CONSERVATION AGRICULTURE, A WAY TO CONSERVE SOIL CARBON FOR SUSTAINABLE AGRICULTURE PRODUCTIVITY AND MITIGATING CLIMATE CHANGE: A REVIEW

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ABSTRACT

Improvement in food security and environmental preservation should be the major concern of innovators of farming system. Huge global population with high consumption of food, water, and other agricultural products are putting pressure on agricultural sector, and thus has replaced traditional practices of agriculture with advanced technologies. Conventional agriculture focuses on advancing the agriculture technologies for increasing the potential yield of crop. Conventional agriculture cannot fulfill the needs of 7 billion human populations without destroying the integrity of soil environment. Consequently, loss of carbon from soil as soil carbon (C) is a major constituent of global carbon cycle and its management can affect atmospheric carbon dioxide concentration. Soil carbon has also been recognized as carbon sink for sequestering the atmospheric CO_2. Carbon dioxide is main emitter among the greenhouse gases by agriculture in the global food web. Soils of the arable land are mainly depleted of the soil organic carbon (SOC) and the threshold level of SOC is 1.5-2% at root zone. For sustainable agricultural productivity and stable environment, it is necessary to build up the soil carbon contents by increasing carbon inputs, or decreasing decomposition of organic matter in soil. While, soil carbon can also be improved by adapting the conservation agriculture practices like no tillage, intensifying crop rotation and by optimizing the agronomic practices like fertilizer, pesticides and irrigation etc. Therefore, conservation agriculture could also play major role in reducing C emission from the agricultural sector. This paper represents the status and relationship of C contents in soil and atmosphere and elaborates the effect of climatic factor, burning of crop residues, biofertilizer and microbial activity on soil organic carbon. The review also focuses on issues related to low soil C contents and how to conserve the soil carbon through conservation agriculture practices.

KEYWORDS:
Soil carbon, conservation agriculture, fertilizer, tillage, biofertilizer, microbial activity, greenhouse gases, cropping system.

INTRODUCTION

Soil contains carbon in two different forms, viz., organic and inorganic pool. Sum of both pools is considered as total carbon. Soil inorganic carbon pool largely consist of carbonate minerals composed of soil parent material (lithogenic, primary) or developed during the soil formation process (pedogenic, secondary). Formation of secondary carbonate results by the reaction of carbonic acid with Ca^{2+} or Mg^{2+} which is brought in from outside the local ecosystem i.e. manure, dust, ocean drift, runoff and sediments [1]. While soil organic carbon (SOC) pool is the carbon which exists in soil organic matter (SOM). Usually, it contributes to 58% of the soil organic matter mass [2]. The SOM is organic segment of soil that comprises of decomposed animal materials, plants and microbial biomass, but it does not contain fresh plant parts and other undecomposed plant materials like straw and litter which lies on surface of the soil [3].

The SOC should be considered as a basis of sustainable agriculture. It strongly affects the quality, health and functionality of soil [4]. This is of great significance for soil in its all fertility related aspects of physical, biological and chemical nature. The SOC improves the soil architecture by binding all soil particles together which is facilitative in enhancing the physical properties of soil like water infiltration, water holding capacity, root growth, gases exchange and also helpful in cultivation [3]. Soil organic matter (SOM) is fragment of food web for different flora and fauna in soil as it is a big source of food for different soil inhabitants which are helpful in creating burrows, nutrient cycling and also in suppressing different crop diseases. It also acts as buffers for harmful substances like heavy metals and toxins.

Keeping in view the importance of SOC, it must be preserved in soil. The SOC could be preserved by selection of plant varieties which may use less C, type and frequency of tillage practices and also by time and rate of fertilizers application [5]. The carbon loss from soil would be reduced by minimum soil disturbance and also by maintaining the soil vegetative cover which promote maximum water use by plants and hence more production.

In agricultural systems, carbon level in soil varies and it depends on the management practices. However, evaluations of SOC gains and losses are based on many methodological aspects bases [6]. Addition of biomass carbon increase carbon storage in soil while removals of biomass carbon decrease carbon storage in soil. Addition of biomass carbon depends on the carbon input by plant root, above ground carbon input, carbon input by water run-on or windblown sediments and management related inputs i.e. plants/animal residues, compost and cover crop etc. Removal of biomass carbon carried out by mineralization/oxidation process, leaching and erosion induced carbon losses [7]. Some management practices like cultivation, or removal of stubbles, overgrazing and fallowing replenish the SOC either by increasing decomposition of SOM or by decreasing carbon inputs to soil. Keeping soil bare for longer time period also replenish the SOC as decomposition rate of SOM is increased at bare soil [3].

