GMR
The Original

ASSESSMENT OF CARBON POOLS IN PADDY UNDER VARIOUS GROWING PRACTICES OF UPLAND AND LOWLAND PADDY FIELDS

Tejaswini A. Umbarkar [1], G.S. Mhasal[2*], Dr. J.R. Katore[3], Dr. S.M. Mule[4], Dr. Savita G. Pawar[5], K.P. Solanke[6], Dr. Ankita G. Angaitkar[7], T.S. Kamdi[8], Dr. S. S. Balpande[9]

[1]PG Scholar, Dept. SSAC, COA, Nagpur, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, Email ID: umbarkartejaswini94@gmail.com
[2*]Programme Assistant (Lab. Technician), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, Email ID: gajananmhasal11@gmail.com
[3]Senior Scientist-cum-Head, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, Email ID: jivankatore@pdkv.ac.in
[4]Subject Matter Specialist (AHDS), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, Email ID: drsachinmule2025@gmail.com
[5]Subject Matter Specialist (Agril.Engg.), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, Email ID: savitapawar100@gmail.com
[6]Farm Manager, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, Email Id: kishorpsolanke@gmail.com
[7] Subject Matter Specialist (Extension Education), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, Email ID: ankita.angaitkar@gmail.com
[8]Junior Research Assistant, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India. Email ID: tusharkmd@gmail.com
[9]Associate Professor, Dept. SSAC, COA, Nagpur, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, Email ID: ssbalpande@pdkv.ac.in
***Corresponding Author**: G.S. Mhasal, ORCID ID: 0000-0002-5685-0472

ABSTRACT
A field experiment was conducted during 2018–19 to evaluate the carbon pools in paddy soils managed under different upland and lowland rice-growing practices. The study was undertaken in four villages of Parseoni taluka in Nagpur district. A total of 30 farmers practicing five distinct rice production systems—conventional lowland, organic lowland, integrated nutrient management (INM) lowland, conventional upland, and INM upland-were selected for the study. Soil samples collected at the maturity stage of paddy were analyzed for inorganic carbon, organic carbon and different labile carbon fractions, viz., cold-water-extractable organic carbon (CWOC), hot-water-extractable organic carbon (HWOC) and readily oxidizable carbon (ROC). The results revealed considerable variation in carbon pools among the different growing practices. Organic carbon content ranged from 5.15 to 6.28 g kg^{-1}, with the highest value recorded under organic lowland practice (6.28 g kg^{-1}) and the lowest under conventional upland practice (5.15 g kg^{-1}); however, the differences were statistically non-significant. Cold-water-extractable carbon varied from 28.47 to 52.40 mg kg^{-1}, with the maximum value under organic lowland and minimum under INM lowland practice. Hot-water-extractable carbon ranged from 53.34 to 66.20 mg kg^{-1}, with the highest value observed under organic lowland and the lowest under INM upland practice. Readily oxidizable carbon showed a range of 116.98 to 194.76 mg kg^{-1}, with the highest value recorded under organic lowland and the lowest under conventional lowland practice. Inorganic carbon also varied among the growing practices, with comparatively higher values under upland conditions

KEYWORDS: Paddy soil, Carbon pools, Organic carbon, Labile carbon fractions, Rice production systems, Nutrient management.

