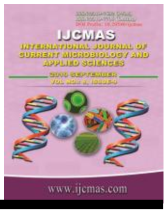
Int.J.Curr.Microbiol.App.Sci (2019) *8*(9): 2920- 2935

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 09 (2019)**
Journal homepage: http://www.ijcmas.com



Review Article https://doi.org/10.20546/ijcmas.2019.809.336

Effect of Conservation Tillage and Residue Management on Soil Organic Carbon Storage, Ecosystem Dynamics and Soil Microbial Biomass in Sub-tropical Agro-ecosystem: A Review

S. S. Dhaliwal[1], Yogesh Kumar[2], S. P. Singh[3], Vivek[4], Robin Kumar[5], N. C. Mahajan[6], S. K. Gupta[7], Amit Kumar[8], Mayank Chaudhary[9*], S. P. Singh[10], S. K. Tomar[11] and R. K. Naresh[4]

[1]Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab, India
[2]Department of Soil Science, [3]KGK, Bareilly, [4]Department of Agronomy, [9]Department of GPB,
[10]K.V.K.Shamli, SardarVallabhbhai Patel University of Agriculture & Technology, Meerut, U.P., India
[5]Department of Soil Science, Narendra Dev University of Agriculture & Technology, Kumarganj, Ayodhya, U.P., India
[6]Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U. P., India
[7]Department of Agronomy, Bihar Agricultural University - Sabour, Bhagalpur, Bihar, India
[8]Department of Agronomy, CCS Haryana Agricultural University – Hisar, Haryana, India
[11]K.V.K.Belipur, Gorakhpur, Narendra Dev University of Agriculture & Technology, Kumarganj, Ayodhya, U.P., India
**Corresponding author*

ABSTRACT

Investigating microbial metabolic characteristics and soil organic carbon (SOC) within aggregates and their relationships under conservation tillage may be useful in revealing the mechanism of SOC sequestration in conservation tillage systems. Crop residue retention has been considered a practicable strategy to improve soil organic carbon (SOC) but the effectiveness of residue retention might be different under varied tillage practices. The concentrations of SOC in the 0–10 cm layer were higher under no-tillage than under conventional tillage, no matter whether crop residues were retained or not. Residue retention increased SOC concentrations in the upper layers of soil to some degree for all tillage practices, as compared with residue removal, with the greatest increment of SOC concentration occurred in the 0–10 cm layer under rotary tillage, but in the 10–30 cm layer under conventional tillage. The stocks of SOC in the 0–50 cm depth increased from 49.89 Mg ha^{-1} with residue removal to 53.03 Mg ha^{-1} with residue retention. However, no-tillage did not increase SOC stock to a depth of 50 cm relative to conventional tillage, and increased only by 5.35% as compared with rotary tillage. Previous crop residue (S) treatments had higher SOC concentration of bulk soil (12.9%), >0.25 mm aggregate (11.3%), and <0.25 mm aggregate (14.1%) than residue removal (NS) treatments. Compared with conventional intensive tillage (CT) treatments, no tillage (NT) treatments increased MBC by 11.2%, 11.5%, and 20%, and dissolved organic carbon (DOC) concentration by 15.5%, 29.5%, and 14.1% of bulk soil, >0.25 mm aggregate, and <0.25 mm aggregate in the 0−5 cm soil layer, respectively. Compared with NS treatments, S treatments significantly increased MBC by 29.8%, 30.2%, and 24.1%, and DOC concentration by 23.2%, 25.0%, and 37.5% of bulk soil, >0.25 mm aggregate, and <0.25 mm aggregate in the 0−5 cm soil layer, respectively. Overall, straw return was an effective means to improve SOC accumulation, and soil quality. Straw return-induced improvement of soil nutrient availability may favor crop growth, which can in turn increase ecosystem C input. Tillage reduction and residue retention both increased the proportion of organic C and total N present in soil organic matter as microbial biomass. Microbial immobilization of available-N during the early phase of crops and its pulsed release later during the period of greater N demand of crops enhanced the degree of synchronization between crop demand and N supply. The maximum enhancement effects were recorded in the minimum tillage along with residue retained treatment. Furthermore, conservation tillage increased SOC in aggregates in the topsoil by improving microbial metabolic activities in the Sub-tropical Agro-ecosystem.

Keywords

Ecosystem dynamics; microbial biomass, conservation tillage, straw return

Article Info

Accepted:
25 August 2019
Available Online:
10 September 2019

Introduction

Soil organic carbon (SOC) is an important soil component that plays a crucial role in soil fertility (Brar *et al.,* 2013) environmental protection (Ghosh *et al.,* 2018) and sustainable agricultural development (Li *et al.,* 2018). It has therefore been regarded as the foundation of soil quality and function (Brar *et al.,* 2013). Farmland SOC sequestration is closely related to the reduction of CO_2 emissions (Poulton *et al.,* 2018) the enhancement of soil fertilization, the maintenance of soil structure (Sainju *et al.,* 2009) and the promotion of microbial diversity (Fonte *et al.,* 2012; Bhattacharyya *et al.,* 2018) among other items. Hence, it is the decisive factor affecting the quality of cultivated land and crop yield (Hassan *et al.,* 2016; Naresh *et al.,* 2018).

However, the SOC content in Chinese farmland soil is generally low (Chen *et al.,* 2017) which is lower than the world average by more than 30% and that of Europe by more than 50% (Chen *et al.,* 2018).

Therefore, the improvement of the SOC content of cultivated soil has been a topic of great concern in the field of agricultural science. In addition to the influence of natural factors such as regional weather and soil conditions (Tang *et al.,* 2018; Gonçalves *et al.,* 2017) the variation in the agriculture SOC stock is most strongly affected by human activities (Ghosh *et al.,* 2018; Liang *et al.,* 2012).

The effect of management practices on farmland SOC content has been extensively investigated, and most studies have indicated that conservation farming measures (e.g., no-tillage, application of organic fertilizer, and straw return) not only increase the agriculture SOC stock (Liu and Zhou*et al.,* 2017; Piccolo *et al.,* 2018) but also improve crop yield (He *et al.,* 2018; Bai *et al.,* 2016). These measures mainly increase farmland SOC content by increasing SOC input and improving soil aggregate retention (Arai *et al.,* 2013; Kuhn *et al.,* 2016).

The environmental impact on soils of straw return have been well studied, including soil water potential, temperature (Yang *et al.,* 2016), enzyme activities (Zhao *et al.,* 2016), soil organic matter fractions (Chen *et al.,* 2017; Karlsson *et al.,* 2017), soil quality and crop productivity (Hansen *et al.,* 2017), soil greenhouse gas emissions (Zhou *et al.,* 2017), soil chemical properties (Yu *et al.,* 2018), and soil microbial communities (Li *et al.,* 2017; Maarastawi *et al.,* 2018). These results provide basic understanding in terms of how straw return may change soil carbon retention, soil quality, and soil ecosystem functions, and revealed a number of positive consequences, such as reducing soil water potential, increasing soil temperature and the activities of hydrolytic enzymes, and enhancing soil microbial functional diversity. Crop straw (i.e. wheat and rice straw) is an important source of organic C in agro-ecosystems in IGP (Liu *et al.,* 2014). Returning crop straw to soil is an important practice to balance the C loss due to mineralization in agricultural soil (Chen *et al.,* 2014). The SOC change rate is two times higher for straw return treatments (0.29 g kg^{-1} yr^{-1}) than that for chemical fertilizer application only (0.14 g kg^{-1} yr^{-1}) in paddy soils (Tian *et al.,* 2015). Zheng *et al.,* (2015) found that returning straw could significantly increase total organic C (TOC) content. Zhu *et al.,* (2015) also observed that short-term (two year) crop straw return significantly increased the TOC, DOC and MBC concentrations compared to no straw return in the 0–7-cm soil layer. Crop residue return also significantly affects soil microbial community composition (Zhao *et al.,* 2016).

