated within the water body) and allochthonous DOC (originated from soils and terrestrial plants). It is a direct source of food to soil microbes and a biodegraded portion of DOM (Nahum et al., 2005) [25] and (Toming et al., 2013) [26]. It includes those organic molecules which can pass through a 0.45 μm filter which originates from those sources plant litter, humus, microbial biomass, carbon dissolved in rain, etc. Whose concentration is largely influenced by microbes (Yang et al., 2016) [27]. DOC plays an important role in transporting carbon hydrologically among different pools (Zhou et al., 2016) [28] and (Lv et al., 2019) [29]. DOC includes low molecular weight substances (amino acids, carbohydrates, and organic acids), high molecular weight substances (fulvic, humic acids, and humin), and microbial-induced DOC substances (subeans, murein, chitin etc) (Olk et al., 2019) [30]. DOC influences the degradation of organic and inorganic substances in the soil. Based on biodegradability DOC is classified as labile, semi-labile and non-labile (Panagiotopoulos et al., 2019) [31] and (Li et al., 2017) [32]. Labile carbon is considered as a prime source of energy to microbes as this source is readily decomposable which includes simple sugars, amino acids etc (Khaatoon et al., 2017) [33]. Semi-labile are transformed to labile forms with time which includes compounds like cellulose, hemicellulose etc. (Roviraa et al., 2002) [34] and (Zhang et al., 2020) [35]. Non-labile carbon is that fraction of carbon which is resistant to microbial decomposition and persists in soil for years which includes compounds like fulvic, humic acids, and humin (Sootahar et al., 2019) [36].

Microbial biomass carbon

Soil microbial biomass carbon is that fraction of carbon present within the living component of soil organic matter, thereby acting as an indicator of soil quality (Brookes, 2001) [37]. The microbial biomass is mostly concentrated within 10 cm of soil from top (Liu et al., 2012) [38]. This fraction usually helps in ecosystem functioning through recycling of energy and nutrients (Mcintyre et al., 2006) [39].

Agronomic Interventions on Carbon Dynamics

Effect of soil tillage and residue management on SOC

Among different crop production factors tillage plays a key role in modification of soil properties esp. soil structure, affecting soil resource utilization ( Alam et al., 2014) [40]. Tillage was reported to expose SOC to degradation enzymes thereby hastening the process of mineralization and biodegradation of SOC (Muruganandam et al., 2009) [41] and (Kumar et al., 2019) [42]. The labile fraction of SOC is reported to get exhausted rapidly from top soil due to influence of tillage on land use change (Naresh et al., 2018) [43]. SOC is directly influenced by intensity of tillage (Haddaway et al., 2018) [44] such that zero or No-tillage prevented the loss of SOC with an aim to mitigate the loss on soil quality thereby promoting carbon accumulation than intensive tillage, comparatively (Busari et al., 2015) [45] and (Gadermaier et al., 2010) [46]. This might be due to increased disruption of soil aggregates and losses in organic matter due to intensive conventional tillage operations however, in the No-till system SOC is protected from degradation through increased stability in aggregate formation (Aminian et al., 2015) [47]. Conventional tillage has profound influence on crop production in short term basis while in long term basis conservation tillage is reported to have positive influence and serves as a key indicator of soil quality (Aziza et al., 2013) [48]. In addition, conservation or No-till systems are reported to improve carbon accumulation compared to intensive tillage (Lal et al., 1997) [49]. Similarly, addition of residues reported to play a significant role in minimizing soil erosion and enhancing the stability of soil aggregates (Somasundaram et al., 2012) [50]. In the long run this residue addition can have a mulching action protecting the soil moisture loss due to evaporation (Shirish et al., 2013) [51]. Further, residue
management has an influence on various soil microbial communities through its impact on thermal and moisture regimes of the soil (Borowik and Wyszkowska, 2016) [52].

Effect of intercropping and crop rotation on SOC
Intercropping is a process cultivating two or more crops on the same piece of land at the same time (Finley and Ryan, 2018) [53]. It is one of the key components of conservation agriculture characterized to cover the barren space in the field, minimizing soil loss and enriching biodiversity (Scherr and Mcneely, 2008) [54]. (Ghosh et al., 2017) [55] reported that due to increased soil biomass and comparatively less disturbed topsoil might have minimized the oxidation of organic carbon thereby resulting in increased accumulation of organic carbon in intercropped soils.

Crop rotation plays an important role in management of SOC stocks, due the influence of added residues on SOC’s residence and turn over time in the soil (Jarecki and Lal, 2003) [56]. In addition to this the duration of cropping system and time for which the land is left fallow also affects the SOC stocks in the soil (Sharma et al., 2019) [57]. Cropping system which produces higher biomass found to be successful in improving the net build up of SOC stock (Wang et al., 2010) [58]. Such that increased cropping intensity and addition of legumes in the rotation is potential enough to improve biomass production and carbon sequestration (Mikha et al., 2014) [59]. Legumes can fix atmospheric nitrogen into the soil and lead to increase in plant residue input, consequently total organic carbon in the soil. This is in consensus with (Chen et al., 2018) [60].