INTRODUCTION
Carbon is a fundamental component of soil organic matter and plays an important role in maintaining soil fertility, nutrient cycling, aggregation and overall soil quality. In rice-based production systems, the quantity and distribution of soil carbon are strongly influenced by crop management, nutrient application, residue return, organic amendments and water regimes. Paddy soils are particularly important in the global carbon cycle because prolonged periods of flooding alter decomposition processes, carbon stabilization and the transformation of different soil carbon pools. Therefore, assessment of different carbon fractions provides a better understanding of carbon dynamics and the long-term sustainability of rice-based agroecosystems. (Ghimire et al, 2017). Soil carbon exists in different pools that differ in their stability and susceptibility to decomposition. Organic carbon fractions such as water-soluble or water-extractable organic carbon (CWOC), hot-water-extractable organic carbon (HWOC) and readily oxidizable carbon (ROC) are generally considered useful indicators of changes in soil organic matter and management-induced changes in carbon availability. These labile carbon fractions respond relatively rapidly to the addition of organic materials and changes in nutrient management and can therefore serve as sensitive indicators of soil quality. Carbon inputs from crop residues, roots and rhizodeposition contribute substantially to the soil carbon pool in rice systems, while management practices determine the extent to which this carbon is retained or lost from the soil. (Liu et al, 2019) Nutrient management is one of the important factors governing soil carbon accumulation in paddy soils. Continuous application of inorganic fertilizers can increase crop productivity and consequently enhance carbon inputs through greater biomass production; however, incorporation of organic materials provides an additional direct source of carbon to the soil. Integrated application of organic and inorganic nutrient sources

can therefore improve carbon accumulation by simultaneously supplying nutrients and increasing organic matter inputs. A meta-analysis of long-term experiments in paddy soils reported that combined organic and inorganic fertilization generally showed greater potential for soil organic carbon sequestration than inorganic fertilizers alone. (Zhu et al, 2015) Long-term evidence from South Asian cropping systems indicates that balanced fertilization can enhance plant-derived carbon inputs, total organic carbon and several active carbon fractions, while the addition of organic manures along with mineral fertilizers can further increase carbon accumulation. Thus, evaluation of individual carbon pools under contrasting growing practices is essential for understanding the capacity of different management systems to maintain soil carbon and improve soil health (Singh and Singh, 2025). The experimental data showed considerable variation among the growing practices, indicating that the nature of crop establishment and nutrient management influenced both total and labile carbon pools. Therefore, assessment of these carbon fractions at crop maturity can provide valuable information on the effect of different growing practices on carbon storage, carbon availability and the sustainability of paddy production systems.

MATERIAL & METHODS

The four locations of Nagpur districts were selected Locations : Villages of Parseoni taluka of Nagpur District with 30 farmers field are selected and The farmers followed five different paddy-growing practices, namely conventional lowland, organic lowland, INM lowland, conventional upland and INM upland practices. In conventional lowland paddy, manure use was rare and low (2–3 t ha^{-1}), with transplanting, low-dose fertilizer application, fertilizer spray and low residue addition in the form of root stubbles, while no biofertilizer was used. Organic lowland paddy received regular and higher manure application (10 t ha^{-1}), transplanting, no chemical fertilizer, application of manurial liquid (500 L ha^{-1}), straw incorporation at 5 t ha^{-1} and use of Azolla as a biofertilizer. INM lowland paddy involved regular manure application (5 t ha^{-1}), transplanting, optimum fertilizer application, spraying of 2% urea solution, addition of 2–3 t ha^{-1} straw and use of blue-green algae. In conventional upland paddy, manure use was rare and low (2–3 t ha^{-1}), drilling was followed for sowing, low-dose fertilizer was applied, 2% urea solution was sprayed, and only low amounts of root stubbles were retained, with no biofertilizer use. In INM upland paddy, regular manure application (5 t ha^{-1}), drilling, optimum fertilizer application, spraying of 2% urea solution, low residue addition in the form of root stubbles and use of Azotobacter were followed.

Determination of SOC fractions:

Readily Oxidizable Carbon(mg kg-1)

It was determined by KMnO4 Oxidation method given by Blair et al, (2001). Take a test tube, add 0.2 M KMnO4 and distilled water and mix it add soil sample in tube and cap it, then shake it for 2 min. Then stand it for 10 min. Then take 45ml distilled water in volumetric flask and add 0.5ml of supernant make up volume up to 50ml with distilled water and shake it. Then detect a absorption rate on spectrophotometer at 550 nm wavelength.