Soil microorganisms play an important role in mediating changes in soil TOC via mineralization–immobilization of soil organic matter (Breulmann *et al.*, 2014). The process of straw decomposition is mainly mediated by soil microorganisms, and is affected by many factors including soil texture, straw quality and climate (Chen *et al.*, 2014). Soil microbial communities respond differently to different stages of crop straw decomposition (Marschner *et al.*, 2011): in the first stage, bacteria dominate microbial communities and fungi dominate the latter stage (Marschner *et al.*, 2011). Naresh *et al.*, (2017) determined that reducing tillage and maintaining surface residues in a long-term study increased soil organic C and N in the surface 2.5 cm of soil. When corn stover was returned to the soil, Clapp *et al.*, (2000) reported a 14% increase in soil organic C in the top 15 cm, but soil organic C content decreased in the 15–30 cm depth. Similar apparent re-distributions of soil C, where increases in surface organic C generated by conservation tillage were offset by decreases in subsurface organic C content, have been documented (Ellert and Bettany, 1995).

Soil-specific responses to tillage-induced C storage were reported by Wander *et al.*, (1998) in which carbon accretion was not apparent in all soils in that trial. Plowing was shown to move dispersed organic C from the 0–20 cm soil depth down to the 60– 80 cm depth in corn plots (Romkens *et al.*, 1999). Therefore, the objectives of this study were to examine the effects of conservation tillage crop straw return on SOC and soil microbial community composition, investigate the sensitivity of the LOCFs under short-term crop straw return in a rice–wheat cropping system in the sub-tropical agro-ecosystem in IGP and to explore an optimal management practice combination of tillage and straw return for improving the soil quality and increasing the ecosystem dynamics. The Review of the conservation tillage and residue management and its probable effects on soil organic carbon storage, ecosystem dynamics and soil microbial biomass is discussed under the following heads;

Effect of Conservation Tillage and Residue Management on Soil Organic Carbon Storage

Soil organic carbon is a measureable component of soil organic matter. Organic matter makes up just 2–10% of most soil's mass and has an important role in the physical, chemical and biological function of agricultural soils. Organic matter contributes to nutrient retention and turnover, soil structure, moisture retention and availability, degradation of pollutants, carbon sequestration and soil resilience.

Soil carbon storage is a vital ecosystem service, resulting from interactions of ecological processes. Human activities affecting these processes can lead to carbon loss or improved storage.

Mandal *et al.*, (2012) reported that the SOC stock was highest within 0–15-cm soil and gradually decreased with increase in depth in each land use systems. In 0–15 cm depth, highest SOC stock (16.80 Mg ha^{-1}) was estimated in rice–fallow system and the lowest (11.81 Mg ha^{-1}) in the soils of guava orchard.

In 15–30 cm, it ranged from 8.74 in rice–rice system to 16.08 Mg ha^{-1} in mango orchard. In the 30–45-cm soil depth, the SOC stock ranged from 6.41 in rice–potato to 15.71 Mg ha^{-1} in rice–fallow system.

The total SOC stock within the 0–60-cm soil profile ranged from 33.68 to 59.10 Mg ha^{-1} among rice-based systems, highest being in soils under rice– fallow system and the lowest for rice–rice system. The mango and guava orchard soils had 68.53 and 54.71 Mg ha^{-1} of SOC, respectively, in the 0–90-cm soil depth.

Bhattacharyya *et al.,* (2012) and Naresh *et al.,* (2018) suggested that returning rice straw to fields could increase the SOC content. Moreover, higher TOC levels in the soil layers above and below the straw layer, and reflected the carbon sequestration potential of the straw returning method. This might be due to the following reasons: firstly, the straw was condensed in a limited soil space and submerged in water during the rice season, which meant that the buried straw was under a reduced environment. This would result in the decomposition of the straw being slowed down and therefore the SOC's mineralization rate (Wu *et al.,* 2010). Secondly, some of the carbon-containing compounds in the straw were decomposed, mineralized and released as CO_2 into the atmosphere, while others were transformed into humus that accumulated in the soil, which is the main source of soil organic matter (Stockmann *et al.,*2013). Kuhn *et al.,* (2016) also found that the benefit of NT compared to CT on the changes of SOC stocks varied across different soil depths. In topsoil layers (above 20 cm), NT in general had greater SOC stocks than CT but the benefit tended to decline with soil depths, and even turned to be negative in soil layers deeper than 20 cm. In addition, in each soil layer, except for the top 5 cm, the total SOC stocks generally declined with the number of years after NT adoption.

Mehra *et al.,* (2018) revealed that soils have become one of the most endangered natural resources in the world. Each year, an estimated 25–40 billion tons of fertile soil are lost globally. Hence, improving soil health through sustainable land management should be a common goal for land managers, to protect, maintain and build their most vital resource – soils. Soils are the major reservoir of C in terrestrial ecosystems, and soil C plays a dynamic role in influencing the global C cycle and climate change while regulating soil health and productivity (Singh *et al.,* 2018).

Singh *et al.,* (2014) also found that carbon stock of 18.75, 19.84 and 23.83 Mg ha^{-1} in the surface 0.4 m soil depth observed under CT was increased to 22.32, 26.73 and 33.07Mg ha^{-1} in 15 years of ZT in sandy loam, loam and clay loam soil. This increase was highest in clay loam (38.8%) followed by loam (34.7%) and sandy loam (19.0%) soil. The carbon sequestration rate was found to be 0.24, 0.46 and 0.62 Mg ha^{-1} yr^{-1} in sandy loam, loam and clay loam soil under ZT over CT. Thus, fine textured soils have more potential for storing carbon and ZT practice enhances carbon sequestration rate in soils by providing better conditions in terms of moisture and temperature for higher biomass production and reduced oxidation (Gonzalez-Sanchez *et al.,* 2012) [28]. Bhattacharya *et al.,* (2013) reported that tillage-induced changes in POM C were distinguishable only in the 0- to 5- cm soil layer; the differences were insignificant in the 5- to 15-cm soil layer. Plots under ZT had about 14% higher POM C than CT plots (3.61 g kg^{-1} bulk soil) in the surface soil layer.

Gathala *et al.,* (2011) revealed that Conservation tillage generally increased SOC concentration of plow layer which is probably because conservation tillage can reduce soil disturbance, promote root development in the topsoil, and increase crop residue accumulation on the soil surface, thus enhancing soil aggregate stability. This increase in SOC concentration can be attributed to a combination of less soil disturbance and more residues returned to the soil surface under conservation tillage (Dikgwatlhe *et al.,* 2014). Triberti *et al.,* (2008) reported that crop residues can significantly increase SOC concentration. Dikgwatlhe *et al.,* (2014) also reported similar results wherein conservation tillage increased SOC concentration in the 0−5 cm top soil. They suggested that the increase may be due to the lack of residues incorporated to soil and intensive soil tillage that accelerated soil organic matter decomposition. Alvarez *et al.,* (2009) also found that NT increases SOC and total N concentrations in the first centimeters of the soil profile because NT maintains surface residues.

