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Changes in carbon pools and microbial activities of soil under conservation agriculture: A review

Rajat Kumar Parit, Kaberi Mahanta, Prem Kumar Bharteey and Shyamal Kishore Bordoloi

Abstract
Conservation agriculture (CA) "A resource-saving agricultural crop production system that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment". Conservation agriculture practices accelerate deposition of soil organic matter and augment associated biological properties of soil through enhanced inputs of organic carbon (Parihar *et al.,* 2018). Also it minimizes soil erosion, conserves water within the root zone and improves soil fertility and productivity. Carbon is an important part of life on earth. It is found in all living organisms and is the major building block for life on earth and moves through the atmosphere, oceans, plant, soil and earth in short and long term cycles over a time. Carbon pools act as storage houses for large amount of carbon. Any movement of carbon between these carbon pools is called a flux. Soil plays a major role in maintaining balance between global carbon cycle through sequestration of atmospheric carbon as soil organic carbon. Soils store about three times as much carbon as the terrestrial vegetation (Lal, 2004). Soil organic carbon (SOC) is the epicenter of soil physical, chemical and biological health of the soil and is the major source of energy for the soil biota. Soil microbial activity refers any microbiological processes in soil like mineralization, biological nitrogen fixation, decomposition, nutrient cycling etc. Conservation agricultural practices increase microbial population and activity as well as microbial biomass in soil (Balota, 2003). Again residue incorporation in soil increases the source of carbon which favors better proliferation of soil microbes. Soil enzymes play key biochemical functions in the decomposition of organic matter, mineralization of nutrient and making nutrient available to the crop plants. They are process level indicators, which reflect past soil biological activity as influenced by various soil management.

Keywords: Carbon pools, microbial activities, conservation agriculture

Introduction
Conservation agriculture (CA) "A resource-saving agricultural crop production system that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment". Conservation agriculture practices accelerate deposition of soil organic matter and augment associated biological properties of soil through enhanced inputs of organic carbon (Parihar *et al.,* 2018) [13]. Also it minimizes soil erosion, conserves water within the root zone and improves soil fertility and productivity. Agronomic practices (tillage and crop rotations) can affect soil health. Karlen *et al.* (2013) [8] observed that intensive deep ploughing with a mould board plough had a significant negative effect on soil health and quality. Halvorson *et al.* (2002) [7] had encouraging results with minimum tilling of soil compared to conventional tillage; it increased soil organic matter content and biological activity, improved soil structure with the maintenance of soil aggregates and reduced oxidation of soil organic matter. Similarly, diversification in crop rotations can also affect soil health by affecting carbon contents because of differences in root activities and chemical composition of different crop residues that are added to soil Srinivasa rao *et al.*, (2013) [16]. Positive changes in SOC and soil biological properties have been reported with CA practices in different cropping systems under varied agro-ecological conditions (Chivenge *et al.*, 2007; Das *et al.*, 2013; Choudhary *et al.,* 2018) [5, 6]. Different tillage practices cause changes in soil physical properties, such as bulk density (Wander *et al.*, 1998), water holding capacity (Trojan and Linden, 1998) [18], pore size distribution (Azooz *et al*., 1996) [1], and aggregation (Chan *et al*., 1988) [4]. Conventional tillage can lead to soil microbial communities dominated by aerobic microorganisms, while conservation tillage practices increase microbial population and activity (Staley, 1999) [17] as well as microbial biomass (Balota *et al*., 2003) [2].

Conservation of soil organic matter (SOM) is considered a central component of sustainable soil health (Verma and Sharma, 2007) [19]. Labile soil organic C pools like dissolved organic C (DOC), microbial biomass C (MBC), and particulate organic matter C (POC) are the fine indicators of soil quality which influence soil function in specific ways (e.g. immobilization–mineralization) and are much more sensitive to change in soil management practices (Xu *et al.* 2011) [20]. Moreover, POMC can be used as an indicator of soil quality rather than total organic matter. Organo–mineral fractions of specific particle size (<0.053mm) can lead to development of stable micro-aggregates and slow decomposition rate within aggregates with respect to their composition and turnover.

Carbon is an important part of life on earth. It is found in all living organisms and is the major building block for life on earth and moves through the atmosphere, oceans, plant, soil and earth in short and long term cycles over a time. Carbon pools act as storage houses for large amount of carbon. Any movement of carbon between these carbon pools is called a flux. Soil plays a major role in maintaining balance between global carbon cycle through sequestration of atmospheric carbon as soil organic carbon. Soils store about three times as much carbon as the terrestrial vegetation (Lal, 2004) [9]. Soil organic carbon (SOC) is the epicenter of soil physical, chemical and biological health of the soil and is the major source of energy for the soil biota.

Soil microbial activity refers any microbiological processes in soil like mineralization, biological nitrogen fixation, decomposition, nutrient cycling etc. Again residue incorporation in soil increases the source of carbon which favours better proliferation of soil microbes. Soil enzymes play key biochemical functions in the decomposition of organic matter, mineralization of nutrient and making nutrient available to the crop plants. They are process level indicators, which reflect past soil biological activity as influenced by various soil management.

Basic components of Conservation agriculture

- Minimum soil disturbance
- Crop residue incorporation
- Suitable crop rotations

1. **Minimum soil disturbance:** Minimum tillage is a soil conservation system like Strip- till with the goal of minimum soil manipulation necessary for a successful crop production. It is a tillage method that does not turn the soil over. It is contrary to intensive tillage, which changes the soil structure using ploughs. It includes minimum tillage and zero tillage.
2. **Crop residue incorporation:** is the process through which the crop left over in the field is incorporated in the field to increase and the maintain the fertility level.
3. **Crop rotation:** The practice of growing different crops in succession on the same land chiefly to sustain the productive capacity of the soil.

Carbon: History and Background

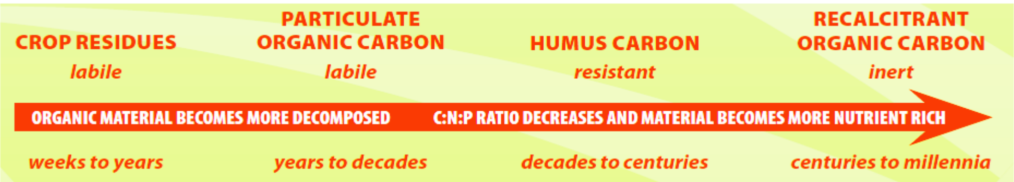
Carbon is the element having atomic number 6 and atomic mass 12.016 u. Carbon was known to human civilization since 3750 BC. But was first recognized as an element in 1789 by Joseph Black, a Scottish physician and chemist. The word Carbon is derived from latin word "charcoal".

