International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(4): 2173-2178

Received: 13-05-2020
Accepted: 15-06-2020

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

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DOI: https://doi.org/10.22271/chemi.2020.v8.i4x.9951

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

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

Introduction

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

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

SOC plays a key role in improving the soil aggregate stability and in turn prevents soil degradation and enhances physical, chemical and biological properties of soil (Liu *et al*., 2019) [8]. SOC is a common constituent of SOM which is considered as a reservoir of nutrients to crops, improves nutrient availability, retains moisture, reduces soil crusting, thus ultimately influencing the productive capacity of soil (Canqui and Lal, 2009) [9].There are several fractions with varying degree of decomposition and stability which are very essential to understand the influence of management practices on SOC dynamics (Yadav and George, 2007) [10]. These fractions are gaining importance because the total organic carbon in soil is composed of labile and non-labile forms and wherein labile forms reported to have comparatively more oxidizable nature (Juan, *et al*., 2018) [11]. Further, labile fractions are also sensitive to different agronomic interventions (Yang, *et al*., 2003) [12].

The soil organic carbon stored in the soil is controlled by several other factors like climate, physical properties of soil, Soil depth, Soil microorganisms and Topography/relief (Oliveira, *et al*., 2018) [13] and (Esmaeilzadeh and Ahangar, 2014) [14]. Several studies reported that the modification of these factors through agronomic interventions have marked influence on carbon dynamics.

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

Soil Organic Carbon Fractions

Total organic carbon

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

Particulate organic carbon

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

Dissolved organic carbon

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

Microbial biomass carbon

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

Agronomic Interventions on Carbon Dynamics

Effect of soil tillage and residue management on SOC

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

Effect of intercropping and crop rotation on SOC

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

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

Effect of mulching on SOC

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

Effect of nutrient management on SOC

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

Effect of water management on SOC

Water management plays a major role for assured crop production and even a short term deficit in water during the crop growing season results in substantial decline in biomass (Morison *et al*., 2008) [81]. An efficient management of water indirectly affects the total biomass production which in turn influences the carbon sink capacity (Adugna, 2016) [82]. Subsequently, efficient water management also influences the total microbial activity in the soil in turn increasing the rate of decomposition of soil accumulated biomass (Prommer *et al*., 2008) [83]. This is ultimately influencing the SOC content in the soil. In a long term investigation when a desert is being converted into an irrigated arable land rapid increase in soil organic carbon was observed under irrigated ecosystems over a desert, comparatively (Li *et al*., 2017) [32]. Further, irrigation water management role in regulating the soil thermal regime directly influences soil microbial activity and with the increased soil moisture, the microbial activity increases and vice-versa.

