***Review Article***

Evaluating the Impact of Resource Conservation Practices on Soil Carbon Sequestration in Agricultural Lands

ABSTRACT

|  |
| --- |
| Carbon sequestration is accumulating atmospheric carbon dioxide, deplete to the soil degradation, augmenting soil fertility, enhancing organic carbon and carbon stocks. Various resource conservation practices involving incorporation of organic manures, cover cropping, zero tillage, mulching, conservation tillage, fertility management, agroforestry, and crop rotation are the enhancing in carbon stocks on agricultural lands. Sequestration of carbon in soil is the importance of that potential is more significant. appropriation of zero tillage bulk density may be enlarge than conventional tillage. The soil aggregates disturbance in the surface layers and decline in the amount of total SOC, mainly due to the macroaggregates, occurs under conventionally tilled soil. The SOC response to cover cropping or diverse crop rotation was more observable in medium-textured soils than soils types. mixed cropping systems with conservation tillage sequestered 10% more SOC than conventional tilled crop-fallow systems, rises than SOC sequestration with diverse cropping or conservation tillage. Diversified crop rotation dispenses an opportunity to produce very large biomass C that impact SOC by changing the quantity and the quality of organic matter input more than under mono cropping.  |

*Keywords:* **Carbon sequestration and potential, Carbon stock, Resource conservation Practice, Mulching**

1. INTRODUCTION

 Revival of soil health through soil organic carbon management is a significant concern for tropical region soils. The arid region is rate of decomposition is high that causes mineralization process fast resulting in loss of soil organic carbon . Soil organic carbon which controlling following factors Land use pattern, fertility, climatic, biological activity(soil microbiology), vegetation pattern (Jenny and Raychaudhuri 1960).

Carbon sequestration refers to the process of apprehending and storing atmospheric carbon dioxide (CO2) to mitigate global warming and climate change. There are various types of carbon sequestration they are direct or indirect, and biological, chemical, geological, or physical in nature. the inorganic CO2 is sequestered directly by plants through photosynthesis. The carbon sequestration is the crucial factor for the sustain soil microbial diversity, enhance the soil fertility, boost the productivity and production. It is maintaining the environments balance of carbon is captured and stored in soil, ocean, ice. Respiration process of the plant carbon dioxide is captured in the photosynthesis metabolism this is natural process. The concentration of atmospheric carbon dioxide increases due to the anthropogenic activity this is cement manufacturing, deforestation, combustion of the fuels, biomass burning etc which responsible to the increasing global warming.

 Carbon sequestration potential which is depends on the climatic factors they regulate various process of soil. The arid climate is high temperature the of decomposition of organic matter high and mineralization process is high due to this process loss of organic carbon is high. The arid climate also less of the carbon stock. The humid and cool region rate of decomposition is negligible also mineralization process is slow that why the carbon stock is high the humid climate.

 Potential of the Carbon sink ability also differ due to soil types, land use, (McNally *et al*.,2013). The changing of agroecosystem is effect on the Soil organic carbon storage. soil is one of the important terrestrial stock and which two to three time more potential. Soil organic carbon is a center for the soil functioning and determining of the soil capacity to hold and release water and essential nutrients that are importance for the plant growth.

2 **CARBON CYCLE**

Towards the end of the nineteenth century, where as anthropogenic disturbance of the global C cycle during the twentieth century has been an historically extraordinary phenomenon. The significance of atmospheric concentration of CO2 on global temperature was understand by Arrhenius .

 

The data on C pools among major reservoirs are from Batjes (1996), Falkowski *et al.* (2000) and Pacala & Socolow (2004), and the data on fluxes are from IPCC (2001).

 **Table No.1. Estimated potential of carbon sequestration in global croplands**

Understanding the global C cycle and its disruption by anthropogenic activities is important for developing applicable strategies for mitigating climate change. The rate of future increase in atmospheric CO2, concentration will depend on the anthropogenic activities, the biogeochemical interaction of climate processes on the global C cycle and interaction among between principal C pools. show reserves of fossil fuel include 678 Pg of coal .