Importance of Carbon

- Carbon is the basic building block for any form of life.
- Carbon, the chemical basis for most of the biomolecules like carbohydrates, lipids, proteins and nucleic acids, DNA, RNA etc.
- Source of energy for all the living organisms.

Role of carbon in maintaining the Soil Health

1. Soil structure: Organic matter plays a vital role in the process of aggregation. With the addition of organic matter in soil it binds the soil particles producing a porous and crumby soil structure. Again decomposition of organic matter produces humic acid, fulvic acid and humin and all the humus substances have the cementing property. These substances stabilizes the soil structure.
2. Water infiltration capacity: As the soil structure becomestabilize and crumby due to addition of the organic matter and so the rate of infiltration will increase and run-off of water from the agricultural field will decrease.
3. Water holding capacity: As the organic matter are very porous in nature and they have high surface area about $1150m^2/g$. This large surface area allows the organic matter to hold a greater quantity of water. And with the addition of the organic matter in the soil it increases the water holding capacity of the soil.
4. Source of food: soil organic matter is the rich source of carbon and energy for all form of soil biota i.e. soil microbes, earthworms and other soil arthropods.
5. Management of soil pH: In alkaline soil, with addition of organic matter, its decomposition produces humic acid, fulvic acid, humin and all these acids helps in lowering soil pH towards neutral.
6. Nutrient availability: in acid soil addition of organic matter increases the availability nutrient specially phosphorus. As the decomposition of the organic matter produces humus substances which have chelating property. These chelates will bind with the Al^{3+} and $Fe^{3+}$and form complex reducing their concentration in the soil. Due to the reduction in the concentration of these Al^{3+} and Fe^{3+} the phosphorus availability increases.
7. Enhance Soil fertility and nutrient status: Organic carbon indirectly enhances the soil fertility and nutrient status by acting as the source of food for the microbes. As the microial population and activity increases in the soil and thus mineralization of the plant nutrient takes place.



Soil Organic Carbon Pools

Organic carbon is made up of four different pools that decompose at different rates, Bell and Lawrence, 2009.

Total carbon pool in biosphere: World soil constitutes **3rd** largest global Carbon pool

Total carbon pool in biosphere

Carbon pools	Amount (Pg) (Approx.)
Ocean	38,100
Fossil fuel	4130
Soil	2550
Atmosphere	760
Vegetation	610

Source: Lal *et al.*, 2008

Soil Microbial Activity

Microbiological processes in soil like mineralization, nutrient cycling, biological nitrogen fixation, decomposition etc.

Classification of Soil microorganisms: Soil microbes are classified as Bacteria, Fungi, Actinomycetes, algae, protozoa etc.

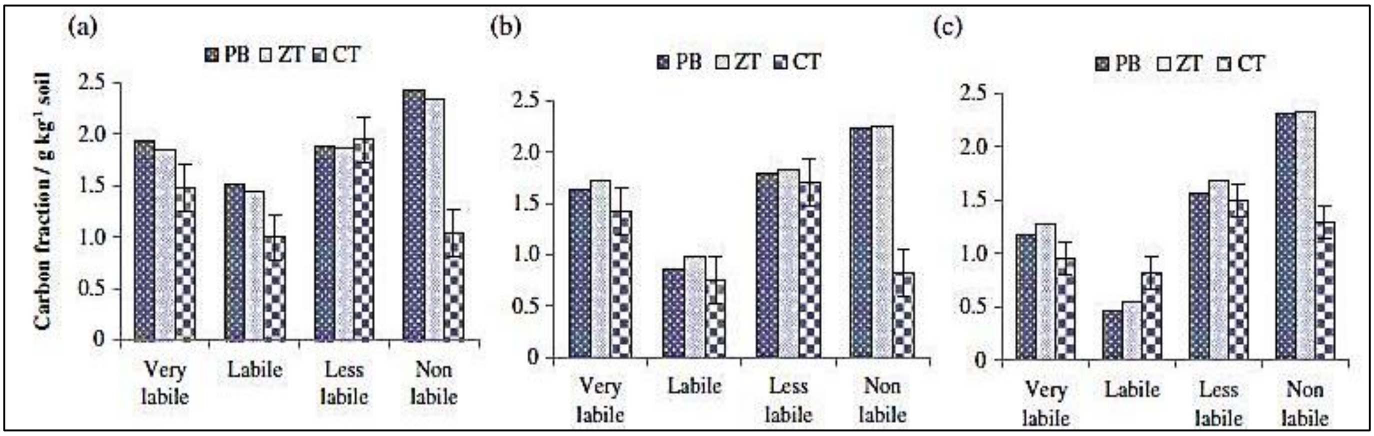
Role of soil microbes in maintaining the Soil Health

1. Nutrient Cycling:
2. Improves the Fertility Status of the soil
3. Decomposition
4. Soil structure development :

Research findings

Changes in carbon pools and biological activities of a sandy loam soil under medium-term conservation agriculture and diversified cropping systems.

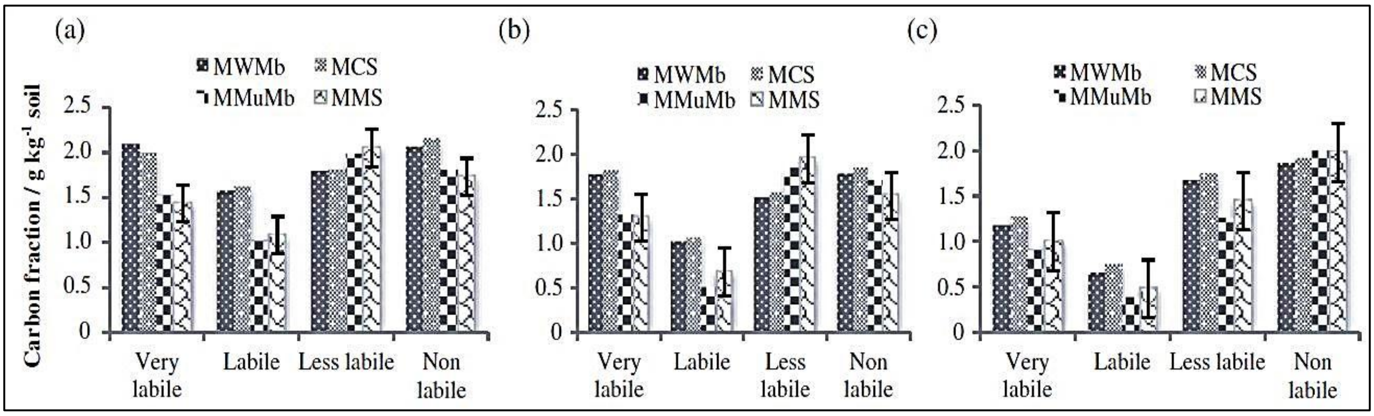
Parihar *et al.* in the year 2018 [13] conducted one experiment to study the effect of conservation agriculture on soil carbon pool and microbial activity. They took 3 tillage treatments i.e. permanent bed (PB), minimum tillage (MT) and conventional tillage (CT) and four cropping system i.e. Maize– Wheat– Mungbean (MWMb), Maize– Cowpea– *Sesbania*(MCS), Maize– Mustard– Mungbean (MMuMb), Maize– Maize– *Sesbania* (MMS).