Effect of soil amendments on SOC

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

Conclusion

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

References

1. Ahmed N, Khan IT, Augustine A. Climate change and environmental degradation, a serious threat to global security. European Journal of Social Sciences Studies. 2018; 1(3):2501-8590.
2. Kumar K, Pandey A, Rana R, Yadav A. Climate Change and Mitigation through Agroforestry. International Journal of Current Microbiology and Applied Sciences. 2019; 8(6):1662-1667.
3. Gross DC, Harrison BR. The case for digging deeper: soil organic carbon storage, dynamics, and controls in our changing World. Journal of MDPI. 2019; 3(2):28.
4. Nunes JR, Catarina IR, Carlos JP, Nuno MC. Forest Contribution to Climate Change Mitigation: Management Oriented to Carbon Capture and Storage. Journal of MDPI. 2020; 8(2):1-20.
5. Gurmu G. Soil organic matter and its role in soil health and crop productivity improvement. Academic Research Journal of Agricultural Science and Research. 2019; **7**(7):475-483.
6. Thompson JA, Kolka RK. Soil carbon storage estimation in a forested watershed using quantitative soil-landscape modeling. Soil Science Society of America Journal. 2005; 69:1086-1093.
7. Lv H, Liang Z. Dynamics of soil organic carbon and dissolved organic carbon in *Robina pseudoacacia* forests. Journal of Soil Science and Plant Nutrition. 2012; 12(4):763-774.
8. Liu M, Han G, Zang Q. Effects of soil aggregate stability on soil organic carbon and nitrogen under land use change in an erodible region in Southwest China. International Journal of Environmental Research and Public Health. 2019; 16(20):3809.
9. Canqui HB, Lal R. Crop residue removal impacts on soil productivity and environmental quality. Critical Reviews in Plant Sciences. 2009; 28(3):139-163.
10. Yadav V, George M. Progress in soil organic matter research: litter decomposition, modelling, monitoring and sequestration. Progress in Physical Geography. 2007; 31(2):131-154.
11. Juan L, Wena Y, Xuhua L, Yanting L, Yanga X, Zhian L *et al*. 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 Research. 2018; 175:281-290.
12. Yang YJ, Dungan RS, Ibekwe AM, Solano CV, Crohn DM, Crowley DE. Effect of organic mulches on soil bacterial communities one year after application. Biology and Fertility of Soils. 2003; 38(5):273-281.
13. Oliveira CCF, Ferreira DWG, Souza SLJ, Vieira OEM, Podrotti A. Soil physical properties and soil organic carbon content in northeast Brazil: long-term tillage system effect. Soils and Plant Nutrition. 2018; 77(4):1-6.
14. Esmaeilzadeh J, Ahangar AG. Influence of soil organic matter content on soil physical, chemical and biological properties. International Journal of Plant, Animal and Environmental Sciences. 2014; 4(4):2231-4490.
15. Canqui HB, Shapiro CA, Wortmann CS, Drijber RA, Mamo M, Shaver TM *et al*. Soil organic carbon: The value to soil properties. Journal of Soil and Water Conservation. 2015; 68(5):129-134.
16. Srivastava P, Kumar A, Behera SK, Sharma YK, Singh N. Soil carbon sequestration: an innovative strategy for reducing atmospheric carbon dioxide concentration. Biodiversity and Conservation. 2012; 21(5):1343-1358.
17. Sahoo UK, Singh SL, Gogo A, Kenye A, Sahoo SS. Active and passive soil organic carbon pools as affected by different land use types in Mizoram, Northeast India. PLOS ONE. 2019; 14(7):1-16.
18. Dumale WAJ, Miyazaki T, Taku N, Seki K. Short-Term Dynamics of the Active and Passive Soil Organic Carbon Pools in a Volcanic Soil Treated With Fresh Organic Matter. E-International Scientific Research Journal. 2011; 3(2):2094-1749.
19. Lorenz K, Lal R, Shipitalo MJ. Stabilized Soil Organic Carbon Pools in Sub-soils under Forest Are-Potential Sinks for Atmospheric CO_2. Forest Science. 2011; 57(1):19-25.
20. Lamberti GA, Gregory SV. CPOM Transport, Retention, and Measurement. Methods of stream Ecology. 2007; 13(2):273-289.
21. Michaud L, Blancheton JP, Bruni V, Piedrahita R. Effect of particulate organic carbon on heterophic bacterial populations and nitrification efficiency in biological filters. Aquacultural Engineering. 2006; 34(3):224-233.
22. Zeller B, Dambrine EX. Coarse particulate organic matter is the primary source of mineral N in the topsoil of three beech forests. Soil Biology and Biochemistry. 2006; 43(3):542-550.
23. Guo LJ, Zhang ZS, Wang DD, Fang CL, Cao CG. Effects of short-term conservation management practices on soil organic carbon fractions and microbial community composition under a rice-wheat rotation system. Biology and Fertility of Soils. 2014; 51(1):65-75.
24. Rizinjirabakea F, Tenenbaum DE, Pilesjo P. Sources of soil dissolved organic carbon in a mixed agricultural and forested watershed in Rwanda. Journal of catena. 2019; 27:1-5.
25. Nahum ZS, Markovitch O, Tarchitzky J, Chen Y. Dissolved organic carbon (DOC) as a parameter of compost maturity. Soil Biology and Biochemistry. 2005; 181:2019-2116.
26. Toming K, Tuvikene L, Vilbaste S, Agasild H, Viik M, Kisand A *et al*. Contributions of autochthonous and allochthonous sources to dissolved organic matter in a large, shallow, eutrophic lake with a highly calcareous catchment. Limnology Oceanography. 2013; 58(4):1259-1270.
27. Yang XM, Drury CF, Reynolds WD, Yang JY. How do changes in bulk soil organic carbon content affect carbon concentrations in individual soil particle fractions. Scientific Reports. 2016; 6:27173.
28. Zhou WJ, Zheng HL, Zhang YP, Sha LQ, Schaefer DA, Song QH *et al*. Hydrologically transported dissolved organic carbon influences soil respiration in a tropical rainforest. Biogeosciences. 2016; 13:5487-5497.
29. Lv S, Yu Q, Wang F, Wang Y, Yan W, Li Y. A synthetic model to quantify dissolved organic carbon transport in the changjiang river system: model structure and spatiotemporal patterns. Journal of Advances in Modeling Earth Systems. 2019; 11(9):3024-3041.
30. Olk DC, Bloom PR, Perdue EM, Mcknight DM, Chen Y, Farenhorst A, Senesi N *et al*. Environmental and Agricultural Relevance of Humic Fractions Extracted by Alkali from Soils and Natural Waters. Journal of Environmental Quality. 2019; 48(2):217-232.