Some management practices like fertilizer application, more irrigation and improved cultivars comes under conventional methods which are helpful in enhancement of crop productivity but these practices consumed more energy and thus increased CO_2 emission. Increase in productivity can also be attained by different crop intensification practices or conservational methods like opportunity cropping, double or multiple cropping. Conservation agriculture is a rapidly gaining acceptance as good farming practice to increase the soil health. As conservation agriculture involves the minimum disturbance of the soil by tillage operation and increase organic matter by cover crop and crop rotation in order to benefit both the farmer and environment. In conservation tillage, tillage is reduced (no-tillage) and crop residues are retained on soil surface. It preserves the C in soil and plays a crucial role in increasing the soil productivity as well as reduction of greenhouses gases. It is dire need of time to switch the conventional agriculture methods to conservation agriculture [8]. Thierfelder et al. [9] reported that no tillage practice with addition to mulch decrease the soil surface crusting, lessen the run-off, increase water infiltration and gives more production as compared to tilled soils. In conservation agriculture, application of fertilizer like in conventional agriculture is amended with organic manure such as composts and plants which are high in organic C and thus they add more C in soil system as compared to the fertilizers.

STATUS OF SOIL AND ATMOSPHERIC CARBON

The share of agriculture in the greenhouse gases is about 10-12% [2]. According to FAO, the greenhouse gases emitted from agriculture has doubled from the last fifty years and this amount will increase further by 30% up to year 2050. It has been estimated that agriculture, forestry and other land uses contribute about more than 10 billion tons of greenhouse gases. It is apparent from the carbon cycle presented in Figure 1 that, CO_2 is the main part of greenhouse gases emitted from agricultural sector in global food web. Soil is basic and most important medium for agricultural sector and C in soil is important for environment in maintaining soil productivity, fauna and moisture etc. Carbon is continuously depleting from the soil which resulting in enhancement of CO_2 and nitrous oxide level in the atmosphere (C cycle Figure 1). The rate of C depletion due to erosion by using the conventional tillage practice is 100 times more than the rate at which soil formed. Due to loss of soil C from last 25 years, one quarter of the land area is showing declined agricultural production.

Carbon is a basic component of CO_2; however, the potential of its physical and gaseous forms is continuously changing. It has been estimated that soil medium comprised 1550 peta-grams (Pg) of organic C globally up to 1-meter (m) depth, which is almost three times higher than the amount found in vegetation (560 Pg) and almost double of the soil organic carbon exists in the atmosphere (800 Pg). The amount for C buildup under non-tillage (NT) farming is approximately 350 kg ha^{-1} of carbon annually. The annual variations of CO_2 from the land to atmosphere and vice versa (respiration and residue burning) are each of the order of 60 Pg of C annually [10].

Stockmann et al. [11] estimated that almost 2344 giga-tons (Gt) of SOC are present in the upper 3 m of soil, with 1500 Gt i.e. 54% of SOC present in the upper 1 m of soil and about 615 Gt present in upper most 20 cm. Globally, SOC potential usually rise as mean annual temperature, cold humid regions contain maximum SOC. About 1672 Gt of C is present in the arctic and boreal ecosystems of the northern hemisphere which is a big part of the global soil C [11]. It has been predicted that agricultural land is biospheric source of C in European cropland system. European agricultural land emits the 300 tera-gram (Tg) C per year [12]. While in China, the situation is more alarming because it is responsible for producing three quarters of the C emissions around the globe mainly from the cement production industry and fossil fuels burning between 2010 and 2012 [13]. Whereas in Australia, C stock in the plough layer (0-10 cm) is limited due to its vulnerability to environmental and cropland managing practices [14, 15]. Grain yield in developing countries can be enhanced many times by increasing the SOC pool. It has been predicted that 1 Mg annual increase of C per ha can enhance the yield up to 24-39 million Mg^{-1} [10, 16]. According to the U.S Environmental Protection Agency (EPA), agriculture sector of U.S and Canada produce less than 10 and 8% of the total emissions of greenhouse gases. Forest generate 829 million t (Tg) of CO_2 while agricultural soils are a sink of only 32 Tg of CO_2 [17].