Source: Parihar *et al*., 2018 [13]

Fig 2: Depth-wise distribution of different SOC fractions across medium-term tillage practices

In their study they found that the very labile and labile carbon is high in case of permanent bed and zero tillage and lowest was found under conventional tillage and this might be due to minimum disturbance of the soil in case of permanent bed (PB) and zero tillage (ZT) which favours the microbial proliferation, store moisture for longer period of time which accelerates the decomposition and there is less evolution of CO_2 as compared to conventional tillage (CT). In case of less and non-labile carbon highest was observed under the PB and ZT across all the depths and this might be due the residual carbon build up in soil after the decomposition of the organic matter as the decomposition process will be more in PB and ZT system as compared to CT.As the depth is increasing the amount of less and non-labile carbon is increasing and this might be due to less microbial activity at the lower depth.



Source: Parihar *et al*., 2018 [13]

Fig 3: Distribution of various SOC fractions across intensified cropping systems

In the figure 3, we can see that the very labile and labile carbon was found highest under Maize-Wheat-Mung bean (MWMb) and Maize-Cowpea-Sesbania (MCS) cropping system as compared to other two system. The reason behind this may be the presence off two legume crops in the cropping system which produces large biomass and are very succulent in nature which decomposes very easily. Again legume crop fixes nitrogen in soil which increase the nitrogen availability in soil which favours the microbial growth and development as microbes also requires nitrogen for their growth and development.

Table 1: Effect of medium-term tillage practices on soil Microbial Biomass Carbon (µg C/g soil)

Treatments	Winter season		Summer season		Wet season	
	Soil Depth(cm)					
	0-5	**5-15**	**0-5**	**5-15**	**0-5**	**5-15**
PB	439.7	423.1	421.3	408.3	**485.3**	435.6
ZT	448.2	426.4	414.6	426.6	454.0	460.7
CT	339.0	272.6	**258.6**	286.7	331.0	306.2
SE	11.4	16.6	28.5	18.3	8.8	7.4
LSD (<0.05)	44.8	65.2	111.8	72.0	34.4	28.7

Source: Parihar *et al*., 2018 [13]

PB, permanent bed; ZT, zero tillage; CT, conventional tillage; LSD, least significant difference; SE, standard error of mean

Microbial biomass carbon is one of the major pool of soil organic carbon which comes from the soil microorganism like fungi, bacteria, actinomycetes, protozoa, algae etc. After their death the cell disintegrates and becomes the labile source of carbon for the other soil microbes. They found highest amount of soil MBC in the PB in wet season. The reason behind this may be the more microbial population and activity in the PB soil as these soils are less disturbed which encourages the growth of the microorganism and more microbial population is directly correlated with the oil MBC. It was found highest in wet season because of the better availability of the soil moisture and lowest was found under CT in summer season due to more disturbance of the soil as shown in the Table 1.

Table 2: Effect of medium-term tillage practices on Soil Dehydrogenase Activity (µg TPF/g soil/day)

Treatments	Winter season		Summer season		Wet season	
	Soil Depth(cm)					
	0-5	**5-15**	**0-5**	**5-15**	**0-5**	**5-15**
PB	50.6	36.2	55.8	40.7	**57.1**	39.6
ZT	46.1	37.9	50.9	42.7	52.5	41.6
CT	32.7	24.2	35.7	27.1	36.3	25.4
SE	1.6	1.1	1.6	1.1	2.1	1.4

Source: Parihar *et al*., 2018 [13]

PB, permanent bed; ZT, zero tillage; CT, conventional tillage; LSD, least significant difference; SE, standard error of mean

Soil dehydrogenase one of the most important soil enzyme and commonly used to indicate the soil microbial activity. The enzyme has a key place in determining the health of the soil as it is the integral part of the intact cell and does not accumulate extracellularly. From the table2. They found highest DHA activity in PB in wet season and this might due to more microbial population and activity in the PB soil as these soils are less disturbed which encourages the growth of the microorganism and more microbial cell is directly correlated with the soil DHA as it is the integral part of the cell. The lowest was found under CT in summer season due less microbial population and less soil moisture availability during summer season.

Table 3: Effect of Intensified cropping systems on soil Microbial Biomass Carbon (MBC µg/g soil)

Treatments	Winter season		Summer season		Wet season	
	SoilDepth(cm)					
	0-5	**5-15**	**0-5**	**5-15**	**0-5**	**5-15**
MWMb	448.4	417.8	401.5	409.7	449.0	443.0
MCS	470.0	463.3	412.1	419.3	511.5	453.5
MMuMb	344.4	304.9	299.9	325.8	352.1	324.9
MMS	373.2	337.2	345.8	340.6	381.2	381.9
SE	12.0	11.5	18.2	16.8	14.9	9.8
LSD (P<0.05)	35.4	34.1	54.2	50.0	44.3	28.9

Source: Parihar *et al*., 2018 [13]

MWMb: Maize–Wheat–Mungbean; MCS: Maize–Cowpea–*Sesbania*; MMuMb: Maize–Mustard–Mungbean; MMS: Maize–Maize–*Sesbania*.