31. Panagiotopoulos C, Pay PM, Benavides M, Wambeke VF, Sempere R. The composition and distribution of semi-labile dissolved organic matter across the South West Pacific. Biogeosciences. 2019; 16(1):105-116.
32. Li J, Wen Y, Li X, Li Y, Yanga X, Lin Z *et al*. Soil labile organic carbon fraction sand soil organic carbon stocks as affected by long-term organic and mineral fertilization regimes in the North China Plain. Soil & Tillage Research. 2017; 175:281-290.
33. Khatoon H, Solanki P, Narayan M, Tewari L, Rai JPN. Role of microbes in organic carbon decomposition and maintenance of soil ecosystem. International Journal of Chemical Studies. 2017; 5(6):1648-1656.
34. Roviraa P, Vallejo VR. Labile and recalcitrant pools of carbon and nitrogen in organic matter decomposing at different depths in soil: an acid hydrolysis approach. Geoderma, 2017; 107(1):109-141.
35. Zhang L, Chen X, Xu Y, Jin M, Ye X, Gao H *et al*. Soil labile organic carbon fractions and soil enzyme activities after 10 years of continuous fertilization and wheat residue incorporation. Scientific Reports. 2020; 10:11318.
36. Sootahar MK, Zeng X, Su S, Wang Y, Bai L, Zhang Y *et al*. The effect of fulvic acids derived from different materials on changing properties of albic black soil in the northeast plain of china. Molecules Journal. 2019; 24(8):1535.
37. Brookes P. The soil microbial biomass: concept, measurement and applications is soil ecosystem research. Microbes and Environments. 2001; 16(3):131-140.
38. Liu N, Zhang Y, Chang S, Kan H, Lin L. Impact of grazing on soil carbon and microbial biomass in typical steppe and desert steppe of Inner Mongolia. PLOS ONE. 2012; 7(5):1-9.
39. Mcintyre PB, Jones LE, Flecker AS, Vanni MJ. Fish extinctions alter nutrient recycling in tropical freshwaters. Proceedings of the National Academy of Sciences of the United States of America. 2006; 104(11):4461-4466.
40. Alam MK, Islam MM, Salahin N, Hasanuzzaman M. Effect of tillage practices on soil properties and crop productivity in wheat-mungbean-rice cropping system under subtropical climatic conditions. The Scientific World Journal. 2014; 2014(3):1-15.
41. Muruganandam S, Lsrael DW, Robarge WP. Activities of nitrogen-mineralization enzymes associated with soil aggregate size fractions of three tillage systems. Soil Biology and Biochemistry. 2009; 73(3):751-759.
42. Kumar A, Naresh RK, Singh S, Mahajan NC, Singh O. Soil aggregation and organic carbon fractions and indices in conventional and conservation agriculture under vertisol soils of sub-tropical ecosystems: A review. International Journal of Current Microbiology and Applied Sciences. 2019; 8(10):2236-2253.
43. Naresh RK, Purushottam Kumar S, Malik M, Kumar S, Choudhary U. Effects of tillage; residue and nutrient management on top soil carbon stocks and soil labile organic carbon fractions in the indo-gangetic plains of north west India: a review. Journal of Pharmacognosy and Phytochemistry. 2018; 7(3):1818-1842.
44. Haddaway NR, Hedlund K, Jackson LE, Katterer T, Lugato E, Thomsen IK, *et al*. How does tillage intensity affect soil organic carbon? A systematic review protocol. Environmental Evidence. 2018; 30(6):1-48.