Naresh *et al.,* (2015a) also found that conservation tillage practices significantly influenced the total soil carbon (TC), total inorganic carbon (TIC), total soil organic carbon (SOC) and oxidizable organic carbon (OC) content of the surface (0 to 15 cm) soil. Wide raised beds transplanted rice and zero till wheat with 100% (T_9) or with 50% residue retention (T_8) showed significantly higher TC,SOC content of 11.93 and 10.73 g kg^{-1} in T_9 and 10.98 and 9.38 gkg^{-1}, respectively inT_8 as compared to the other treatments. Irrespective of residue incorporation/ retention, wide raised beds with zero till wheat enhanced 40.5, 34.5, 36.7 and 34.6% of TIC, TC, SOC and OC in surface soil as compared to CT with transplanted rice cultivation. Aulakh *et al.,* (2013) showed that PMN content after 2 years of the experiment in 0-5 cm soil layer of CT system, T_2, T_3 and T_4 treatments increased PMN content from 2.7 $mgkg^{-1}$ $7d^{-1}$ in control (T_1) to 2.9, 3.9 and 5.1 $mgkg^{-1}$ $7d^{-1}$ without CR, and to 6.9, 8.4 and 9.7 $mgkg^{-1}$ $7d^{-1}$ with CR (T_6, T_7 and T_8), respectively. The corresponding increase of PMN content under CA system was from 3.6 $mgkg^{-1}$ $7d^{-1}$ in control to 3.9, 5.1 and 6.5 $mgkg^{-1}$ $7d^{-1}$ without CR and to 8.9, 10.3 and 12.1 $mgkg^{-1}$ $7d^{-1}$ with CR. PMN, a measure of the soil capacity to supply mineral N, constitutes an important measure of the soil health due to its strong relationship with the capability of soil to supply N for crop growth.

Dhaliwal *et al.,* (2018) revealed that the mean SOC concentration decreased with the size of the dry stable aggregates (DSA) and water stable aggregates (WSA). In DSA, the mean SOC concentration was 58.06 and 24.2% higher in large and small macro-aggregates than in micro-aggregates respectively; in WSA it was 295.6 and 226.08% higher in large and small macro-aggregates than in micro-aggregates respectively in surface soil layer. The mean SOC concentration in surface soil was higher in DSA (0.79%) and WSA (0.63%) as compared to bulk soil (0.52%).
Kumar *et al.,* (2018) also found that the ZTR (zero till with residue retention) (T_1) and RTR (Reduced till with residue retention) (T_3) showed significantly higher BC, WSOC, SOC and OC content of 24.5%, 21.9%,19.37 and 18.34 gkg^{-1}, respectively as compared to the other treatments. Irrespective of residue retention, wheat sown in zero till plots enhanced 22.7%, 15.7%, 36.9% and 28.8% of BC, WSOC, SOC and OC, respectively, in surface soil as compared to conventional tillage. Simultaneously, residue retention in zero tillage caused an increment of 22.3%, 14.0%, 24.1% and 19.4% in BC, WSOC, SOC and OC, respectively over the treatments with no residue management. Similar increasing trends of conservation practices on different forms of carbon under sub-surface (15– 30 cm) soil were observed however, the magnitude was relatively lower. Zhu *et al.,* (2011) compared to conventional tillage (CT) and zero-tillage (ZT) could significantly improve the SOC content in cropland. Frequent tillage under CT easily exacerbate C-rich macro-aggregates in soils broken down due to the increase of tillage intensity, then forming a large number of small aggregates with relatively low organic carbon content and free organic matter particles. Free organic matter particles have poor stability and are easy to degradation, thereby causing the loss of SOC Song *et al.,* (2011).

Effect of Conservation Tillage and Residue Management on Ecosystem’s Dynamics

Ecosystem Dynamics an ecosystem is a community of living organisms (plants, animals, and microbes) existing in conjunction with the nonliving components of their environment (air, water, and mineral soil), interacting as a system. Ecosystems include both living and nonliving components. These living, or biotic, components include habitats and niches occupied by organisms. Nonliving, or abiotic, components include soil, water, light, inorganic nutrients, and weather. An organism's place of residence, where it can be found, is its habitat. A niche is often viewed as the role of that organism in the community, factors limiting its life, and how it acquires food. Producers, a major niche in all ecosystems, are autotrophic, usually photosynthetic, organisms. In terrestrial ecosystems, producers are usually green plants. Freshwater and marine ecosystems frequently have algae as the dominant producers.

Organic N mineralization from remaining residue can increase soil inorganic N concentration (Kumar *et al.,* 2018b). Shindo and Nishio (2005) noted that ~10% of organic N existing in wheat straw was converted into microbial biomass and soil inorganic N content derived from wheat straw ranged between 1.93 and 2.37 mg N/kg. When plant residues are given back to the soil, mineralization of crop residue N contributes to the soil inorganic nitrogen pool. The magnitude of this contribution is governed by the quality of CRs. However, abiotic immobilization of N by CRs can decrease the content of soil mineralizable organic N. Because added inorganic N in CR is transformed into microbial nitrogen, microbial biomass nitrogen, microbial residual nitrogen, and the subsequent nitrogen remineralisations rate are enhanced by adding straw residues to the soil (Singh *et al.,* 2017c).

However, the effects of CRs on direct inorganic N transformations to soil organic nitrogen remain unknown. There is close interaction between C and N dynamics during the decay of plant stubbles due to the immediate assimilation of C and N by heterotrophic soil micro-flora involved in the process.

Dou *et al.,* (2008) reported that SMBC was 5 to 8%, mineralized C was 2%, POM C was 14 to 31%, hydrolyzable C was 53 to 71%, and DOC was 1 to 2% of SOC. No-till significantly increased SMBC in the 0- to 30-cm depth, especially in the surface 0 to 5 cm. Under NT, SMBC at 0 to 5 cm was 25, 33, and 22% greater for CW, SWS, and WS, respectively, than under CT, but was 20 and 8% lower for CW and WS, respectively, than under CT at the 5- to 15-cm depth. At the 15- to 30-cm depth, no consistent effect of tillage was observed. Enhanced cropping intensity increased SMBC only under NT, where SMBC was 31 and 36% greater for SWS and WS than CW at 0 to 30 cm. Awale *et al.,* (2013) also found that compared with CT, ST and NT had significantly higher SOC concentration by 3.8 and 2.7%, SOC stock by 7.2% and 9.2%, CPOM-C by 22 and 25%. Naresh *et al.,* (2015a) also found that conservation tillage practices significantly influenced the total soil carbon (TC), total inorganic carbon (TIC), total soil organic carbon (SOC) and oxidizable organic carbon (OC) content of the surface (0 to 15 cm) soil. Wide raised beds transplanted rice and zero till wheat with 100% (T_9) or with 50% residue retention (T_8) showed significantly higher TC,SOC content of 11.93 and10.73 g kg^{-1} in T_9 and 10.98 and 9.38 gkg^{-1}, respectively in T_8 as compared to the other treatments. Irrespective of residue incorporation/ retention, wide raised beds with zero till wheat enhanced 40.5, 34.5, 36.7 and 34.6% of TIC, TC, SOC and OC in surface soil as compared to CT with transplanted rice cultivation.