Table 4: Effect of Intensified cropping systems on soil Dehydrogenase Activity (DHA) (µg/TPFg/day)

Treatments	Winter season		Summer season		Wet season	
	Soil Depth(cm)					
	0-5	**5-15**	**0-5**	**5-15**	**0-5**	**5-15**
MWMb	43.4	32.5	47.8	39.3	49.0	35.1
MCS	50.8	36.7	57.0	41.1	59.1	41.1
MMuMb	37.5	30.4	40.5	32.6	40.8	32.0
MMS	40.8	31.4	44.6	34.2	45.7	34.0
SE	2.0	1.1	2.0	1.1	2.2	1.8

Source: Parihar *et al*., 2018 [13]

MWMb, Maize–Wheat–Mungbean; MCS, Maize–Cowpea–*Sesbania*; MMuMb, Maize–Mustard–Mungbean; MMS, Maize–Maize–*Sesbania*.

Regarding cropping system, the found highest soil MBC and DHA in Maize–Cowpea–*Sesbania* (MCS) system and lowest was found under Maize–Mustard–Mungbean (MMuMb). This may be due to high biomass production in MCS cropping system which increases the source of food for the microbes which favours the better proliferation of microbes. Again these legume crops are very succulent in nature which causes the rapid decomposition of the biomass increasing microbial biomass and DHA.

Impact of No-Tillage and Conventional Tillage Systems on Soil Microbial Communities in maize based cropping system

Mathew *et al.* in theyear 2012 [11] conducted an experiment to study the effect of no tillage and conventional tillage on soil microbial community.In this study, the effects of long-term conventional and no-tillage practices on microbial community structure, enzyme activities, and selected physicochemical properties were determined in a continuous corn system on a Decatur silt loam soil. The long-term no-tillage treatment resulted in higher soil carbon and nitrogen contents, viable microbial biomass, and phosphatase activities at the 0–5 cm depth than the conventional tillage treatment. Soil microbial community structure assessed using phospholipid fatty acid (PLFA) analysis. The abundance of PLFAs indicative of fungi, bacteria, arbuscularmycorrhizal fungi and actinobacteria was consistently higher in the no-till surface soil.

Table 5: Total PLFAs, Phosphatase and PDE aseactivities in no-till (NT) and conventional-till (CT) soils

Treatment	Total PLFA (nmol/g soil)		Acid P (µg p-nitrophenol/g/hr)		Alkaline P (µg p-nitrophenol/g/hr)		PDE (µg p-nitrophenol/g/hr)	
	Depth							
	0-5	5-15	0-5	5-15	0-5	5-15	0-5	5-15
NT	104a	38b	367a	307ab	321a	87b	132a	36b
CT	39b	30c	200b	202b	44c	89b	32b	34b

Source: Mathew *et al.*, 2012 [11]

NT, No-tillage; CT- Conventional tillage; PLFA, phospholipid fatty acid; Acid P, acid phosphatase; Alkaine P, alkaline phosphatase; PDE, phosphodiesterase

Phospholipid fatty acid is one of the major component of the cell membrane and it is found in all the living cell and in soil it is associated with the soil microorganism so it can be used as an indicator of soil health. Its amount in soil is directly related to the microbial activity of the soil. In their study as shown in the table 5, they found that total PLFA was highest in NT and lowest was under CT. The most probable reason behind this may be more abundance of the microorganism in the NT soil as these soils were least disturbed which favours the better proliferation of the microbes. Regarding acid and alkaline phosphatase activity, and PDEase these were found highest in the NT and the probable reason might be the more microbial population.

Table 6: PLFA biomarkers and ratiosin no-till (NT) and conventional-till (CT) soils

Treatment	Depth	PLFA Fungi/bacteria (nmol/g)	G+/G- bacteria	Fungi		Bacteria	
				Abundance (mol%)	PLFA (nmol/g)	Abundance (mol%)	PLFA (nmol/g)
NT	0-5	0.08a	1.48a	3.97a	4.47a	53.1a	20.9b
	5-15	0.04b	1.76a	2.2b	0.76b	53.00a	16.9c
CT	0-5	0.07a	1.54a	3.87a	1.41b	57.00b	50.9a
	5-15	0.03b	1.84a	2.00b	0.68b	54.2a	21.3b

Source: Mathew *et al.*, 2012 [11]

NT, No-tillage; CT- Conventional tillage; PLFA, phospholipid fatty acid; G+, Gram positive; G-, Gram Negative

In table 6, they estimated the PLFA ratio of fungi and bacteria, ratio of G+ and G- bacteria abundance of fungi and bacteria. The PLFA ratio will indicate the relative abundance of fungi to bacteria and it was found highest under NT system. This might be due to more population of fungi in NT system as compared to CT system. The ration of G+ and G- was found more in CT because most of the G+ bacteria are aerobic in nature and in CT system aeration is very good as the soils are disturbed at the time of tillage. Abundance of fungi was found more in case of NT system because of least disturbance of soil which encourages the better growth of the fungal hyphae but the abundance of bacteria was found more in CT system because of good aeration.

Soil Organic Carbon, Carbon Sequestration, Soil Microbial Biomass Carbon and Nitrogen and Soil Enzymatic Activity as Influenced by Conservation Agriculture in Pigeonpea and Soybean Intercropping System

Naveen *et al.* in the year 2018 conducted one field experiment to study the influence of conservation tillage, land configuration and residue management practices on soil health in a pigeonpea+ soybean intercropping systemat Conservation Agriculture Project plot, MARS, Dharwad, Karnataka. The experiment consisted of 6 tillage systems [CT1: Conservation tillage with BBF and crop residue retained on the surface, CT2: Conservation tillage with BBF and incorporation of crop residue, CT3: Conservation tillage with flatbed with crop residue retained on the surface, CT4: Conservation tillage with flatbed with incorporation of crop residue, CT5: Conventional tillage with incorporation of crop residue and CT6: Conventional tillage without crop residue. The conservation treatments were found to significantly improve soil health. The pooled data revealed that, all the conservation tillage systems i.e. CT1, CT2, CT3 and CT4 recorded significantly higher soil organic carbon at 0-15 cm depth (0.62, 0.64,060 ad 0.62 %, respectively) and 15-30 cm depth (0.56, 0.56, 0.54 and 0.55 %, respectively), higher soil carbon sequestration (15.07, 15.39, 14.58 and 14.72 t ha-1, respectively) over conventional systems.