45. Busari AM, Kukal SS, Kaur A, Bhatt R, Dulazi AA. Conservation tillage impacts on soil, crop and the environment. International Soil and Water Conservation Research. 2015; 16(2):119-129.
46. Gadermaier F, Berner A, Fliebbach A, Friedel JK, Mader P. Impact of reduced tillage on soil organic carbon and nutrient budgets under organic farming. Renewable Agriculture and Food System. 2010, 1-13.
47. Aminiyan MM, Sinegani AAS, Sheklabadi M. Aggregation stability and organic carbon fraction in a soil amended with some plant residues, nanozeolite, and naturalzeolite. International Journal of Recycling of Organic Waste in Agriculture. 2015; 3(6):11-22.
48. Aziza I, Mahmoodb T, RafiqIslam K. Effect of long term no-till and conventional tillage practices on soil quality. Soil and Tillage Research. 2013; 131:28-35.
49. Lal R, Kimble JM. Conservation tillage for carbon sequestration. Nutrient Cycling in Agroecosystems. 1997; 49(1):243-253.
50. Somasundaram J, Singh RK, Ali S, Sethy BK, Singh D, Lakaria BL *et al*. Soil aggregates and other properties as influenced by different long term land uses under table landscape topography of Chambal region, Rajasthan, India. Indian Journal of Soil Conservation. 2012; 40(3):212-217.
51. Shirish PS, Tushar KS, Satish BA. Mulching: a soil and water conservation practice. Research Journal of Agriculture and Forestry Sciences. 2013; 1(3):26-29.
52. Borowik A, Wyszkowska J. Soil moisture as a factor affecting the microbiological and biochemical activity of soil. Plant Soil Environ. 2016; 62(6):250-255.
53. Finley KAB, Ryan MR. Advancing intercropping research and practices in industrialized agricultural landscapes. MDPI Agriculture Journal. 2018; 8(80):1-24.
54. Scherr SJ, Mcneely JA. Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. Philosophical Transactions of The Royal Society B Biological Sciences. 2008; (1491):477-94.
55. Ghosh S, Sarkar S, Sau S, Karmakar S, Bramhachari K. Influence of Guava (*Psidium guajava* L.) based Intercropping Systems on Soil Health and Productivity in Alluvial Soil of West Bengal, India. International Journal of Current Microbiology and Applied Sciences. 2017; 6(11):241-251.
56. Jarecki MK, Lal R. Crop management for soil carbon sequestration. Critical Reviews in Plant Sciences. 2003; 22(5):471-502.
57. Sharma G, Sharma LK, Sharma KC. Assessment of land use change and its effect on soil carbon stock using multitemporal satellite data in semiarid region of Rajasthan, India. Ecological Processes. 2019; 42(8):1-17.
58. Wang Q, Li Y, Alva A. Cropping Systems to Improve Carbon Sequestration for Mitigation of Climate Change. Journal of Environmental Protection. 2010; 1(3):207-215.
59. Mikha MM, Benjamin JG, Vigil MP, Nielson DC. Cropping intensity impacts on soil aggregation and carbon sequestration in the central great plains. Soil and Water Management Conservation. 2014; 74(5):1712-1719.
60. Chen J, Heiling M, Resch C, Mbaye M, Gruber R, Dercon G. Does maize and legume crop residue mulch matter in soil organic carbon sequestration. Agriculture, Ecosystems and Environment. 2018; 265:123-131.
61. Ramakrishnaa A, Tamb HM, Wania SP, Long TD. Effect of mulch on soil temperature, moisture, weed infestation