Ma *et al.,* (2016) reported that the stratification ratio (SR) of TOC was significantly higher under PRB and FB than under TT at all depth ratios. SR was calculated from the TOC concentration at 0–5 cm divided by that at 5–10, 10–20 and 20–40, 40–60 and 60–90 cm. Up to 40 cm depth, SR did not reach the threshold value of 2. At depths greater than 40 cm, SR was >2 for PRB and FB but not for TT. The higher SR of TOC for PRB and FB suggests that conservation tillage increased TOC concentration at the soil surface (0–5 cm). Franzluebbers (2002) suggested that the SR of SOC may be a better indicator of soil health than SOC because surface SOM is absolutely essential to erosion control, water and nutrient conservation. Differences in SMBC were limited to the surface layers (0–5 and 5–10 cm) in the PRB treatment. There was a significant reduction in SMBC content with depth in all treatments. SMBC in the PRB treatment increased by 19.8%, 26.2%, 10.3%, 27.7%, 10% and 9% at 0–5, 5–10, 10–20, 20– 40, 40–60 and 60–90 cm depths, respectively, when compared with the TT treatment. The mean SMBC of the PRB treatment was 14% higher than that in the TT treatment. The continuous no tillage with high standing stubbles and crop residue coverage on the soil surface in the PRB and FB treatments would create favorable environments for the cycling of C and formation of macro-aggregates. Moreover, POC acts as a cementing agent to stabilize macro-aggregates and protect particulate organic matter, thereby increasing TOC contents (Naresh *et al.,* 2017).

Bijay- Singh, (2018) reported that fertilizer N, when applied at or below the level in the build-up of SOM and microbial biomass by promoting plant growth and increasing the amount of litter and root biomass added to soil. Only when fertilizer N was applied at rates more than the optimum, increased residual inorganic N accelerated the loss of SOM through its mineralization. Soil microbial life was also adversely affected at very high fertilizers rates. Optimum fertilizer use on agricultural crops reduces soil erosion but repeated application of high fertilizer N doses may lead to soil acidity, a negative soil health trait. Application of optimum doses of all nutrients is important, but due to fundamental coupling of C and N cycles, optimization of fertilizer N management is more closely linked to build-up of SOC and soil health

Ye *et al.,* (2019) observed that particulate organic N, microbial biomass N and water-extractable organic N levels were the greatest in 0–10 cm layer under NTS treatment; and in 10–30 cm layer, the corresponding values were the highest under NPTS treatment. NPTS treatment could immobilize the mineral N in 10–30 cm layer, and reduced leaching losses into deeper soil layers (40–60 cm).

Effect of Conservation Tillage and Residue Management on Soil Microbial Biomass

Soil microbial biomass is a relatively small component of the SOM—the MBC comprises only 1–3% of total soil C and MBN is 5% of total soil N—but they are the most biologically active and labile C and N pools (Deng *et al.,* 2000). Microbial biomass (bacteria and fungi) is a measure of the mass of the living component of soil organic matter. The microbial biomass decomposes plant and animal residues and soil organic matter to release carbon dioxide and plant available nutrients. Microbial biomass represents a relatively small standing stock of nutrients, compared to soil organic matter, but it can act as a labile source of nutrients for plants, a pathway for incorporation of organic matter into the soil, and a temporary sink for nutrients. Microbial biomass is the main agent that controls the flow of C and cycling of nutrient elements in terrestrial ecosystems. The large size of the soil microbial biomass implicates it as a major nutrient sink during C immobilization (growth) and as a source during mineralization (decay). It consists of bacteria, fungi, actinomycetes, and protozoa etc. However, fungi and bacteria are the dominant organisms both with regards to biomass and metabolic activities (Anderson and Domsch, 1973).

Important parameters of soil like soil moistures, nutritional availability in agro-ecosystems, and soil structure are governed by the disintegration of SOM by the soil microorganism. The soil microbial biomass (SMB) can be defined as live part of SOM. It has been projected as another helpful and important sign of soil qualities, as it is a source and pool of organically accessible nutrients and encourages the formation of soil structure and aggregation. The presence of soil microbial population in soil is possibly affected by many ecological factors like soil temperature and moistures (Debosz *et al.*, 1999) and by soil management practices, i.e., crop residue inputs (Govaerts *et al.*, 2007). The maintenance of crop residues is a significant aspect in exciting SMB and microbes' activities in the soil.

Dou *et al.*, (2008) reported that SMBC was 5 to 8%, mineralized C was 2%, POM C was 14 to 31%, hydrolyzable C was 53 to 71%, and DOC was 1 to 2% of SOC. No-till significantly increased SMBC in the 0- to 30-cm depth, especially in the surface 0 to 5 cm. Under NT, SMBC at 0 to 5 cm was 25, 33, and 22% greater for CW, SWS, and WS, respectively, than under CT, but was 20 and 8% lower for CW and WS, respectively, than under CT at the 5- to 15-cm depth. At the 15- to 30-cm depth, no consistent effect of tillage was observed. Enhanced cropping intensity increased SMBC only under NT, where SMBC was 31 and 36% greater for SWS and WS than CW at 0 to 30 cm. The relationship between tillage and POM C in the 5- to 15-cm depth, however, was different from the surface soil. Particulate organic matter C for the above cropping sequences at this depth was 35, 42, and 51% lower for NT than CT, but at 15 to 30 cm showed a similar pattern as in the surface soil. Liang *et al.*, (2011) observed that in the 0–10 cm soil layer, SMBC and SMBN in the three fertilized treatments were higher than in the unfertilized treatment on all sampling dates, while microbial biomass C and N in the 0−10 cm soil layers were the highest at grain filling. Zhu *et al.*, (2014) revealed that the Soil TOC and labile organic C fractions contents were significantly affected by straw returns, and were higher under straw return treatments than non-straw return at three depths. At 0–7 cm depth, soil MBC was significantly higher under plowing tillage than rotary tillage, but EOC was just opposite. Rotary tillage had significantly higher soil TOC than plowing tillage at 7–14 cm depth. However, at 14–21 cm depth, TOC, DOC and MBC were significantly higher under plowing tillage than rotary tillage except for EOC.

Yeboah *et al.*, (2016) reported that compared with the T and NT, NTS increased soil microbial biomass carbon by 42% and 38% in 0–30 cm depth, respectively. Root biomass was significantly increased in NTS by 47% and 54% over T and NT, respectively. Across the three years, NTS had an average grain yield of 53% and 41% higher than T and NT, respectively

Kumar *et al.*, (2018) reported that after 2 years of the experiment, potentially mineralizable nitrogen (PMN) and microbial biomass nitrogen (MBN) content showed that in 0- 15 cm soil layer T_1 and T_3 treatments increased from 6.7 and 11.8 mgkg^{-1} in conventional tillage (T6) to 8.5, 14.4 and 7.6, 14.1 mgkg^{-1} in ZT and RT without residue retention and 12.4, 10.6, 9.3 and 20.2, 19.1,18.2 mg kg^{-1} ZT and RT with residue retention and CT with residue incorporation (T_1, T_3, T_5), respectively.