**3.Soil Carbon sequestration potential**

Carbon sequestration potential which is depends on the climatic factors they regulate various process of soil.Soil itself capable to maintain the atmospheric balance gain and loss of carbon dioxide emission. The ability of a soil system to sequester C lies in the balance between net gains and net losses. The industrial revolution increases in Carbon emissions the global C cycle, or C flux was maintained at a near balance between uptake of CO2 (sinks) and its release back into the atmosphere (sources). Soil organic carbon can be characterized as a dynamic equilibrium between gains and losses. Practices that either increase inputs or reduce losses can promote soil C sequestration.

The photosynthesis catch atmospheric carbon is gain the soil carbon is called net primary productivity. The agriculture land use change is increasing continuously atmospheric carbon dioxide. Global greenhouse gas 24% emissions accounting by (TSU, I. S. IPCC AR5 Synthesis Report 2014) . Carbon management is practices soil act as both the sources and sinks reforestation (replanting trees in deforested areas) and afforestation (planting trees in areas that were previously non-forested). Significantly more carbon is stock in the world’s soils than is present in the atmosphere. The global soil carbon pool to 1 m depth, estimated at 2500 Pg C of which about 1500

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sr.No | Total estimated C stored in croplands | Estimated annual C sea potential in global croplands | Percentages of initiatives target (3.5 Pg C/yr )  | References  |
| 1 | 83 Pg C | 0.34 Pg C/yr | 10% | PadarianJ.,*et.al*.(2022) |
| 2 | 135 PgC | 0.19 Pg C/yr | 5.4 -32% | Lal *et.al* (2018) |
| 3 | 131.81 Pg C | 0.90 to1.85 Pg C/yr | 26-53% | Zomer,R.J.*et.al*(2017) |

 The global soil carbon pool to 1 m depth, estimated at 2500 Pg C of which about 1500 Pg C is soil organic is about 3.2 times the size of the atmospheric pool and 4 times that of biotic pool(Lal 2010).

 Resource conservation practices which is increasing soil organic stocks this practises are organic manure, cover cropping, rotational grazing, agroforestry, mulching, conservation tillage, fertility management, (Paustian *et al*.2016.). Increasing global warming is increasing earth temperature above 1.5C (*Baker et.al.* 2018). Weather patterns may affect terrestrial C storage changing due to the global warming.

**Table No.2 Carbon pool depth in soil orders**

Soils Carbon pool to 1-m depth

 Organic Inorganic

Ultisols 101 0

 Andisols 69 1

 Aridisols 110 1044

 Oxisols 150 0

 Inceptisols 267 258

 Alfisols 136 127

 Mollisols 72 139

 Vertisols 38 25

 Spodosols 98 0

 Entisols 106 117

Histosols 390 0

 Miscellaneous 18 0

 Total 1555 17

(Eswaran *et al*. 1995)

The net primary production soil C decomposition and C inputs to the soils rates are significantly affected by the change in precipitation, temperature, and CO2 concentration. Changing climatic patterns may also accelerate land-use change and alters the terrestrial C fluxes (Zeng *et.al.*2019). Soil C sequestration is also necessary for improving resource use efficiency and increasing soil nutrition status of crop plants to ensure better growth and productivity in a sustainable agriculture. Through denaturation and filtration of pollutants soil C sequestration also helps to enhances biodiversity by protecting land for nature conservancy and improve soil water status. Lack of an accurate estimation of soil C sequestration and including special heterogeneity of SOC, inherent soil variability, hinder the identification of suitable management practices (Srinivasarao *et.al .*2020)

Estimates of soil organic carbon and inorganic carbon pools in world soils given by (Eswaran *et al*. 1995) . Studied that the inorganic carbon was found more in arid and semi-arid regions in aridisols which is approximately 1044 tons per hacter aridisols are soils .The organic carbon was found more in Histosols. Table 2 shows Histosols are soils which contain organic carbon percentage more as compared to other soil orders. the content of organic carbon and inorganic carbon content in world soil given in tons per hacter .