and yield of groundnut in northern Vietnam. Field Crops Research. 2005; 95(2-3):115-125.
62. Telkar SG, Kant K, Solanki SPS. Effect of Mulching on Soil Moisture Conservation. Biomolecule Reports. 2017, ISSN:2456-8759.
63. Kroisova D, Adach K, Fijalkowski M. Natural organic-inorganic material utilized as a filler in polymer systems. Nanocon: International Conference, At Brno, Czech Republic. November 5th -7th 2014.
64. Mir SH, Nagahara LA, Thundat T, Tabari PM, Furukawa H, Khosla A. Review-Organic-Inorganic Hybrid Functional Materials: AnIntegrated Platform for Applied Technologies. Journal of The Electrochemical Society. 2018; 165(8):B3137-B3156.
65. Jodaugiene D, Pupaliene R, Sinkeviciene A, Marcinkeviciene A, Zebrauskaite K, Baltaduonyte M *et al*. The influence of organic mulches on soil biological properties. Zemdirbyste. 2010; 97(2):33-40.
66. Yang YJ, Dungan RS, Ibekwe AM, Solano CV, Crohn DM, Crowley DE. Effect of organic mulches on soil bacterial communities one year after application. Biology and Fertility of Soils. 2003; 38(5):273-281.
67. Cattanio JH, Kuehne R, Vlek PLG. Organic material decomposition and nutrient dynamics in a mulch system enriched with leguminous trees in the Amazon. Revista Brasileira de Ciencia do Solo. 2008; 32(3):1073-1086.
68. Bajoriene K, Jodaugiene D, Pupaliene R, Sinkeviciene C. Effect of organic mulches on the content of organic carbon in the soil. Estonian Journal of Ecology. 2013; 62(2):100-106.
69. Wade J, Culman SW, Logan JAR, Poffenbarger H, Demyan MS, Grove JH *et al*. Improved soil biological health increases corn grain yield in N fertilized systems across the corn Belt. Scientific Reports. 2020; 10(1):3917.
70. Naab JB, Mahama GY, Koo J, Jones JW, Boote KJ. Nitrogen and phosphorus fertilization with crop residue retention enhances crop productivity, soil organic carbon, and total soil nitrogen concentrations in sandy-loam soils in Ghana. Nutrient Cycling in Agroecosystems volume. 2015; 102:33-43.
71. Singh M, Sarkar B, Sarkar S, Churchman J, Bolan N, Mandal S *et al*. Stabilization of soil organic carbon as influenced by clay mineralogy. Advances in Agronomy. 2018; 148:33-84.
72. Rillig MC, Mummey DL. Mycorrhizas and soil structure. New Phytologist. 2006; 171(1):41-53.
73. Peng S, Guob T, Liu G. The effects of arbuscular mycorrhizal hyphal networks on soil aggregations of purple soil in southwest China. Soil Biology and Biochemistry. 2013; 57:411-417.
74. Huda SMS, Sujauddin M, Shafinat S, Uddin MS. Effects of phosphorus and potassium addition on growth and nodula-tion of *Dalbergia sissoo* in the nursery. Journal of Forestry Research. 2007; 18(4):279-282.
75. Maltas A, Kebli H, Oberholzer RH, Weisskopi P, Sinaj S. The effects of organic and mineral fertilizers on carbon sequestration, soil properties, and crop yields from a long-term field experiment under a Swiss conventional farming system. Land Degradation and Development. 2017; 29:926-938.
76. Brar BS, Singh J, Singh G, Kaur G. Effects of Long Term Application of Inorganic and Organic Fertilizers on Soil Organic Carbon and Physical Properties in Maize–Wheat Rotation. Journal of Agronomy. 2015; 5(2):220-238.
77. Zhao Z, Zhang C, Li F, Gao S, Zhang J. Effect of compost and inorganic fertilizer on organic carbon and activities of carbon cycle enzymes in aggregates of an intensively cultivated Vertisol. PLOS ONE. 2020; 15(3):1-16.
78. Jalali M, Ranjbar F. Rates of decomposition and phosphorus release from organic residues related to residue composition. Journal of Plant Nutrition and Soil Science. 2009; 172(3):353-359.
79. Khan AA, Bibl H, Ali Z, Sharif M, Shah SA, Ibadullah, H, Khan K *et al*. Effect of compost and inorganic fertilizers on yield and quality of tomato. Academia Journal of Agricultural Research. 2017; 5(10):287-293.
80. Dignac MF, Derrien D, Barre P, Barot S, Cecillon L, Chenu C *et al*. Increasing soil carbon storage: mechanisms, effects of agricultural practices and proxies. A review. Agronomy Sustainable Development. 2017; 37(14):1-27.
81. Morison JIL, Baker NR, Mullineaux PM, Davies WJ. Improving water use in crop production. Philosophical Transactions Royal Society. 2008; 363:639-658.
82. Adugna G. A review on impact of compost on soil properties, water use and crop productivity. Academic Research Journal of Agricultural Science and Research. 2016; 4(3):93-104.
83. Prommer J, Walker TWN, Wanek W, Braun J, Zezula D, Hu Y *et al*. Increased microbial growth, biomass, and turnover drive soil organic carbon accumulation at higher plant diversity. Global Change Biology. 2020; 26:669-681.
84. Wang X, Tang C, Baldock JA, Butterly CR, Gazey C. Long-term effect of lime application on the chemical composition of soil organic carbon in acid soils varying in texture and liming history. Biology and Fertility of Soils 2016; 52(3):295-306.
85. Cho SJ, Kim MH, Lee YO. Effect of pH on soil bacterial diversity. Journal of Ecology and Environment. 2016; 40(10):1-9.
86. Manea A, Dumitru M, Matei M, Lacatusu A, Matei S, Dumitru S. Effects of acidification on the soil microbiological activity in the zlatna area. Journal of Environmental Protection and Ecology. 2016; 17(2):503-511.
87. Wuddivira MN, Roach CG. Effects of organic matter and calcium on soil structural stability. European Journal of Soil Science. 2007; 58(3):722-727.
88. Aye NS, Sale P, WG, Tang C. The impact of long-term liming on soil organic carbonand aggregate stability in low-input acid soils. Biology and Fertility of Soils. 2016; 52(5):697-709.