Fig.1 Effect of SOM on soil properties and plant growth (Oshins and Drinkwater 1999)

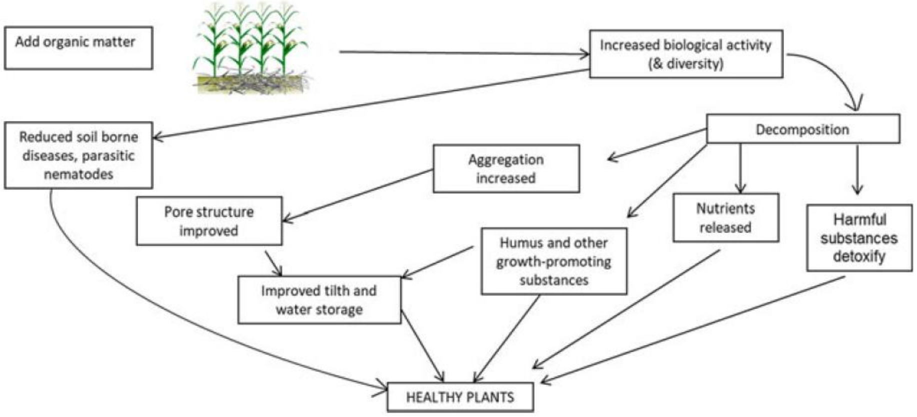
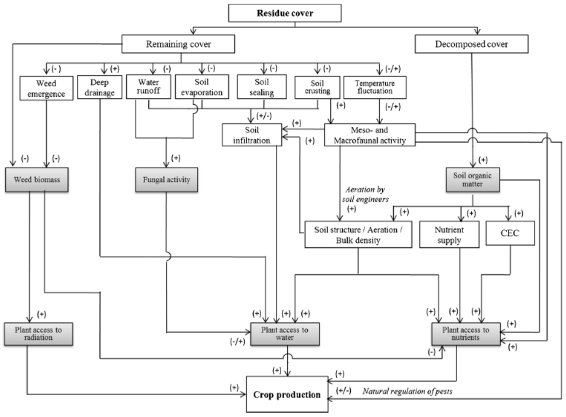


Fig.2 Agro-ecological functions of surface crop residues. (+) and (−) signs designate positive and negative effects, respectively, adapted from Lu et al. (2000) and Turmel et al. (2014)



In 15 -30 cm layer, the increasing trends due to the use of tillage crop residue practices were similar to those observed in 0 -15 cm layer however, the magnitude was relatively lower. Continuous retention of crop residue resulted in considerable accumulation of PMN and MBN in 0–15 cm soil layer than unfertilized control plots.

Soils under the 200 kgNha^{-1} (F_4), treated plots resulted in higher PMN in the 0–15 cm soil layer over those under the 120 kg Nha^{-1} and 80 kg Nha^{-1} treated plots. The PMN in surface soil were in the order of 200 kg Nha^{-1} (F_4), 10.4 mgkg^{-1} > 160 kg Nha^{-1} (F_3), 9.8 mgkg^{-1}>120 kg Nha^{-1} (F_2), 8.9 mgkg^{-1}>80 kg Nha^{-1} (F_1), 7.3 mgkg^{-1}>unfertilized control (3.6 mgkg^{-1}). However, increase in PMN was more in surface as compared to sub-surface soil, which indicate that higher accumulation of organic carbon due to retention of crop residue was confined to surface soil. The increase in PMN in 160 kg Nha^{-1} (F_3) and 120 kg Nha^{-1} (F_2) treatments in surface layer was 63.3 and 59.6% over unfertilized control, while they were 25.5 and 17.9% greater over 80 kg Nha^{-1} (F_1) treatment, respectively. Highest DOC change (28.2%) was found in ZT with residue retention (T_1) plots followed by RT with residue retention (T_3) plots (23.6%).

The use of ZT and RT with residue retention (T_1 and T_3) plots for two wheat crop cycle increased DOC by 21.2 and 16.1% more than that of ZT and RT without residue retention and conventional tillage (T_2, T_4 and T_6), respectively. Lack of soil disturbance under ZT provides steady source of organic C substrates for soil microorganisms, which enhances their activity and accounts for higher soil MBC as compared with CT – where a temporary flush of microbial activity with tillage events results in large losses of C as CO_2 (Balota *et al.,* 2003). Dalal *et al.,* (1991) studied the effects of 20 years of tillage practice, CR management and fertilizer N application on microbial biomass and found that MBN was significantly affected by tillage, residue and fertilizer N individually as well as through their interaction.

Soil microbial communities possess important functions in SOC decomposition and C sequestration processes through metabolizing organic matter sources (Dong *et al.*, 2014).

On one hand, SOC decomposition is controlled by the quality and availability of organic C resources utilized by microbial communities (Dong *et al.,* 2014). Several studies suggested that labile fractions (including MBC and DOC) are closely related to SOC dynamics (Helgason *et al.,* 2010; Guo *et al.,* 2015). On the other hand, soil microbial community and their interactions with the environment are important factors that affect SOC dynamics, and any change in soil microbial community may alter SOC availability (Dong *et al.,* 2014). Stewart *et al.,* (2008) reported that soil C sequestration capacity is mainly determined by the degree of SOC protection from decomposition provided by the spatially hierarchical organization of soil aggregate structure. Moreover, microbial metabolic diversity influenced SOC directly through DOC in >0.25 mm aggregate, and directly and indirectly through DOC and MBC in <0.25 mm aggregate under tillage and straw systems. Soil microenvironment contributes to the heterogeneous distribution of microorganisms within aggregates (Young *et al.,* 2008) thus leading to different effects of microorganisms on SOC within aggregates. Macro-aggregates exhibit faster turnover time than micro-aggregates because macro-aggregates are mainly formed through binding of micro-aggregates and organic amendments (Choudhury *et al.,* (2014) therefore, macro-aggregates more easily obtain fresh organic matter. Choudhury *et al.,* (2014) also reported that straw returning results in the preponderance of macro-aggregates compared with micro-aggregates caused by the formation of water-stable aggregates. The presence of more stable macro-aggregates is the first condition required for C sequestration (Jha *et al.,* 2012). Therefore, conservation tillage can be speculated to promote the accumulation of straws in the top soil layer (0−5 cm), which leads to rapid straw decomposition accompanied by microbial growth (Miltner *et al.,* 2012). Zhang *et al.,* (2013) reported that soil microbial communities promote the accumulation of C directly and indirectly through MBC, and the input level of microbial-derived C and MBC regulate SOC within aggregates.

Conservation tillage (CT) systems have been observed to contribute to the role of soil as a carbon sink. By minimizing soil disturbance, reduced tillage decreases the mineralization of organic matter. The result is a larger store of soil organic carbon than with conventional tillage. The latter is used to mix topsoil to recover lost nutrients, prepare the seedbed and control weeds, but has been associated with losses in SOC, which lead to a significant decline in soil quality.

Soil aggregation is an imperative mechanism contributing to soil fertility by reducing soil erosion and mediating air permeability, water infiltration, and nutrient cycling. Soil aggregates are important agents of SOC retention and protection against decomposition. Quantity and quality of SOC fractions have an impact on soil aggregation that in turn physically protect the carbon from degradation by increasing the mean residence time of carbon.