**TableNo.3. Effect of Zero tillage and conservation tillage on SOC Stock**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sr.No. | Treatment | Soil organic carbon (g kg−1) | Total soil organic C stock (t ha−1) | Change in total SOC stock (t ha−1) |
|  |  | 0–15 cm | 15–30 cm | 0–15 cm | 15–30 cm | 0–30 cm |
| 1 | ZT | 6.23 | 5.23 | 14.8 | 13.4 | 7. 7 2 |
| 2 | CT | 4.73 | 4.33 | 11.2 | 10.7 | 0.88 |

 Parihar *et al*.(2020)

**Forms of conservation agriculture**

 Major forms of conservation agriculture includes

 • Minimum, reduced or no tillage

 • Crop and pasture rotation

 • Contour farming and strip cropping

 • Cover and green manure cropping

 • Fertility management

 • Erosion control

 • Agro-forestry and alley cropping

 • Organic and biodynamic farming

• Stubble mulching

• Integrated nutrient management (INM) Patle *et.al*  (2013)

**4.Relation Soil organic carbon in to the SOM**

Soil organic matter consists of complex organic substances, including humic substances, organic crop residues, and microbial bodies that decompose at various stages. It affects plant growth and a reservoir for plant nutrients, yield by enhancing soil structure and serving as containing 2.5 exagrams (Eg) of carbon (1 Eg = 1018 g). The formation of clay-humus complexes improves soil buffering capacity and creates stable complexes with certain metals, making them more available for plant uptake. Soil carbon is primarily originate in the form of organic matter or humus. Soil organic carbon (SOC) content ranges from 1% in coarse-textured soils to 3.5% in grasslands. Tropical, subtropical, arid, and semi-arid climates soils low SOC levels , as well as practices like frequent tillage, excessive use of agrochemicals like( fertilizers , pesticides, fungicides,) and removal of crop residues. Soil organic matter (SOM) can be categorized into different pools based on the time required for complete decomposition and the turnover time of these products in the soil.

**5.Conservation agriculture**

Conservation Agriculture is crucial practice of agriculture which maintain the environmemnt and ecological balance . It helps to boost productivity and production. Soil organic carbon (SOC) concentration increase due incorporating of the crop cover to the soil. Diversified crop rotation also helps to increase the SOC. Legume-based systems, in particular, contribute higher amounts of aromatic carbon, maintaining optimal C:N ratios and thereby boosting productivity. The SOC was increased by 72% with a CA-based maize-wheat-mungbean system and 83% with the rice-wheat mungbean system compared to conventional RW system (Parihar *et al*.(2018). Conservation agriculture significantly increased SOC content in both 0–15 cm and 15–30 cm depth compared with CT in the maize-based cropping system (Parihar *et al*.(2018)(Table 3).

**Table No.4. Soil Aggregate Stability and Aggreagate Associated Carbon Under Different Tillage**

|  |  |
| --- | --- |
| Soil depth (cm) | Soil organic C concentration (g kg-1) |
| MP-R | MP+R | RT | NT |
| 0-5 | 10.26±0.19 | 11.35±0.42 | 13.59±0.18 | 14.33±0.62 |
| 5-10 | 10.84±0.30 | 10.83±0.34 | 13.57±0.05 | 12.31±0.48 |
| 10-20 | 10.41±0.26 | 10.72±0.38 | 9.7±0.17 | 9.03±0.42 |
| 20-30 | 7.46±0.12 | 7.84±0.07 | 7.15±0.14 | 7.09±0.42 |

 MP-R moldboard plough without residue; MP+R moldboard plough with residue;RT, rotary tillage with residue; NT,no tillage with residue

 Zhang-liul *et.al*(2013)

Following Principle of conservation agriculture can be described by FAO.

 1.No tillage or Minimal soil disturbance: The disturbed area must be no wider than 15 cm or 25% of the cropped area, whichever is smaller. Periodic tillage should not exceed these limits.

2. Soil cover residue: Ground cover must exceed 30%. Which reduce soil loss by degradation.

3. Crop Diversification: Rotation should involve at least three different crops. Avoid the monocropping

Soil organic carbon influences various factors which are types of soil, Tillage operation practices, topography in slopes, application of fertilizers, land use as essential factors. variability of soil organic carbon (Zhang et al. 2020). The soil colloids availlability Important factor of carbon sequestration(Naitam et al. 2004) because the rate of carbon sequestration is high in clay soil. Appropriate sustainable management practices, such as suitable crop rotations, balanced nutrient management, and conservation tillage mulching , cover cropping , can help overcome challenges related with soil carbon sequestration (Nath et al. 2017). Conserving soil fertility sustainably is importance of improve soil physical , chemical and biological properties of the soils. Which reduce soil erosion, better the soil structure, improve water holding capacity, cation exchange capacity, buffering capacity, and microbial populations. which helps to maintain the soil carbon stocks.