Table 7: Soil organic carbon as influenced by different conservation agricultural practices

Treatments	Soil organic carbon (%)	
	0-15cm	15-30 cm
CT1	0.60a	0.53a
CT2	0.63a	0.53a
CT3	0.57ab	0.51a
CT4	0.59ab	0.51a
CT5	0.53bc	0.43b
CT6	0.50c	0.38b

Source: Naveen *et al.*, 2018 [12]

CT1: Conservation tillage with BBF and crop residue retained on the surface
CT2: Conservation tillage with BBF and incorporation of crop residue
CT3: Conservation tillage with flatbed with crop residue retained on the surface
CT4: Conservation tillage with flatbed with incorporation of crop residue
CT5: Conventional tillage with incorporation of crop residue
CT6: Conventional tillage without crop residue

In the experiment they estimated soil organic carbon and found highest soil organic carbon in the treatment T2 (i.e. Conservation tillage with BBF and incorporation of crop residue) in 0-15cm depth as shown in the table 7. The more amount of SOC was found under treatment T2 might be due to conservation tillage and incorporation of the residue while lowest was found under CT6 treatment because of conventional tillage and removal of the crop residue.

Table 8: Soil microbial biomass carbon as influenced by different conservation agricultural practices

Treatments	Soil microbial biomass carbon (mg/kg soil)		
	2014	2015	Pooled
CT1	372.00a	356.00a	364.10a
CT2	375.20a	335.20a	355.20a
CT3	342.40a	312.00a	327.20a
CT4	383.20a	340.80a	362.00a
CT5	342.13a	308.80a	325.47a
CT6	312.80b	275.20b	294.00b

Source: Naveen *et al.*, 2018 [12]

CT1: Conservation tillage with BBF and crop residue retained on the surface
CT2: Conservation tillage with BBF and incorporation of crop residue
CT3: Conservation tillage with flatbed with crop residue retained on the surface
CT4: Conservation tillage with flatbed with incorporation of crop residue
CT5: Conventional tillage with incorporation of crop residue
CT6: Conventional tillage without crop residue

Table 9: Soil dehydrogenase activity at 75 DAS as influenced by different conservation tillage practices and intercropping systems

Treatments	Soil dehydrogenase activity (µg /TPF g/ day)		
	2014	2015	Pooled
CT1	34.27a	30.31ab	32.39a
CT2	33.88a	30.71a	32.29a
CT3	33.49a	28.79cd	31.14b
CT4	33.62a	29.48bc	31.55ab
CT5	31.31b	28.09d	29.70c
CT6	29.04c	25.82e	27.43d

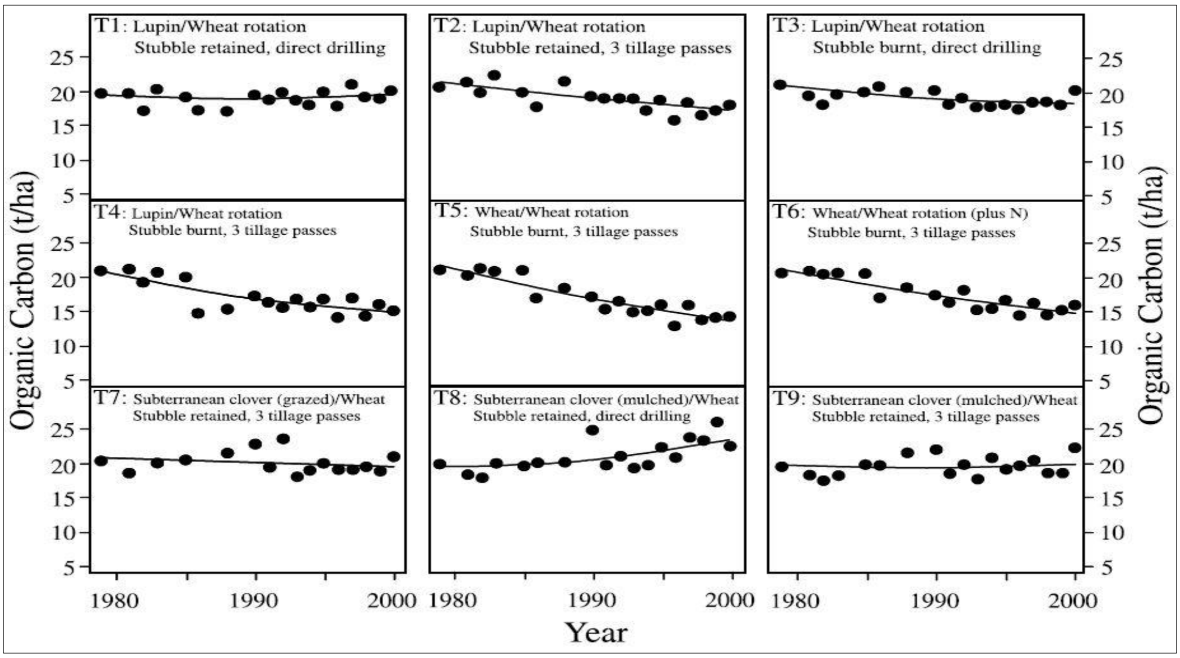
Source: Naveen *et al.*, 2018 [12]

CT1: Conservation tillage with BBF and crop residue retained on the surface
CT2: Conservation tillage with BBF and incorporation of crop residue
CT3: Conservation tillage with flatbed with crop residue retained on the surface
CT4: Conservation tillage with flatbed with incorporation of crop residue
CT5: Conventional tillage with incorporation of crop residue
CT6: Conventional tillage without crop residue

From the table 8, they concluded that highest amount of soil MBC was in treatment T1 and lowest was in treatment T6. The probable reason behind this may be the conservation tillage and crop residue retention in treatment T1 while conventional tillage and removal of crop residue from treatment T6. As the crop residue are retained on surface in T1, there will be abundant source of food for microorganism and thus their population will increase producing more soil microbial biomass. In the table 9, Soil DHA was found highest and the reason is same i.e. retention of crop residue on surface in treatment T1 while removing of residue in treatment T6.

The Role of Crop Residues in Improving Soil Fertility

Singh *et al*. conducted a long term (from 1980-2000) experiment to study the role of organic residue in improving the fertility of the soil. They took 9 various treatments i.e. T1: Lupin/Wheat rotation, stubble retained, direct drilling, T2: Lupin/Wheat rotation, stubble retained, 3 tillage passes, T3: Lupin/Wheat rotation, stubble burnt, direct drilling, T4: Lupin/Wheat rotation, stubble burnt, 3 tillage passes, T5: Wheat/Wheat rotation, stubble burnt, 3 tillage passes, T6: Wheat/Wheat rotation(plus N), stubble burnt, 3 tillage passes, T7: Subterranean clover(grazed)/Wheat, Stubble retained and 3 tillage passes, T8: Subterranean clover(muched)/Wheat, Stubble retained and direct drilling, T9: Subterranean clover(mulched)/Wheat, Stubble retained and 3 tillage passes. After the experiment they concluded that crop residue has a potential to improve the physico-chemical and biological activity of the soil and can increase the soil organic matter content if the soil is less disturbed.