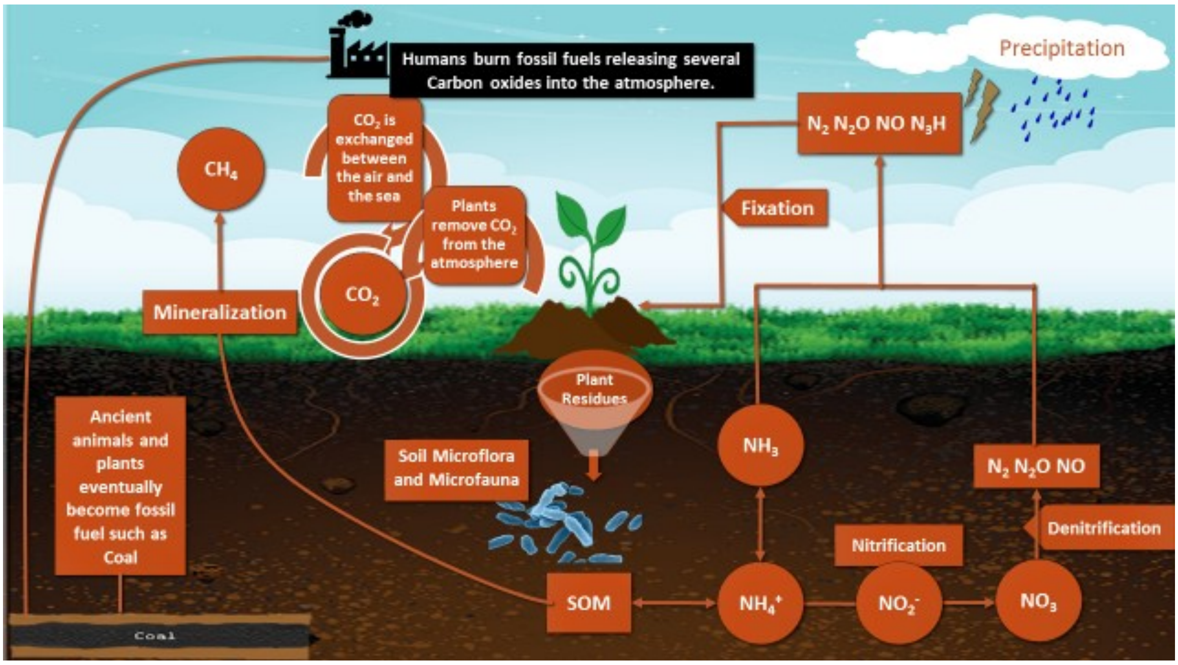

FIGURE 1
Carbon and nitrogen cycle in environment.

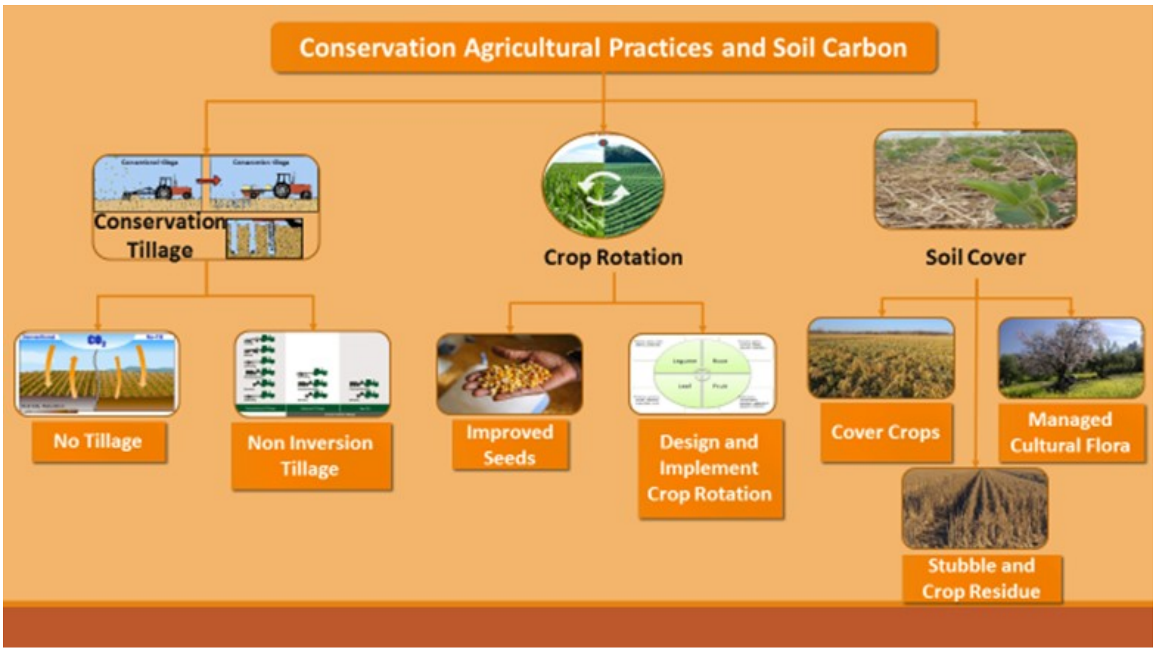

FIGURE 2
Soil management practices for C sequestration

EFFECTS OF CLIMATIC FACTORS ON SOC

Soil C content is controlled by number of climatic factors including temperature, humidity and precipitation. Soil moisture is a major limiting factor for degradation of SOC. Studies revealed that climatic consequence on C sequestration prospective of soils demonstrating that comparatively low precipitation is important for significant C improvements in conservation tillage practices [18]. Previously, it was concluded from all measured data of 11 sites of Taiyuan city, China that annual mean soil respiration ranged from 2.50 to 5.19 µmol CO_2 m^{-2} S^{-1} [19]. While temporal variations of soil respiration were dominantly controlled by soil temperature all over the year. However, during early summer due to limited water supply, soil respiration is minimized and soil water controls the soil respiration. Thus, the effects of soil temperature and moisture content on soil respiration vary from location to location [20] (Figure 2).