Soil management through the use of different tillage systems affects soil aggregation directly by physical disruption of the macro-aggregates, and indirectly through alteration of biological and chemical factors. Crop residue plays an important role in SOC sequestration, increasing crop yield, improving soil organic matter, and reducing the greenhouse gas. Tillage reduction and residue retention both increased the proportion of soil organic matter as microbial biomass. Microbial immobilization of available-N during the early phase of crops enhanced the degree of synchronization between crop demand and N supply. The maximum enhancement was reported in the minimum tillage along with residue retained treatment.

References

Alvarez CR, Taboada MA, Gutierrez Boem FH, Bono A, Fernandez PL, *et al.*, 2009. Topsoil properties as affected by tillage systems in the rolling Pampa region of Argentina. Soil Sci Soc Am J 73:1242–1250.

Anderson, J.P.E. and K.H. Domsch, 1973. Quantification of bacterial and fungal contributions to soil respiration. Arch. Mikrobiol., 93: 113-127.

Arai, M. *et al.*, 2013. Changes in soil aggregate carbon dynamics under no-tillage with respect to earthworm biomass revealed by radiocarbon analysis. *Soil Tillage Res.* 126: 42–49.

Aulakh MS, Garg Ashok K, Kumar Shrvan. Impact of Integrated Nutrient, Crop Residue and Tillage Management on Soil Aggregates and Organic Matter Fractions in Semiarid Subtropical Soil under Soybean-Wheat Rotation. Am. J Plant Sci. 2013; 4:2148-2164.

Awale R, Chatterjee A, David Franzen. 2013. Tillage and N-fertilizer influences on selected organic carbon fractions in a North Dakota silty clay soil. Soil Tillage Res. 134:213-222.

Bai, W. *et al.*, 2016.The combination of subsoil and the incorporation of corn stover affect physicochemical properties of soil and corn yield in semi-arid China. Toxicol. Environ. Chem. 98: 561–570.

Balota EL, Colozzi-Filho A, Andrade DS, Dick RP. 2003 Microbial biomass in soils under different tillage and crop rotation systems. Biol Fertility Soils. 38:15-20.

Bhattacharyya, P., Roy, K.S., Neogi, S., Adhya, T.K., Rao, K.S., and Manna, M.C. 2012. Effects of rice straw and nitrogen fertilization on greenhouse gas emissions and carbon storage in tropical flooded soil planted with rice. Soil Tillage Res. 124: 119–130.

Bhattacharyya, R., Pandey, S.C., Bisht, J.K., Bhatt, J.C., Gupta, H.S., Tuti, M.D., *et al.*, 2013. Tillage and Irrigation Effects on Soil Aggregation and Carbon Pools in the Indian Sub-Himalayas. Agro J.105(1):101-112

Bhattacharyya, R. *et al.*, 2018. Aggregate-associated N and global warming potential of conservation agriculture-based cropping of maize-wheat system in the north-western Indo-Gangetic plains. *Soil Tillage Res.* 182:66–77.

Brar, B. S., Singh, K., Dheri, G. S. and Balwinder, K. 2013. Carbon sequestration and soil carbon pools in a rice-wheat cropping system: effect of long-term use of inorganic fertilizers and organic manure. *Soil Tillage Res.* 128: 30–36.

Breulmann, M., Masyutenko, N.P., Kogut, B.M., Schroll, R., Dorfler, U., Buscot, F., Schulz, E., 2014. Short-term bioavailability of carbon in soil organic matter fractions of different particle sizes and densities in grassland ecosystems. Sci. Total Environ. 497-

498: 29–37.

Choudhury SG, Srivastava S, Singh R, Chaudhari SK, Sharma DK, Singh SK, *et al.*, 2014. Tillage and residue management effects on soil aggregation, organic carbon dynamics and yield attribute in rice–wheat cropping system under reclaimed sodic soil. Soil Tillage Res 136: 76–83.

Chen, L., Zhang, J., Zhao, B., Yan, P., Zhou, G., Xin, X. 2014. Effects of straw amendment and moisture on microbial communities in Chinese fluvo-aquic soil. J. Soils Sediments 14: 1829–1840

Chen, Y., Xin, L., Liu, J., Yuan, M., Liu, S., Jiang, W., *et al.*, 2017. Changes in bacterial community of soil induced by long-term straw returning. *Sci. Agric*. 74: 349–356.

Chen, Z. *et al.*, 2018. Changes in soil microbial community and organic carbon fractions under short-term straw return in a rice–wheat cropping system. *Soil Tillage Res.* 165: 121–127.

Clapp CE, Allmaras RR, Layese MF, Linden DR, Dowdy RH. 2000. Soil organic carbon and ^{13}C abundance as related to tillage, crop residue, and nitrogen fertilization under continuous corn management in Minnesota. Soil Tillage Res. 55:127-142.

Debosz K, Rasmussen PH, Pedersen AR. 1999. Temporal variations in microbial biomass C and cellulolytic enzyme activity in arable soils: effects of organic matter input. Appl Soil Ecol 13:209–218

Dhaliwal J, Kukal SS, Sharma S. 2018. Soil organic carbon stock in relation to aggregate size and stability under tree-based cropping systems in Typic Ustochrepts. Agroforestry Syst.92 (2):275-284.

Dikgwatlhe SB, Chen ZD, Lal R, Zhang HL, Chen F.2014. Changes in soil organic carbon and nitrogen as affected by tillage and residue management under wheat–maize cropping system in the North China Plain. Soil Tillage Res 144:110–118.

Dalal RC, Henderson PA, Glasby JM. Organic Matter and Microbial Biomass in a Vertisol after 20 yr of Zero-Tillage. Soil Bio Biochem. 1991; 23(5):435-441.

Dong HY, Kong CH, Wang P, Huang QL. 2014. Temporal variation of soil friedelin and microbial community under different land uses in a long-term agro-ecosystem. Soil Biol Biochem 69:275–281.

Dou F, Wright AL, Hons FM. 2008. Sensitivity of labile soil organic carbon to tillage in wheat-based cropping systems. Soil Sci Soc Am J. 72:1445-1453.

Du Z, Ren T, and Hu C.2010. Tillage and residue removal effects on soil carbon and nitrogen storage in the North China Plain. Soil Sci Soc Am J74:196–202

Ellert BH, Bettany JR. 1995.Calculations of organic matter and nutrients stored in soil under contrasting management. Can. J Soil Sci. 75:529-538.

Fonte, S. J., Quintero, D. C., Velásquez, E., and Lavelle, P.2012 Interactive effects of plants and earthworms on the physical stabilization of soil organic matter in aggregates. *Plant Soil* 359:205–214.

Franzluebbers, A.J. 2002. Soil organic matter stratification ratio as an indicator of soil quality. Soil Tillage Res. 66: 95–106.

Gathala MK, Ladha JK, Saharawat YS, Kumar V, Sharma PK.2011. Effect of tillage and crop establishment methods on physical properties of a medium-textured soil under a seven-year rice-wheat rotation. Soil Water management conservation. Soil Sci Soc Am J 75:851–1862.

Ghosh, A. *et al.*, 2018. Long-term fertilization effects on soil organic carbon sequestration in an Inceptisol. *Soil Tillage Res.* 177: 134–144.