 Conservation agriculture helps is improving the soil properties while positively influencing climate change mitigation (Kassam, 2021). Conservation practices helps to minimizes soil compaction,weed infestation, reduce the cost of cultivation ,minimize the green house gases (Giller *et al.,* 2009)and (Hobbs *et al*., 2008). Zero tillage is keeping of crop residues on the surface of the top soil which minimize the soil degradation, boosting soil fertility, and improving soil organic matter sequestration which helps to mitigates global warming (Wang *et al*., 2020).Zero tillage is effect majorly depends upon the the quantity and quality of crop residue return to the field(DeMoraesSa *et al.,* 2009).

Conservation tillage practices no tillage with residue is increased SOC Content in the depth of 0-5 cm (Zhang *et.al*.2013) Table No. 4.

**Several anthropogenic activities also contribute to soil carbon losses**, including:

1. Deforestation

2. Soil erosion

3. Excessive ploughing

4. Burning of crop residues

5. Summer fallow

6. Bare soil during the winter season

7. Monocropping

8. Inefficient recycling of elements

9. Nutrient depletion

10. Water deficiency

11. Low-input subsistence farming and soil fertility mining

12. Intensive cropping and cultivating marginal soils (Chatterjee et al., 2020).

**Conclusion**

 Carbon sequestration on agricultural lands can be achieved through various soil management strategies, potentially leading to significant benefits if implemented widely. These practices help maintain atmospheric carbon balance by reducing greenhouse gases and increasing atmospheric carbon dioxide. Certain agricultural management practices show promise for restoring soils and sequestering a substantial portion of atmospheric carbon. Additionally, carbon sequestration contributes to reduced soil degradation, enhanced soil nutrients and health, improved water quality, better wildlife habitat, and economic benefits for farms.

**References**

Baker, H.S.; Millar, R.J.; Karoly, D.J.; Beyerle, U.; Guillod, B.P.; Mitchell, D.; Shiogama, H.; Sparrow, S.; Woollings, T.; Allen, M.R. Higher CO2 concentrations increase extreme event risk in a 1.5 C world. Nat. Clim. Chang. 2018, 8, 604–608.

 Blanco-Canqui, H. 2022. Cover crops and carbon sequestration: Lessons from U.S. studies. Soil Science Society of America Journal 86(3):501–519. doi.org/10.1002/saj2.20378

Bhan S, Behera UK. Conservation agriculture in India—Problems, prospects and policy issues. International Soil and Water Conservation Research. 2014;2(4):1-12

 Dick, W; Durkalski, J. No-tillage production agriculture and carbon sequestration in a Typic Fragiudalf soil of northeastern Ohio. In Management of Carbon Sequestration in Soil; Lal, R., Kimble, J.M., Follett, R.F., Stewart, B.A., Eds.; CRC Press: Boca Ration, FL, USA, 1998; pp. 59–71.

 DeMoraes Sa, J.C.; Lal, R. Stratification ratio of soil organic matter pools as an indicator of carbon sequestration in a tillage chrono sequence on a Brazilian Oxisol. Soil Tillage Res. 2009, 103, 46–56.

 DeMoraesSa,J.C.; Cerri, C.C.; Dick, W.A.; Lal, R.; Filho, S.P.V.; Piccolo, M.C.; Feigl, B.E. Organic matter dynamics and carbon sequestration rates for a tillage chrono sequence in a Brazilian Oxisol. Soil Sci. Soc. Am. J. 2001, 65, 1486–1499.

 Eagle, A.J. and L.P. Olander. 2012. Greenhouse gas mitigation with agricultural land management activities in the United States — A side-by-side comparison of biophysical potential. Advances in Agronomy 115:79–179. doi. org/10.1016/B978-0-12-394276-0.00003-2

Eswaran H, Vandenberg E, Reich P 1995 Organic carbon in soils of the world. Soil Science Society of America Journal 57: 192 194.