Effect of mulching on SOC
Mulch is a layer of any material applied to any given surface area primarily to reduce ET losses, conserve moisture, regulate soil temperature and to control weeds (Ramakrishna et al., 2005) [61] and (Telkar et al., 2017) [62]. Materials used can either be organic or inorganic in nature (Kroisova et al., 2014) [63] and (Mir et al., 2018) [64]. Organic mulches, when added to soil, add organic matter to the soil, directly influencing soil microbial activity and in turn SOC content (Jodaugiene et al., 2010) [65] and (Yang et al., 2003) [66]. Similarly, if mulches of synthetic origin are added into soil they are not able to add organic matter but still influence SOC by playing a role in accelerating the process of decomposition organic matter (Cattanio et al., 2008) [67]. In an experiment the influence of organic mulches and different thickness of mulch layer on soil organic carbon content was evaluated which witnessed significantly higher SOC under all mulched treatments with a thickness 10 cm over control with no mulch (Bajorene, 2013) [68].

Effect of nutrient management on SOC
Proper nutrient management is vital to achieve higher crop production, biological activity and to improve carbon sequestration in the soil (Wade et al., 2020) [69] and (Jarecki and Lal, 2003) [56]. Mineral fertilizer application even though it increases the quality and quantity of crop residues. However, due to its influence on soil pH and ionic concentration on aggregation thereby not necessarily leading to increase in SOC pool (Naab et al., 2015) [70] and (Singh et al., 2018) [71]. It has been observed that AM fungi population is directly correlated with P content in the soil which is responsible for aggregate formation in the soil (Rillig and Mummey, 2006) [72] and (Peng et al., 2013) [73]. In addition, soil P also have a positive impact on root growth, shoot growth and thereby on total dry matter production (Huda et al., 2007) [74]. In comparison with mineral fertilizers the organic fertilizers have marked influence on aggregate stability and carbon sequestration (Malata et al., 2017) [75]. Majority of studies clearly highlighted that the long term application of organic manures have significant improvement in stable aggregate formation (Brar et al., 2015) [76] and (Zhao et al., 2020) [77]. This enhanced ability of organic manures is due to its virtue of slower rate of decomposition (Jalali and Ranjbar, 2009) [78]. This impact was further enhanced by ideal integration both organic and inorganic fertilizers this might be due to increased increase in crop residues associated with increased dry matter production (Khan et al., 2017) [79]. Consequently, all these contribute to higher microbial population which leads to higher soil moisture storage, improvement in aggregate stability and greater nutrient availability (Dignac et al., 2017) [80].

Effect of water management on SOC
Water management plays a major role for assured crop production and even a short term deficit in water during the crop growing season results in substantial decline in biomass (Morison et al., 2008) [81]. An efficient management of water indirectly affects the total biomass production which in turn influences the carbon sink capacity (Adugna, 2016) [82]. Subsequently, efficient water management also influences the total microbial activity in the soil in turn increasing the rate of decomposition of soil accumulated biomass (Prommer et al., 2008) [83]. This is ultimately influencing the SOC content in the soil. In a long term investigation when a desert is being converted into an irrigated arable land rapid increase in soil organic carbon was observed under irrigated ecosystems over a desert, comparatively (Li et al., 2017) [82]. Further, irrigation water management role in regulating the soil thermal regime directly influences soil microbial activity and with the increased soil moisture, the microbial activity increases and vice-versa.

Effect of soil amendments on SOC
Several long term results showed a marked decrease in SOC with liming (Wang et al., 2016) [84] which might be attributed due to enhanced microbial activity at higher pH (Cho et al., 2016) [85] and (Manee et al., 2016) [86]. Further, with reduction in SOC the soil aggregate stability was hampered favouring decrease in percentage of macro-aggregates (Liu et al., 2019) [8]. Calcium ions on other hand effect soil aggregation due to formation of cation bridges between clay and soil organic matter particles (Wuddivirra and Roach, 2007) [87]. In contrast, several other studies reported increase in SOC content with application of lime sowing to improved soil structure and higher biomass protection due to higher yields (Aye et al., 2016) [88].

Conclusion
This paper clearly highlighted the potential of soil to sequester atmospheric carbon dioxide into different fractions of carbon. It also highlighted the role of different agricultural management practices in promoting the carbon input and discouraging decomposition from the soil which thereby improved the soil quality. Practices like addition of organic manure, soil amendments provided with minimal soil disturbance and covering the soil with a layer of mulch under a sustainable cropping system aim to provide conditions favorable for higher dry matter accumulation leading towards
increased carbon sequestration. Thus unlocked a new opportunity, potential enough to tackle climate change.

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