Gonçalves, D. R. P. *et al.*, 2017. Soil type and texture impacts on soil organic carbon storage in a sub-tropical agro-ecosystem.*Geoderma* 286: 88–97.

Gonzalez-Sanchez EJ, Ordonez-Fernandez R, Carbonell- Bojollo R, Veroz-Gonzalez O, Gil- Ribes JA. 2012. Meta-analysis on atmospheric carbon capture in Spain through the use of conservation agriculture. Soil Till age Res. 2012; 122:52-60.

Govaerts B, Mezzalama M, Unno Y, Sayre KD, Luna-Guido M, Vanherck K, Deckers J. 2007. Influence of tillage, residue management, and crop rotation on soil microbial biomass and catabolic diversity. Appl Soil Ecol 37(1–2):18–30

Guo LJ, Zhang ZS, Wang DD, Li CF, Cao CG. 2015. Effects of short-term conservation management practices on soil organic carbon fractions and microbial community composition under a rice-wheat rotation system. Biol Fertility Soils 51:65–75

Guo L-J, Lin S, Liu T-Q, Cao C-G, Li C-F. 2016. Effects of Conservation Tillage on Topsoil Microbial Metabolic Characteristics and Organic Carbon within Aggregates under a Rice (*Oryza sativa* L.) –Wheat (*Triticum aestivum* L.) Cropping System in Central China. PLoS ONE 11(1): e0146145.

Hassan, A. *et al.*, 2016. Depth distribution of soil organic carbon fractions in relation to tillage and cropping sequences in some dry lands of Punjab, Pakistan. *Land Degrad. Dev.* 27: 1175–1185

He, Y. T. *et al.*, 2018. Long-term fertilization increases soil organic carbon and alters its chemical composition in three wheat-maize cropping sites across central and South China. *Soil Tillage Res.* 177: 79–87.

Helgason BL, Walley FL, Germida JJ. 2010. Long-term no-till management affects microbial biomass but not community composition in Canadian prairie agro-ecosytems. Soil Biol Biochem 42:2192–2202.

Jha P, Garg N, Lakaria BL, Biswas AK, Rao AS. 2012. Soil and residue carbon mineralization as affected by soil aggregate size. Soil Tillage Res 121:57–62.

Karlsson, H., Ahlgren, S., Sandgren, M., Passoth, V., Wallberg, O., and Hansson, P. A. 2017. Greenhouse gas performance of biochemical biodiesel production from straw: soil organic carbon changes and time-dependent climate impact. *Biotechnol. Biofuels*10:217. doi: 10. 1186/s13068-017-0907-9

Kuhn, N. J. *et al.*, 2016. Conservation tillage and sustainable intensification of agriculture: regional vs. global benefit analysis. *Agric. Ecosyst. Environ.* 216: 155–165.

Kumar S, Kumar R, Mishra JS, Dwivedi SK, Prakash V, Rao KK, Singh AK, Bhatt BP, Singh SS, Haris AA, Kumar V, Srivastava AK, Singh S, Yadav A. 2018b.Productivity and profitability of rice (*Oryza sativa*) genotypes as influenced by crop management practices under middle Indo-Gangetic Plains. Indian J Agron 63(1):45–49

Kumar V, Naresh RK, Satendra Kumar, Sumit Kumar, Sunil Kumar, Vivak, *et al.*,2018. Tillage, crop residue, and nitrogen levels on dynamics of soil labile organic carbon fractions, productivity and grain quality of wheat crop in Typic Ustochrept soil. J. Pharmacog Phytochem. 7(1):598-609.

Li, J. *et al.*, 2018. Soil labile organic carbon fractions and soil organic carbon stocks as affected by long-term organic and mineral fertilization regimes in the North China Plain. *Soil Tillage Res.* 175: 281–290.

Li, P., Li, Y., Zheng, X., Ding, L., Ming, F., Pan, A., *et al.*, 2017. Rice straw decomposition affects diversity and dynamics of soil fungal community, but not bacteria. *J. Soils Sediments* 18: 248–258

Liang B, Yang X, He X, Zhou J.2011. Effects of 17-year fertilization on soil microbial biomass C and N and soluble organic C and N in loessial soil during maize growth. *Biol.* Fertility Soils. 47(2):121-128.

Liang, Q. *et al.*, 2012. Effects of 15 years of manure and inorganic fertilizers on soil organic carbon fractions in a wheat-maize system in the North China Plain. *Nutr. Cycl. Agroecosyst.* 92: 21–33.

Liu, C., Lu, M., Cui, J., Li, B., Fang, C.M. 2014. Effects of straw carbon input on carbon dynamics in agricultural soils: a meta-analysis. Global Change Biol. 20: 1366–1381

Liu, C.A. and Zhou, L. M. 2017. Soil organic carbon sequestration and fertility response to newly-built terraces with organic manure and mineral fertilizer in a semi-arid environment. *Soil Tillage Res.* 172: 39–47.

Lu, Y., C.C., Watkins, K.B., Teasdale, J.R., Abdulbaki, A. 2000. Cover Crops in Sustainable Food Production. Food Rev. Int. 16:121–157.

Mandal KG, Baral U, Padhi JP, Majhi P, Chakraborty H, Kumar A. 2012. Effects of cropping on soil properties and organic carbon stock in Deras region, India. Reg. Environ. Change.12 (4):899-912.

Maarastawi, S. A., Frindte, K., Linnartz, M., and Knief, C. 2018. Crop rotation and straw application impact microbial communities in Italian and Philippine soils and the rhizosphere of Zea mays. *Front. Microbiol.* 9:1295. doi: 10.3389/fmicb.2018.01295

Ma, Z., Chen, J., Lyu, X., Liu, Li-li., and Siddique, K.H.M. 2016. Distribution of soil carbon and grain yield of spring wheat under a permanent raised bed planting system in an arid area of northwest China. Soil Tillage Res. 163: 274–281.

Marschner, P., Umar, S., Baumann, K., 2011. The microbial community composition changes rapidly in the early stages of decomposition of wheat residue. Soil Biol. Biochem.43: 445–451.

Mehra, P., Desbiolles, J., Baker, J., Sojka, R. Miltner A, Bomback P, Schmidt-Brucken B, Kastner M.2012. SOM genesis: microbial biomass as a significant source. Biogeochemistry 111:41–55

Naresh R.K.; Gupta Raj K.;Gajendra Pal; Dhaliwal S.S.; Kumar Dipender; Kumar Vineet; Arya Vichitra Kumar; Raju; Singh S.P.;Basharullah; Singh Onkar and Kumar Pardeep. 2015. Tillage Crop Establishment Strategies and Soil Fertility Management: Resource Use Efficiencies and Soil Carbon Sequestration in a Rice-Wheat Cropping System. Eco. Env. & Cons. 21: 121-128.

Naresh RK, Gupta Raj K, Gajendra Pal, Dhaliwal SS, Kumar, Dipender, *et al.*,2015a. Tillage crop establishment strategies and soil fertility management: resource use efficiencies and soil carbon sequestration in a rice-wheat cropping system. Eco. Env. & Cons. 21:127-134

Naresh RK, Arvind Kumar, Bhaskar S, Dhaliwal SS, Vivek, Satendra Kumar, *et al.*, 2017. Organic matter fractions and soil carbon sequestration after 15- years of integrated nutrient management and tillage systems in an annual double cropping system in northern India. J. Pharmacog Phytochem. 6(6):670-683.