Source: Singh *et al.*, 2007

Fig 4: Changes in soil organic C for different rotation, tillage and stubble management treatments (*T1–T9*) over 21 years

They explained that in the treatment T1, at the starting of the study i.e. during 1980 they estimated about 20t/ha of SOC and at the end i.e. during 2000 there was a slight increase in the OC and this may be due to stubble retention, direct drillig. In treatment T2, there is slight decrease in the SOC content as compared to initial state. This may be due to the tillage practices was being used which causes exposure of the soil resulting in more evlution of CO_2. Again in T3 as the residue were burnt i.e. the field was exempted from the stubble so definitely there will be a decrease in the total SOC content. For this at the end of the research there was a decrease in SOC. In the T4 they were burnt the stubble and used3 tillage and so there was a sharp decrease in the SOC content from 22 t/ha to 15 t/ha. In T5 treatment there was two cereal crops in the sequence. So there will be no BNF and as there is no BNF so the soil microbial growth will be somewhat lesser as microbes also requires N for their metabolism and growth. As a large proportion of soil OC comes from SMBC as a result there is harp decrease in SOC. In T6 treatment all the factors are same as T5 but they are providing additional source of N so here u can see a little increase in the OC content as compared to T5 treatment. Again in T7, here we can that there is no significant difference in SOC over the study period. In this T8 treatment they used clover and wheat rotation and clover as mulch retaining the residue and direct drilling of seeds. And the result u can see that there is a sharp increase in the SOC content from 20 t/ha to 25 t/ha. The reason behind this may be conservation tillage which favours the better microbial growth and this increase in microbial population will boost up decomposition process. Again mulching will increase residual moist content and residue incorporation will increase the SOC content. Lastly in the T9 treatment we can see that the all factors are same as T8 except they are using 3 tillage instead of direct drilling, so the SOC content is almost same during the whole study period.

Effect of *in-situ* recycling of sugarcane crop residues and its industrial wastes on different soil carbon pools under soybean (*Glycine max*) - maize (*Zea mays*) system

Phalke *et al*. conducted a field experiment was conducted during summer 2011-12 at MPKV Farm, Rahuri to evaluate the effect of *in-situ* recycling of sugarcane crop residues and its industrial wastes on soil organic C fractions like labile carbon, microbial biomass C, particulate organic C, KMnO4 extractable C, physically protected particulate organic matter carbon (POMC) and significantly improved water stable aggregates in the cultivated soil under maize- soybean cropping system. They conducted the study with 7 various treatments namely T1 : Burning of sugarcane trash and removal of stubbles, T2 : Removal of sugarcane trash, T3 : *In-situ* decomposition of sugarcane crop residues + cellulose decomposers + 8 kg urea + 10kg SSP, T4 : T3 + Press-mud Cake, T5 : T3 + bio-methenated spent wash, T6 : T3 + Press-mud compost, T7 : T3 + 50% Press-mud cake + 50% bio-methenated spent wash. Application of *in-situ* sugarcane residues with pressmud incorporation retainedabout19.6%, 38.8% and 33% more amount of total organic carbon (TOC), SMBC, AHC respectively, over burning of sugarcane crop residues and removal of stubbles after harvest of maize. The mean values of WSC (43 mg/kg) and the physically protected carbon, i.e. POMC (2014 mg/kg) were greater by 47% and 6.6% respectively, in the treatment (T7) receiving *in-situ* residue decomposition of sugarcane crop residues in combination with equal proportion (50%) of press mud cake and biomethanated spent wash over the burning of sugarcane crop residues and removal of stubbles after harvest of maize. After harvest of maize the maximum recalcitrant fraction (humic acid) of carbon was observed in the treatment T7 (*in-situ* decomposition of sugarcane crop residues + 50% press-mud cake + 50% biomethenated spent wash). This study clearly indicated that resistant fraction of carbon might be accumulated more where decomposed organic matter was applied regularly. It clearly indicated that application of *in-situ* decomposed residues and by-products of industrial waste in combination with NPK enhanced the below and above ground biomass production, SOC stock and carbon pools.

Table 10: Effect of in-situ recycling of sugarcane crop residue on active pools of carbon across the various depth (0-30cm)

Treatments	Labile C (mg/kg)				AHC (mg/kg)			
	F0	F1	F2	Mean	F0	F1	F2	Mean
T 1	546	585	794	642	1990	2102	3078	2390
T 2	348	438	468	418	1864	1874	1982	1906
T 3	427	490	496	471	1826	2021	2233	2024
T 4	596	686	742	675	1719	2471	2970	2387
T 5	670	780	801	750	1849	2772	2899	2507
T 6	685	735	799	740	2082	2864	4592	3180
T 7	630	725	783	713	2498	2632	2984	2705

Source: Phalke *et al.*, 2016
F0: No fertilizer was applied
F1: 50% of the recommended dose was applied
F2: 100% of the recommended fertilizer was applied
T1: Burning of sugarcane trash and removal of stubbles,
T2: Removal of sugarcane trash,
T3: In-situdecomposition of sugarcane crop residues + cellulose decomposers + 8 kg urea + 10kg SSP,
T4: T3 + Press-mud Cake,
T5: T3 + bio-methenated spent wash,
T6: T3 + Press-mud compost,
T7: T3 + 50% Press-mud cake + 50% bio-methenated spent wash

From the table 10 it is very clear that the labile carbon was highest in the treatment T5 (i.e. T3 + bio-methenated spent wash) and this might be due to in-situdecomposition of sugarcane crop residues + cellulose decomposers + 8 kg urea + 10kg SSP+bio-methenated spent wash. This incorporation increases the carbon content in soil and cellulose decomposer will boost up the decomposition. Again additional supply of Nitrogen and Phosphorus will helps the microbes in their growth and development which will increase their population. But in case of T2 treatment (i.e.Removal of sugarcane trash), since we are removing the sugarcane residue so they got lowest. Again in case of Acid Hydrolysable Carbon (AHC) the highest was found under the treatment T6 (i.e. T3 + Press-mud compost) and this might be due to in-situdecomposition of sugarcane crop residues + cellulose decomposers + 8 kg urea + 10kg SSP++ Press-mud compost. This incorporation increases the carbon content in soil and cellulose decomposer will boost up the decomposition. Again additional supply of Nitrogen and Phosphorus will helps the microbes in their growth and development which will increase their population. But in case of T2 treatment (i.e.Removal of sugarcane trash), since we are removing the sugarcane residue so they got lowest.