BURNING EFFECT ON SOIL ENVIRONMENT

Globally especially in Asian countries, burning of crop residues on field is commonly practiced and studies reveal that number of particles and gas emission vary among residue types. This difference is due to combustion behavior of residue type for example gas and particles emitted from burning of rice straw are significantly different from the straw of wheat. Wet straw of rice and barley emit very high amount of CO_2, CH_4 and N_2O which showed that moist burning produce high amount of gases and particles (e.g. particulate organic C, CH_4 and CO) than the dry burning [21].

Another field study was conducted in Canada which suggests that burning is not an active approach to cope with diseases of barley and canola. Destructive effects of burning and tillage on soil productivity and probably on human health and environment suggest that crop residue would be well managed by other approaches [22]. During the process of photosynthesis, plant absorbs CO_2 from the atmosphere and this CO_2 stored in the plant tissue. When a plant die, a lot of CO_2 is returned to the atmosphere but a portion of it remained part of the plant residue which later on stored in the soil. The carbonaceous contaminants released from burning of main agronomic crop residues in the China have been determined by means of an aerosol chamber and self-built burning pan. Burning of straw from field crop mainly adds to volatile organic compounds, $PM_{2.5}$ and OC emissions, whereas the domestic area is the major source of CO, NO_x and EC [23]. A study has been undertaken to investigate the impact of residue management on C dynamics for sugarcane field crop. The contents of microbial biomass C (by a factor of 2.5), particulate organic matter C (by a factor of 3.8) and total C (30% higher), were calculated for the area where residue was unburned for 8 years as compared to the area where residues were burned. Study concluded that total C stocks were increasing in the unburned treatment as compared to burned [24] (Figure 3).

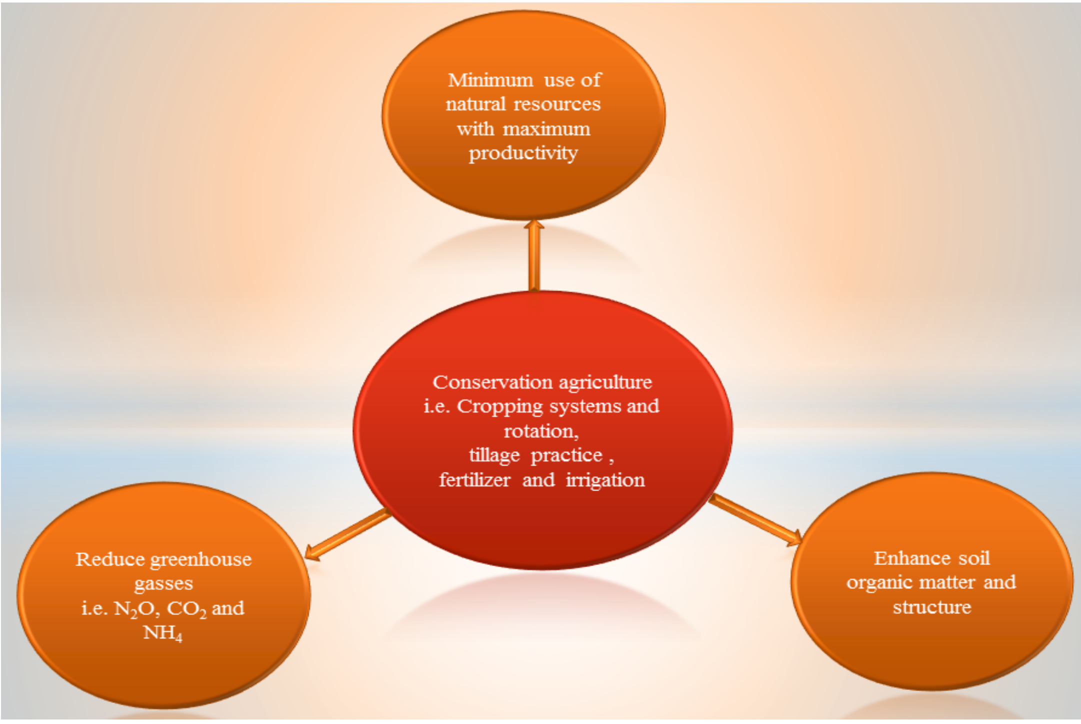

FIGURE 3
Conservation agricultural practices and their role in soil and environment