 FAO, ITPS. Status of the World’s Soil Resources (SWSR) - Main Report. 1–648 (Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, 2015).

 FAO and ITPS. 2021. Recarbonizing global soils – A technical manual of recommended management practices. Volume 2 – Hot spots and bright spots of soil organic carbon. Rome, FAO. <https://doi.org/10.4060/cb6378en>

Falkowski P, Scholes RJ, Boyle E, Canadell J, Canfield D. The global C cycle: The test of our knowledge of earth as a system. Science. 2000;289:270-277

Fargione, J.E., S. Bassett, T. Boucher, S.D. Bridgham, R.T. Conant, et al. 2018. Natural climate solutions for the United States. Science Advances 4(11):eaat1869. doi.org/10.1126/ sciadv.aat1869

 Giller, K.E.; Witter, E.; Corbeels, M.; Tittonell, P. Conservation agriculture and smallholder farming in Africa: The heretics’ view. Field Crop. Res. 2009, 114, 23–34.

 Haddaway, N.R., K. Hedlund, L.E. Jackson, T. Kätterer, E. Lugato, et al. 2017. How does tillage intensity affect soil organic carbon A systematic review. Environmental Evidence 6(1): 30. doi.org/10.1186/s13750-017-0108-9

Hobbs, P.R., K. Sayre and R. Gupta. 2008. The role of conservation agriculture in sustainable agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences 363(1491):543–555. doi.org/10.1098/rstb.2007.2169

 IPCC. Climate Change 2014: Synthesis Report. In Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Core Writing Team, Pachauri, R.K., Meyer, L.A., Eds.; IPCC: Geneva, Switzerland, 2014; p. 151.

 Izaurralde RC, Rosenberg NJ, Lal R. Mitigation of climate change by soil carbon sequestration: Issues of science, monitoring, and degraded lands. Advances in Agronomy. 2000;70:1-75

 Kassam, A.; Friedrich, T. An ecologically sustainable approach to agricultural production intensification: Global perspectives and developments. Field Actions Sci. Rep. J. Field Actions 2012. Available online: http://journals.openedition.org/factsreports/1382 (accessed on 28 July 2021).

 Kassam, A.; Friedrich, T.; Derpsch, R. Global spread of conservation agriculture. Int. J. Environ. Stud. 2019, 76, 29–51.

 Lal, R. Agricultural activities and the global carbon cycle. Nutrient Cycling in Agroecosystems 70, 103–116 (2004).

Lal, R. Managing Soils and Ecosystems for Mitigating Anthropogenic Carbon Emissions and Advancing Global Food Security. BioScience 60, 708–721 (2010).

Lal R. Sequestration of atmospheric CO2 in global C pools. Energy and Environmental Science. 2008;1:86-100

 Mazzoncini, M., T.B. Sapkota, P. Bàrberi, D. Antichi and R. Risaliti. 2011. Long-term effect of tillage, nitrogen fertilization and cover crops on soil organic carbon and total nitrogen content. Soil and Tillage Research 114(2):165–174. doi. org/10.1016/j.still.2011.05.001

 Meurer, K.H.E., N.R. Haddaway, M.A. Bolinder and T. Kätterer. 2018. Tillage intensity affects total SOC stocks in boreo temperate regions only in the topsoil — A systematic review using an ESM approach. Earth-Science Reviews 177:613 622. doi.org/10.1016/j.earscirev.2017.12.015

 Nair, P.K.R., B.M. Kumar and V.D. Nair. 2009. Agroforestry as a strategy for carbon sequestration. Journal of Plant Nutrition and Soil Science 172(1):10–23. doi.org/10.1002/ jpln.200800030

 Naitam, R.; Bhattacharyya, T. Quasi-equilibrium of organic carbon in shrink–swell soils of the subhumid tropics in India under forest, horticulture, and agricultural systems. Soil Res. 2004, 42, 181–188.