Naresh RK, Bhaskar S, Dhaliwal SS, Kumar A, Gupta RK, and Vivek. 2018. Soil carbon and nitrogen mineralization dynamics following incorporation and surface application of rice and wheat residues in a semi-arid area of North West India: a review. J Pharmacogn Phytochem 7:248–259.

Oshins C, Drinkwater L.1999. An introduction to soil health. [A slide set available at the Northeast Region SARE website: www.uvm.edu/~nesare/slide.html]

Piccolo, A. *et al.*, 2018.Effective carbon sequestration in Italian agricultural soils by *in situ* polymerization of soil organic matter under biomimetic photocatalysis. *Land Degrad. Dev.* 29: 485–494.

Poulton, P., Johnston, J., Macdonald, A., White, R., and Powlson, D. 2018.Major limitations to achieving “4 per 1000” increase in soil organic carbon stock in temperate regions: evidence from long-term experiments at Rothamsted research, United Kingdom. *Glob. Change Biol.* 24: 2563–2584.

Romkens PFAM, van der Plicht J, Jassink J.1999. Soil organic matter dynamics after the conversion of arable land to pasture. Biol. Fertil. Soils. 28:277-284

Sainju, U. M., Caesar-TonThat, T., and Jabro, J. D. 2009. Carbon and nitrogen fractions in dryland soil aggregates affected by long-term tillage and cropping sequence. *Soil Sci. Soc. Am. J.* 73: 1488–1495.

Shindo H, Nishio T.2005. Immobilization and remineralization of N following addition of wheat straw into soil: determination of gross N transformation rates by ^{15}N-ammonium isotopedilution technique. Soil Biol Biochem 37:425–432

Singh SK, Abraham T, Kumar R, Kumar R. 2017c. Response of crop establishment methods and split application of nitrogen on productivity of rice under irrigated ecosystem. Environ Ecol 35 (2A):859–862.

Singh, B. P., Setia, R., Wiesmeier, M. and Kunhikrishnan, A. 2018. Agricultural management practices and soil organic carbon storage. In Soil Carbon Storage, 1st Edition: Modulators, Mechanisms and Modeling (Ed., Singh B.): 207–244. Academic Press, London, UK.

Song MW, Li AZ, Cai LQ, Zhang RS. 2011. Effects of different tillage methods on soil organic carbon pool. J Agro-Enviro Sci. 27(2):6222-6226.

Stewart C, Plante A, Paustian K, Conant R, Six, J. 2008. Soil Carbon Saturation: Linking concept and measurable carbon pools. Soil Sci Soc Am J 72:379–392

Stockmann, U., Adams, M.A., Crawford, J.W., Field, D.J., Henakaarchchi, N. Jenkins, M. *et al.*, 2013. The knowns, known unknowns and unknowns of sequestration of soil organic carbon. Agric. Ecosyst. Environ. 164:80–99.

Tang, X. *et al.*, 2018. Carbon pools in China's terrestrial ecosystems: new estimates based on an intensive field survey. *Proc. Natl. Acad. Sci. USA* 115: 4021–4026.

Tian, K., Zhao, Y., Xu, X., Hai, N., Huang, B., Deng, W. 2015. Effects of long-term fertilization and residue management on soil organic carbon changes in paddy soils of China: a meta-analysis. Agric. Ecosyst. Environ. 204: 40–50.

Triberti L, Nastri A, Giordani G, Comellini F, Baldoni G, Toderi G. 2008. Can mineral and organic fertilization help sequestrate carbon dioxide in cropland? Eur J Agron 29:13–20.

Turmel MM-S, Speratti A, Baudron F *et al.*, 2014. Crop residue management and soil health: a systems analysis. Agric Syst 134:6–16.

Wander MM, Bidart MG, Aref S. 1998. Tillage impacts on depth distribution of total and particulate organic matter in three Illinois soils. Soil Sci. Soc. Am. J. 62:1704-1711

Wu, J.M., Peng, H., Ji, X.H., Shi, L.H., Tian, F.X., and Liu, Z.B. 2010. Effect of patterns of straw returning to soil on the cultivated soil organic carbon accumulation in double-crop rice system. Ecol. Environ. Sci. 19: 2360–2365

Yang, H., Feng, J., Zhai, S., Dai, Y., Xu, M., Wu, J., *et al.*, 2016. Long-term ditch-buried straw return alters soil water potential, temperature, and microbial communities in a rice-wheat rotation system. *Soil Tillage Res.* 163: 21–31.

Yeboah, S., Zhang, R., Cai, L., Li, L., Xie, J., Luo, Z., Liu, J., and Wu, J. 2016. Tillage effect on soil organic carbon, microbial biomass carbon and crop yield in spring wheat-field pea rotation, Plant Soil Environ. 62(6): 279–285.

Ye,X,. Ye, Yin., Chai,R., Li,J., Ma, C., Li,H., Xiong, Q., and Gao, H. 2019. The influence of a year-round tillage and residue management model on soil N fractions in a wheat-maize cropping system in central China, *Sci Rep* 9:4767

Young IM, Crawford JW, Nunan N, Otten W, Spiers A. 2008. Microbial distribution in soils: physics and scaling. Adv Agron 100:81–121.

Yu, D., Wen, Z., Li, X., Song, X., Wu, H., and Yang, P. 2018. Effects of straw return on bacterial communities in a wheat-maize rotation system in the North China Plain. *PLoS One* 13:e0198087. doi: 10.1371/journal.pone.0198087

Zhang S, Li Q, Lü Y, Zhang X, Liang W. 2013. Contributions of soil biota to C sequestration varied with aggregate fractions under different tillage systems. Soil Biol Biochem 62:147–156.

Zhao, S., Li, K., Zhou, W., Qiu, S., Huang, S., He, P. 2016. Changes in soil microbial community, enzyme activities and organic matter fractions under long-term straw return in north-central China. Agric. Ecosyst. Environ. 216, 82–88.

Zheng, L., Wu, W.L., Wei, Y.P., Hu, K.L. 2015. Effects of straw return and regional factors on spatio-temporal variability of soil organic matter in a high-yielding area of northern China. Soil Tillage Res. 145, 78–86.

Zhu LQ, Zhang DW, Bian XM. 2011. Effects of continuous returning straws to field and shifting different tillage methods on changes of physical-chemical properties of soil and yield components of rice. Chinese J Soil Sci. 42(1):81-85.

Zhu, L., Hu, N., Zhang, Z., Xu, J., Tao, B., Meng, Y. 2015. Short-term responses of soil organic carbon and carbon pool management index to different annual straw return rates in a rice–wheat cropping system. Catena 135: 283–289.

How to cite this article:

Dhaliwal, S. S., Yogesh Kumar, S. P. Singh, Vivek, Robin Kumar, N. C. Mahajan, S. K. Gupta, Amit Kumar, Mayank Chaudhary, S. P. Singh, S. K. Tomar and Naresh, R. K. 2019. Effect of Conservation Tillage and Residue Management on Soil Organic Carbon Storage, Ecosystem Dynamics and Soil Microbial Biomass in Sub-tropical Agro-ecosystem: A Review. *Int.J.Curr.Microbiol.App.Sci.* 8(09): 2920- 2935.doi: https://doi.org/10.20546/ijcmas.2019.809.336