BIOFERTILIZERS AS SOIL CARBON ENHANCER

The use of biofertilizer is one of the managing practices that are helpful in maintenance or enhancement of the organic matter and in the improvement of soil fertility [25]. Biofertilizer is defined by Vessey [26] as the substance having living micro-organisms and promote the growth by serving primary nutrients to host plants after applying either to seed, plant surface or in soil. Although, biofertilizers are known for many years but few studies have been done to write down their impacts on the soil quality aspects especially on soil organic carbon and on their processes. Some scientists [27, 28] have noticed that biofertilizers accelerated the humification process of fresh organic matter incorporated in soil which increases the soil carbon. Accordingly, when excessive organic matter (biowastes or natural fertilizers) is introduced in soil, the use of biofertilizers became necessary of time to accelerate the organic matter transformation process.

Valarini et al. [29] found increased soil organic carbon percentage at site that was treated with animal manure, crop residues with addition of 30 L ha^{-1} biofertilizer. According to author, this might be due to the speedy decomposition process of animal manure and crop residue because of biofertilizer. Nisha et al. [30] noticed that adding three cyanobacterial isolates of biofertilizer significantly increased total organic carbon in weak (0.35% of organic carbon and 0.06% of nitrogen) in semi-arid soil. Author stated that, increase in organic carbon was due to autotrophic nature of the cyanobacteria that ultimately leads to increase in soil organic matter. Likewise, incubation with cyanobacteria (Nostoc 9v) promoted the organic carbon contents from 0.4 g carbon per kg to 9.0 g carbon per kg of soil [31]. Ramalakshmi et al. [32] found improved soil organic carbon in biofertilizer treated soil. Initially, this increase was 0.30% but highest (0.38%) organic carbon was achieved after 120 days of germination in biofertilizers (mycorrhiza and azophos) treated soil. On the other hand, applying biofertilizer under optimum conditions improve various crop yield by 25% and minimize the inorganic fertilizer application up to 25-50% for nitrogen and 25% for phosphorous [33, 34]. Thus, use of biofertilizer can be helpful in improving the soil organic carbon.

SOIL CARBON SEQUESTRATION AND MICROBIAL ACTIVITY

Olson [35] defined soil organic carbon sequestration as, mechanism of CO_2 transferring from atmosphere to soil via plant residues or other organic solids which already retained in soil as parts of organic matter (humus). To understand the carbon sequestration, it is vital to shed light on role of soil microorganisms that how they influenced by management practices and subsequently effect the carbon sequestration because soil microbial activity and the biodiversity are important component for sufficient sequestration of carbon in any eco-system [36]. Soil microbial contribution in organic carbon is influenced by their community size, process of decomposition and dynamics that affect their stability [37].

The change in organic carbon of any cropping system mainly depend on balance between input by plant sources and loss of organic carbon as leaching, erosion and decomposition by microorganism. However, change in the cropping system and tillage can influence the microbial activity which ultimately affect organic carbon stability in soil. Guzman and Al-Kaisi [38] found significant changes in organic carbon because of soil microbial activity in different cropping and tillage systems. Intensive tillage might lead to more respiration and decomposition process by microorganisms which has serious threat like release of carbon from crop residues as CO_2 in atmosphere. This release of CO_2 may be accelerated with passage of time if more intensive tillage occurs which can affect the organic carbon stability. During decomposition process, CO_2 is released by heterotrophic respiration which is correlated with soil moisture and temperature regimes, nitrogen/lignin ratio and different microbial role in decomposition process [39]. Portion of litter and roots that resist decomposition process may become stable form of organic carbon for hundreds of years until broken by the microorganisms [40]. Although, the interaction between different agricultural practices and soil microbes is very complex but it plays a significant role in retention and loss of organic carbon from soil. Soil microorganisms used soil carbon for different processes like decomposition and mineralization etc. In the absence of carbon, organic matter is a principle substrate of C for microorganisms. During mineralization, some carbon in organic matter is used for the maintenance and growth of microorganisms while rest of the carbon is respired as CO_2 and retrace to atmosphere. Elevated carbon storage in ecosystem may help in stabilization of CO_2 present in atmosphere and minimize global warming. Carney et al. [41] found that increased CO_2 led to more carbon assimilation by plants and loss of carbon from soil. This loss in soil carbon might be due to changes in soil microbial activity composition. Furthermore, microbial fatty acid composition confirmed that elevated CO_2 increase the utilization of soil organic matter. On the other hand, decrease in decomposition rate can occur through soil nutrient availability and plant community [42]. We can conserve the soil carbon by decreasing the decomposition rate and also by selecting the optimal plant community.