 Nath,C.; Das, T.; Rana, K.; Bhattacharyya, R.; Pathak, H.; Paul, S.; Meena, M.; Singh, S. Weed and nitrogen management effects on weed infestation and crop productivity of wheat–mungbean sequence in conventional and conservation tillage practices. Agric. Res. 2017, 6, 33–46.

 Palm, C., H. Blanco-Canqui, F. DeClerck, L. Gatere and P. Grace. 2014. Conservation agriculture and ecosystem services: An overview. Agriculture, Ecosystems & Environment 187:87 105. doi.org/10.1016/j.agee.2013.10.010

*Padarian J, Minasny B, McBratney A, Smith P*. Soil carbon sequestration potential in global croplands. PeerJ. 2022 Jul 21;10:e13740. doi: 10.7717/peerj.13740. PMID: 35891649; PMCID: PMC9308964.

Parihar CM, Prihar MD, Sapkota TB, Nanwal RK, Singh AK, Jat SL, et al. Long-term impact of conservation agriculture and diversified maize nitrogen fractions and nitrous oxide fluxes in inceptisol of India. Science of the Total Environment. 2018;640:1382-1392

Paustian, K. et al. Climate-smart soils. Nature 532, 49–57 (2016).

 Poeplau, C. and A. Don. 2015. Carbon sequestration in agricultural soils via cultivation of cover crops – A meta analysis. Agriculture, Ecosystems & Environment 200:33–41. doi.org/10.1016/j.agee.2014.10.024

Powlson, D.S., C.M. Stirling, C. Thierfelder, R.P. White and M.L. Jat. 2016. Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agroecosystems Agriculture, Ecosystems & Environment 220:164–174. doi.org/10.1016/j.agee.2016.01.005

 Schoeneberger, M.M. 2009. Agroforestry: working trees for sequestering carbon on agricultural lands. Agroforestry Systems 75(1):27–37. doi.org/10.1007/s10457-008-9123-8

Schoeneberger, M.M., G. Bentrup, H. de Gooijer, R. Soolanayakanahally, T. Sauer, et al. 2012. Branching out: Agroforestry as a climate change mitigation and adaptation tool for agriculture. Journal of Soil and Water Conservation 67(5):128A–136A. doi.org/10.2489/jswc.67.5.128A

 Smith, P. et al. Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences 363, 789–813 (2008).

Srinivasarao, C.; Vittal, K.; Venkateswarlu, B.; Wani, S.; Sahrawat, K.; Marimuthu, S.; Kundu, S. Carbon stocks in different soil types under diverse rainfed production systems in tropical India. Commun. Soil Sci. Plant Anal. 2009, 40, 2338–2356.

Srinivasarao, C.; Venkateswarlu, B.; Lal, R.; Singh, A.K.; Kundu, S.; Vittal, K.P.R.; Ramachandrappa, B.K.; Gajanan, G.N. Long term effects of crop residues and fertility management on carbon sequestration and agronomic productivity of groundnut–finger millet rotation on an Alfisol in southern India. Int. J. Agric. Sustain. 2012, 10, 230–244.

 TSU, I. S. IPCC AR5 Synthesis Report - Climate Change 2014. 1–169 (2015).

 Verhulst, N.; Govaerts, B.; Verachtert, E.; Castellanos-Navarrete, A.; Mezzalama, M.; Wall, P.; Deckers, J.; Sayre, K.D. Conservation agriculture, improving soil quality for sustainable production systems. In Advances in Soil Science: Food Security and Soil Quality; CRCPress: Boca Raton, FL, USA, 2010; pp. 137–208.

 Wang,H.; Wang, S.; Yu, Q.; Zhang, Y.; Wang, R.; Li, J.; Wang, X. No tillage increases soil organic carbon storage and decreases carbon dioxide emission in the crop residue-returned farming system. J. Environ. Manag. 2020, 261, 110261.

 Zeng, S.; Liu, Z.; Kaufmann, G. Sensitivity of the global carbonate weathering carbon-sink flux to climate and land-use changes. Nat. Commun. 2019, 10, 1–10

 Zhang, J.; Zhang, M.; Huang, S.; Zha, X. Assessing spatial variability of soil organic carbon and total nitrogen in eroded hilly region of subtropical China. PLoS ONE 2020, 15, e0244322.