Table 11: Effect of *in-situ* recycling of sugarcane crop residues and its industrial wastes on POMC (passive pool of C) after harvest of maize (0 to 30 cm soil depth)

Treatments	POMC (mg/kg)			
	F0	F1	F2	Mean
T 1	946	1332	1350	1209
T 2	923	1080	1190	1064
T 3	1320	1499	1615	1478
T 4	1184	1705	2036	1642
T 5	1092	1631	1902	1542
T 6	1175	1590	1879	1548
T 7	1891	1962	2188	2014

Source: Phalke *et al.*, 2016
F0: No fertilizer was applied
F1: 50% of the recommended dose was applied
F2: 100% of the recommended fertilizer was applied
T1: Burning of sugarcane trash and removal of stubbles,
T2: Removal of sugarcane trash,
T3: In-situdecomposition of sugarcane crop residues + cellulose decomposers + 8 kg urea + 10kg SSP,
T4: T3 + Press-mud Cake,
T5: T3 + bio-methenated spent wash,
T6: T3 + Press-mud compost,
T7: T3 + 50% Press-mud cake + 50% bio-methenated spent wash

Table 12: Effect of *in-situ* recycling of sugarcane crop residues on humic acid and fulvic acid (0 to 30 cm soil depth)

Treatments	Humic acid (%)				Fulvic acid (%)			
	F0	F1	F2	Mean	F0	F1	F2	Mean
T 1	44.42	45.69	47.10	45.74	34.13	35.03	35.2	41.30
T 2	44.27	45.36	45.90	41.72	39.00	42.05	42.84	33.97
T 3	43.07	43.72	43.89	43.56	33.37	33.94	34.59	34.79
T 4	40.16	42.37	42.63	45.18	33.16	35.99	36.16	35.10
T 5	45.20	45.68	45.8	45.59	48.33	48.78	49.00	48.50
T 6	43.38	45.21	46.29	44.96	41.10	41.97	42.32	41.80
T 7	59.30	60.53	60.67	60.17	48.06	48.68	48.77	48.70

Source: Phalke *et al.*, 2016
F0: No fertilizer was applied
F1: 50% of the recommended dose was applied
F2: 100% of the recommended fertilizer was applied
T1: Burning of sugarcane trash and removal of stubbles,
T2: Removal of sugarcane trash,
T3: In-situdecomposition of sugarcane crop residues + cellulose decomposers + 8 kg urea + 10kg SSP,
T4: T3 + Press-mud Cake,
T5: T3 + bio-methenated spent wash,
T6: T3 + Press-mud compost,
T7: T3 + 50% Press-mud cake + 50% bio-methenated spent wash

They also estimated Particulate Organic Matter Carbon (POMC), humic acid and fulvic acid content in soil as shown in table 11 and 12 respectively. They found more amount of POMC in T7 treatment i.e. (T3 + 50% Press-mud cake + 50% bio-methanated spent wash). This may be due to incorporation of sugarcane residue which increases the organic matter content in soil. Again press mud and bio-methanated spent wash also increases the POMC. Again Cellulose decomposer will helps in breaking the large organic matter into particulate organic matter (0.053-2 mm). Lowest POMC was found in T2 treatment due to the removal of sugarcane trash. In case of humic and fulvic acid, highest was found under T7 treatment and lowest under T2. Due to rapid decomposition of organic matter in T7 the amount of humic and fulvic acid increases and due to removal of organic matter in T2 the amount of humic and fulvic acid decrease.

Conservation tillage and weed management effect on soil micro-flora of soybean–wheat cropping system

Priya *et al.* conducted a field experiment during 2013-14 and 2014-15 at Jabalpur to assess the effect of conservation tillage and weed management practices on the total bacteria, fungi, actinomycetes and dehydrogenase activity under soybean - wheat cropping system in vertisols. The results of the investigation revealed that tillage systems to influence significantly the microbial population. Among the tillage treatments, zero tillage + crop residue (soybean) *fb*zero tillage + crop residue (wheat) had higher bacterial, fungal population and dehydrogenase activity during both the seasons. Butactinomycetes population was higher in zero tillage + crop residue (soybean) *fb* zero tillage (wheat)during both seasons. However, there was no adverse effects of herbicides use in soybean-wheat cropping system on microbial population during both crop seasons except *Rabi* season 2014 -15 in which bacterial population was reduced by 27.3% when mesosulfuron (12 g/ha) + iodosulfuron (2.4 g/ha) mixture was applied in wheat following application of pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha)in preceding soybean crop.

Table 15: Effect of conservation tillage and residue management practices on bacterial population

Treatments	Bacteria (10^6cfu/d dry weight of soil)		Fungal (10^4cfu/d dry weight of soil)	
	2013-14	2014-15	2013-14	2014-15
CT	6.7	8.6	4.0	8.9
CT	6.9	33.6	4.3	9.1
ZT+R	7.4	35.8	4.3	11.00
ZT	6.9	41.6	4.4	15.10
ZT+R	7.5	50.0	4.7	15.90
LSD(P=0.05)	NS	13.3	0.2	1.7

Source: Priya *et al.*, 2015
CT: Conventional tillage in soybean / conventional tillage in wheat
ZT+R: Zero tillage + crop residue in soybean/ wheat,
ZT: Zero tillage in wheat/ soybean

They estimated the fungal and bacterial population under various treatments as shown in the table 15. The bacterial and fungal population was found more in treatment ZT+R in both the year. This might be due to less disturbance of soil and residue incorporation. Less disturbance of soil helps in better proliferation of soil microorganism, conserves soil moisture and residue incorporation serves as the source of food for the soil microflora. Lowest bacterial and fungal population was observed under CT treatment. In conventional tillage the soil is disturbed which interferes with the population build-up of microbes. Further residue is not incorporated which reduces the source of food for microbes.