VARIATIONS IN SOIL C CONTENT IN RELATION TO CONSERVATION AGRICULTURAL PRACTICES

Conservation agriculture practices emphasis on the minimum disturbance of the soil and improving accumulation of organic matter in the soil. Presence of organic matter in the soil functions as substrate for the activity of soil microorganism. The high C:N ratio reduces the production of nitrous oxide (a greenhouse gas) by inhibiting the nitrification [43]. Moreover, adoption of the conservation agriculture reduces the emission of greenhouse gases. Flooded rice field are one of the major producer of CH_4 from soil to the atmosphere. In conservation agriculture, the application of direct seeding avoids the flooded condition and reduces the emission of CH_4 [2]. A summary of conservation agricultural practices in relation with soil is presented in figure 2 and 3 but mainly there are three major types of conservation agriculture practices i.e. Crop rotation and cropping systems, tillage practice and stubble management, and use of fertilizer and irrigation.

Cropping systems and crop rotation. The kind and a sequence of the crops grown over a period of time on given soil area is termed as cropping system. While, Crop rotation is repeated succession of the crops on similar piece of land for a year or longer time. In crop rotation, various crops are grown in different sequence at different times with an aim to not disturb the soil health.

In conventional agriculture, intensive soil disturbance, mono cropping, specific crop rotation and poor management of cover crop and crop residue leads toward higher losses of C from soil. Conventional tillage promotes the mixing of bacteria which enhance the microbial activity and results in degradation of organic matter. Studies showed that the deviation from conservation agriculture like specific rotation of single crop and mono cropping has negative impact on SOC [2].

Crop rotation can increase the soil C contents as there is significant evidence that high rotation complexity could possibly leads to rise in soil C reserves for agricultural use [39]. Analysis of continuing agricultural studies established that practicing crop diversity and/or eliminating long-fallow periods brings substantial increase in SOC which means achievement of a new balance after approximately 40-60 years. In Australian agro-system, it was found that increasing crop diversity only enhances the 5.3% C contents in soil, while crop rotation resulted in doubling of the soil C i.e. 10.1%. Growing of perennial crops into rotation led to increasing soil C contents of 17.8% [39]. The Century model simulations also reported that it will be difficult to detect SOC differences between cropping systems [44]. However, pulses and canola crop produce about 10% more C inputs in comparison with wheat. There were no noteworthy alterations in SOC between cropping systems of Canadian prairies after 11 years of observation [45]. Another study has been undertaken to evaluate the impact of crop rotation in Italy. Sicilian rain-fed agro-system seems to have comparatively less C sequestration efficacy in relative to the C inputs. In wheat cropping system, cumulative C input was maximum with greater annual SOC sequestration and most of the SOC was present in the silt-clay fraction and this portion was highly resistant against biodegradation [46].

Furthermore, crops cover plays very important role in soil fertility, soil protection, ground water quality, pest management, soil structure, soil organic contents and stubbles management. Crop covers provide vegetative cover to soil during critical periods and increase SOC sequestration [8]. In Italy, a field study elucidated that quality and quantity of the cover crop seem to be the key aspects influencing the SOC stocks and production in non-tilled soil under tomato cultivation [47]. A comparison between conventional and zero tillage have been undertaken in southern Brazil in relation with various types of crop covers and results showed minimum SOC contents up to 40 cm soil depth was found in winter fallow period in comparison to all other winter cover crop treatments. Highest SOC contents were found within 0 to 20 cm depth [48]. Conservation agricultural techniques involved faster turnaround time between crop harvesting and planting, hence can maximize the opportunity for crop growth. In legume based rotations, residue quality plays vital role in SOC storage under the plow layer than continuous corn, thus they play very important role in increasing soil C pool [49]. Clay soils usually contain SOC at 30-120 cm depth which showed its capability to sequester C in the presence of deep rooted crops. The results of investigations by Bell et al. [50] showed that the presence of perennial forage legumes like alfalfa for shorter period in crop rotation failed to rise SOC or total soil nitrogen (N) and these legumes exhausted plant available phosphorous (P) as compared to crop sequences involving only annual cereal crops. In China, a study has been conducted to observe the metal pollution matter in relation with C retention by soil under wheat and rice crops. Soil CH_4 and CO_2 efflux during the entire growing season was increasing under metal pollution by 14% and 69% in the rice crop while soil CO_2 efflux increased by 13% in the wheat crop, respectively [13].