Table 16: Effect of conservation tillage and residue management practices on dehydrogenase activity

Treatments		Dehydrogenase activity (µg TPF/g soil/24 hr)
	2013-14	2014-15
CT	22.5	31.1
CT	26.6	31.4
ZT+R	31.2	35.5
ZT	34.5	34.2
ZT+R	35.3	36.7
LSD(P=0.05)	4.04	5.2

Source: Priya *et al.*, 2015
CT: Conventional tillage in soybean / conventional tillage in wheat
ZT+R: Zero tillage + crop residue in soybean/ wheat
ZT: Zero tillage in wheat/ soybean

They also observed change in dehydrogenase activity of soil which is shown in the table 16. They observed maximum DHA activity in ZT+R for both the year. As the DHA activityis direct related with the microbes so microbial population will govern this activity. More the microbial population more will be the DHA activity. As Population of microbes was more in ZT+R treatment so the DHA activity was found more in this treatment. Again lowest was observed under CT and this might be due to less microbial population.

Summary and Conclusion

- The practice of conservation agriculture with different tillage practices, crop rotation and residue management has the potential to improve the soil physico-chemical properties, to sequester more carbon and to improve the microbial process in the soil than traditional agriculture.
- We can say that there is positive change in Carbon pool under conservation tillage with crop residue incorporation and various cropping system having atleast one legume crop or green manuring crop
- Microbial activity was also found improved in conservation agriculture than traditional agriculture in all the experiments.
- To feed the increasing population of the world we are blindly using synthetic inorganic fertilizer which is ultimately harming the soil and its health. As a result the soil is loosing its fertility. So in this regard conservation agriculture practices is a better option to increase our production while maintaining the soil health.

Future prospects

- To evaluate the C sequestration capacity of farming practices, their influence on emissions from farming activities should be considered together with their influence on soil C stocks.
- The mechanisms that govern the balance between increased or no sequestration after conversion to zero tillage are not clear.
- Altering crop rotation can influence soil C stocks by changing quantity and quality of organic matter input.

References

1. Azooz RH, Arshad MA, Franzluebbers AJ. Pore size distribution and hydraulic conductivity affected by tillage in Northwestern Canada. Soil Science Society of America Journal. 1996; 60(4):1197-1201.
2. Balota EL, Colozzi-Filho A, Andrade DS, Dick RP. Microbial biomass in soils under different tillage and crop rotation systems. Biology and Fertility of Soils. 2003; 38:15-20.
3. Bidart MG, Aref S. Tillage impacts on depth distribution of total and particulate organic matter in three Illinois soils. Soil Science Society of America Journal. 1998; 62(6):1704-1711.
4. Chan KY, Mead JA. Surface physical properties of a sandy loam soil under different tillage practices. Australian Journal of Soil Research. 1988; 26(3):549-559.
5. Chivenge PP, Murwira HK, Giller KE, Mapfumod P, Six J. Long term impact of reduced tillage and residue management on soil carbon stabilization: implications for conservation agriculture on contrasting soils. Soil & Tillage Research. 2007; 94:328-337.
6. Choudhary M, Datta A, Jat HS, Yadav AK, Gathala MK, Sapkota TB *et al.* Changes in soil biology under conservation agriculture based sustainable intensification of cereal systems in Indo-Gangetic Plains. Geoderma. 2018; 313:193-204.
7. Halvorson AD, Wienhold BJ, Black AL. Tillage,

nitrogen, and cropping system effects on soil carbon sequestration. Soil Science Society of America Journal, 2002; 66:906-912.
8. Karlen DL, Cambardella CA, Kovar JL, Colvin TS. Soil quality response to long-term tillage and crop rotation practices. Soil & Tillage Research. 2013; 133:54-64.
9. Lal R. Soil carbon sequestration to mitigate climate change. Geoderma. 2004; 123:1-22.
10. Lal R, Smith P, Jungkunst HF, Mitsch W, Lehmann J, Nair PK *et al*. The carbon sequestration potential of terrestrial ecosystems. Journal of Soil and Water Conservation. 2018; 73(6):145-152.
11. Mathew RP, Feng Y, Githinji L, Ankumah R, Balkcom KS. Impact of No-Tillage and Conventional Tillage Systems on Soil Microbial Communities. Applied and Environmental Soil Science, 2012, 10. Article ID 548620
12. Naveen BT, Babalad HB. Soil Organic Carbon, Carbon Sequestration, Soil Microbial Biomass Carbon and Nitrogen and Soil Enzymatic Activity as Influenced by Conservation Agriculture in Pigeonpea and Soybean Intercropping System. International Journal of Current Microbiology and Applied Sciences. 2018; 7:323-333.
13. Parihar CM, Jata SL, Singh AK, Datta A, Parihar MD, Vargesh E *et al*. Changes in carbon pools and biological activities of a sandy loam soil under medium-term conservation agriculture and diversified cropping systems. European Journal of Soil Science. 2018; 69:902-912.
14. Phalke DH, Patil SR, Manna MC, Mandal A, Pharande AL. Effect of in-situ recycling of sugarcane crop residues and its industrial wastes on different soil carbon pools under soybean (*Glycine max*) - maize (*Zea mays*) system. Indian Journal of Agricultural Sciences. 2017; 87(4):444-54.
15. Priya S, Sarathambal C, Kewat ML, Singh VP. Conservation tillage and weed management effect on soil microflora of soybean–wheat cropping system. Indian Journal of Weed Science. 2015; 47(4):366-370.
16. Srinivasarao C, Venkateswarlu B, Lal R, Singh AK, Kundu S. Sustainable management of soils of dryland ecosystems of India for enhancing agronomic productivity and sequestering carbon. Advances in Agronomy. 2013; 121:253-325.
17. Staley TE. Soil microbial biomass alterations during the maize silage growing season relative to tillage method. Soil Science Society of America Journal. 1999; 63(6):1845-1847.
18. Trojan MD, Linden DR. Macroporosity and hydraulic properties of earthworm-affected soils as influenced by tillage and residue management. Soil Science Society of America Journal. 1998; 62(6):1687-1692.
19. Verma S, Sharma PK. Effect of long-term manuring and fertilizers on carbon pools, soil structure, and sustainability under different cropping systems in wet-temperate zone of north-west Himalayas. Biology and Fertility of Soils. 2007; 44:235-40.
20. Xu M, Lou Y, Sun X, Wang W, Baniyamuddin M, Zhao K. Soil organic carbon active fractions as early indicators for total carbon change under straw incorporation. Biology and Fertility of Soils. 2011; 47:745-52.