Application of irrigation and fertilizer. Use of fertilizers and irrigation significantly affects the SOC contents as irrigation and fertilization promote plant growth in water and nutrients deficient regions, thus they have the ability to rise SOC stocks by adding C inputs. Fertilizers have prime importance in agriculture sector but their excessive application had negative impacts on soil, crops and on environment [51]. Adeel et al. [52] clearly identified route for contaminants into terrestrial environment through manure application to agricultural land as source of fertilizers for the crops. However, the influence of irrigation and fertilizers on soil C is interrelated [39]. In India, long term experiment including pearl millet-cluster bean-castor sequence has been undertaken. In addition to 33.5 Mg ha^{-1} C inputs by crop residues including farm yard manure resulted in the net reduction of 4.4 Mg C ha^{-1} by 18 years of study. Crops grown without the use of fertilizers had less SOC stocks as compared to conventionally grown crops [50]. Organic fertilizer and chemical fertilizer including the recommended dose of nitrogen (N) minimize the SOC depletion stock and improve the productivity. However, maximum (77%) of the C supplemented was mineralized in this climate and only a minute (23%) was stabilized into SOC stock [53].

The 50% reduction in irrigation water affected both a reduction in the soil CO_2 emissions and in soil C inputs; consequently, the 25% irrigation water reduction appeared to regulate a positive soil C balance. The N fertilization seems to reduce the minute amount of CO_2 emissions from soil but maximize the SOC inputs, therefore a balanced use of N fertilization in accordance with environmental conditions is necessary to improve C balance [54]. Experimental results suggested that SOC present in the subsoil may be linked to infiltration of irrigation water [47].

Tillage management. Tillage management was employed by the farmer to control the weeds and prepare the soil for crop growth. Conventional tillage practices involve the intensive disturbance of soil and it breaks the soil aggregate and loosened the soil. The loosened soil leads to erosion by water or wind. Beside removal of highly enriched nutrient from soil, it also fastens the degradation of organic matter in soil. On the other hand, conservation tillage involves the minimum disturbance of the soil and common conservation tillage practice includes zero tillage (ZT), no till (NT), ridge till (RT) and low till (LT) etc. The most frequently used conservation tillage practice involves the minimum disturbance of soil and leaving of crop residue on the ground which acts as protective cover for soil. These protective covers reduce the soil erosion, enhance the building up of organic matter in the soil and fix the CO_2 from the atmosphere. Shifting of tillage practice from the conventional to conservation tillage practices enhance the accumulation of organic matter in the soil. High organic matter in soil increases the C equilibrium in soil with the passage of time [55].

C storage in soil is dependent on the climate and its interaction with tillage practices; maximize C sequestration potential in dry areas as compared to humid areas and an additional source of variability in the assessments of C sequestration due to reduced tillage [56, 57]. This was exposed by a comparison of western and eastern Canadian sites with SOC storage rate 32 ± 15 g m^{-2} yr^{-1}, -7 ± 27 g m^{-2} yr^{-1} respectively. Mean annual precipitation (MAP) of western and eastern Canadian sites was less than 550 mm and 800 mm respectively [49]. In Australian agriculture system, it was observed that use of conservation tillage only increased SOC in moist areas where rainfall exceeded 500 mm yr^{-1} [39]. The scientists elucidated the relative difference in SOC stocks between no-till (NT) and full inversion of tillage (FIT) treatments in five sites in Aragon (Spain) after 9-20 years. They detected a significant negative and strong relationship between SOC in the 0-5 cm layer and the average yearly rainfall in each area, varying from 355 to 740 mm yr^{-1} [58].

Additionally, about 1,000 pounds per acre C annually can be conserved by proper use of conservation tillage practices. If the potential of conservation agriculture is fully used, then we can preserve C about 450 million tons per year in soil [59]. Moreover, several studies have reported that tillage practices significantly impact the C contents of farming soils. The investigations in Australia, India, France, Canada, America, Spain, Italy and Pakistan were performed regarding effects of tillage techniques possibilities on soil C dynamics by scientists [18, 45, 47, 56, 58, 60, 61]. Evidently, NT wheat after rice produces substantial benefits at the farm level through the combination of a yield effect [62] and an improvement in SOC accumulation than the conventional tillage methods at the 0-10 cm depth after the 26 years of experiment [63]. In another field study Hassan *et al.* [61] found that ZT or minimum tillage (MT) in dry land develops active C pool with legume-based crop rotation system in cultivating layer and with cereal-based crop rotation system in lower soil profile. However, moldboard plow in legume-based crop rotation systems mends slow C pool. Legume-based crop rotation systems also increase passive C stock below the plow layer. For wheat-rice cropping system in India, zero tillage practices are very useful to facilitate the limitations by permitting earlier wheat sowing, which results in enhanced yield [62] (Table 1).

In Australia, during a study practiced by Rochester [47], it has been determined that significant quantity of C can be sequestered in irrigated soils under cotton cultivation, where husk is integrated under a MT system. Maximum amount of C sequestration was observed in those soils that were under legume cultivation. Higher C sequestration happened in the subsoil, than in the external layer of soil 0-30 cm [47]. Another study has been conducted in on-farm conditions under NT and conventional tillage (CT) and the results showed that maximum on average 23% more SOC was calculated under NT than under conventional tillage (CT) [58].

For comparison of NT, shallow till (ST) and full inversion tillage (FIT) in combination with crop managements to calculate SOC changes during 41 years of experiments by using diachronic method it was resulted that tillage or crop management had no major effect on SOC storage after 41 years. Study established that RT or NT made a prominent stratification of SOC stocks over the soil profile and this stratification increases with time, both by incessant accumulation at soil surface and decrease in depth. After 40 years, the effect of RT stocks was minimum [56]. Singh et al. [18] also stated that after the 30 years' field study, reduced tillage or straw retaining had no clear indication regarding total amount of C in the topsoil of 0-15 cm.

TABLE 1
Effect of tillage practices on soil organic carbon

Soil depth (cm)	Treatment	SOC stock (Mg C/ha)	Reference
0-10	NT	36.1 ± 2.6	Calegari et al. [48]
	CT	24.0 ± 0.3	
10-30	NT	55.1 ± 2.1	
	CT	53.8 ± 2.1	
0-10	NT	17.43	Shrestha et al. [63]
	CT	10.59	
10-20	NT	6.11	
	CT	7.55	
20-40	NT	6.34	
	CT	4.99	
0-20	NT	23.53	
	CT	18.15	
0-40	NT	29.88	
	CT	23.13	
0-7.5	MT	15.4	
	NT	15.4	
0-15	MT	28.8	
	NT	29.3	
Plough layer	WCT	7.2	Barbera et al. [46]
	WBCT	6.4	
	WDL	6.4	
	WBDL	6.2	
	WNT	7.2	
	WBNT	6.6	
	CT	6.8	
	NT	6.9	
0-40	CM	190 ± 7	Blanco-Moure et al. [58]
	CT	57.36	
	RT	54.89	
	NT	60.23	
	NAT	57.31	
0-5	CT	1536 ± 114	Singh et al. [18]
5-10		1599 ± 81.1	
10-15		1629 ± 135	
15-20		757 ± 62.8	
20-40		3376 ± 945	
0-5	RT	1580 ± 121	
5-10		1609 ± 93.0	
10-15		1491 ± 132	
15-20		644 ± 79.8	
20-40		3033 ± 909	
5.2	FIT	7.62 **t/ha**	Dimassi et al. [56]
10.7		16.25	
16		24.84	
28		42.32	
31.7		45.15	
5.2	ST	7.66	
10.8		16.22	
16.1		24.72	
28.1		41.96	
31.8		44.76	
5.2	NT	7.72	
10.6		14.44	
15.9		25.04	
27.1		42.52	
31.7		45.39	

NT: no-till, MT: minimum tillage, WCT: wheat conventional tillage, WBCT: wheat/bean rotation conventional tillage, WDL: wheat dual-layer tillage, WBDL: wheat/faba bean rotation dual-layer tillage, WNT: wheat no tillage, WBNT: wheat/faba bean rotation no tillage, CT: conventional tillage, RT: Reduced tillage, NAT: natural soil, FIT: full inversion tillage, ST: shallow tillage.

CONCLUSION

This article was envisioned to describe the various ways of carbon preservation as soil organic carbon is considered as a base for soil productivity. It releases nutrients for plants and act as buffer against the harmful substances like heavy metals and toxins. The soil C contents are twice the amount of C found in plant and atmosphere. SOC is an essential part of C cycle in nature. Increase in SOC can help to mitigate the climatic problems and improve the soil fertility and health. Increase in SOC by adopting best agricultural management practices i.e. conservation agriculture, maintain positive C budget. Conservation agriculture gives promising results in fight against the environmental/agricultural problems in numerous ways including reducing anthropogenic carbon emissions by minimizing the use of agricultural machinery, reducing total increase of atmospheric CO_2, improving soil organic carbon at root zone level above threshold level, sustainable and increase in agricultural productivity, improve use efficiency of agricultural inputs and buffer against soil and plant disease, reducing risk of accelerating non-point source soil pollution and erosion, increasing nutrient and water holding capacity and restoring soil quality and its ecosystem functions. Some of the practices that might play a very important role in soil sequestration are as follow: Use of biofertilizer, avoid burring of agricultural residues, reduced tillage, bare fallow periods, water logging, use plant crops and crop rotations especially perennial pastures and legumes, use composted material, manage soil nutrient levels by choosing nutrient targets and livestock waste, avoid over grazing, use nitrogenous fertilizers when needed by choosing its best source. It is necessary to conduct long term studies for observing significant effects of conservation tillage, manure and fertilizer use, residue management, biofertilizer and crop rotations. Farmers should implement the soil C sequestration as a continuing management tool instead of short-term. The general reimbursements of soil C sequestration need to be observed as an opportunity to improve soil quality and environment.

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