Hot Water extractable Carbon (mg kg-1)

It was determined by soil extracted at 800 C hot water as per method given by Mc Gill et al, (1986). Take a soil sample in test tube add 800C hot distilled water and shaking for 60 min on shaker, 30 min centrifugation at 10,00 rpm, then take a filtrate in conical flask. Then add 0.07 N K2Cr2O7 and conc H2SO4 as well as orthophosphoric acid digest at 1500 C for 30 min and maintain temp up to 800 C titrate against 0.035 N ferrous ammonium sulphate.

Cold Water extractable Carbon (mg kg-1)

It was determined by Soil extracted at 200 C cold water method given by Mc Gill et al, (1986). Take a soil sample in test tube add 200 C cold distilled water and shaking for 60 min on shaker, 30 min centrifugation at 10,00 rpm. Then take a filtrate in conical flask. Then, add 0.07N K2Cr2O7 and conc. H2SO4 as well as orthophosphoric acid digest at 1500 C for 30 min and cool it. Then titrate against 0.035 N ferrous ammonium sulphate.

Acid hydrolysable carbohydrate (g kg-1)

It was assessed by Soil sample reflux with 6M H2SO4 method as per given by Cheshire and Mundie (1966). Anthrone was used to estimate carbohydrate.

CO2 Evolution, organic matter decomposition in soil (g kg-1)

It was determined by organic matter decomposition in soil through carbon dioxide evolution by Alkali Trap Method. The method involves absorption of CO2 evolved during a given period of time in a known volume and strength of alkali (NaOH). When CO2 is absorbed in 0.5N NaOH it is converted to Na2CO3. The excess of NaOH titrated against standard 0.5N H2SO4. prior to titration with H2SO4. Few ml of saturated BaCl2 solution is added to NaOH solution to precipitate the Na2CO3 as BaCO3, Otherwise CO3 in Na2CO3 consumes H2SO4 and underestimate CO2 evolution.

RESULT & DISCUSSION

1. Inorganic carbon

The inorganic carbon content of soil ranged from 18.9 to 24.8 g kg^{-1}, with the highest value recorded under conventional upland (24.8 g kg^{-1}), followed by organic lowland (24.0 g kg^{-1}), INM lowland (21.5 g kg^{-1}), INM upland (21.0 g kg^{-1}) and conventional lowland (18.9 g kg^{-1}) (Table 1; Figure 1). The differences among the growing practices were non-significant at the 5% level. The relatively higher inorganic carbon under conventional upland and organic lowland may be related to differences in soil moisture regime, carbonate dynamics and the decomposition and stabilization of carbon-containing materials. Inorganic carbon is generally influenced more strongly by soil parent material, carbonate accumulation, pH and moisture conditions than by short-term management practices. Therefore, the non-significant variation observed in the present study indicates that the different paddy-growing practices had a comparatively limited effect on the inorganic carbon pool. Similar observations have been reported in long-term nutrient-management studies where management effects were more pronounced for organic and labile carbon fractions than for relatively stable carbon pools (Chaudhary et al, 2017; Saha et al, 2012).

2. Organic carbon

The organic carbon content varied from 5.15 to 6.28 g kg^{-1}, with the highest value under organic lowland (6.28 g kg^{-1}), followed by INM upland (6.20 g kg^{-1}), INM lowland (6.11 g kg^{-1}), conventional lowland (5.29 g kg^{-1}) and conventional upland (5.15 g kg^{-1}) (Table 1; Figure 1). Although the differences were statistically non-significant, the numerical increase in organic carbon under organic and INM practices indicates a beneficial influence of organic nutrient sources and integrated nutrient management on soil carbon accumulation. Organic inputs supply additional carbon substrates to the soil and stimulate microbial activity, residue decomposition and subsequent incorporation of carbon into soil organic matter. Long-term studies under rice-based systems have similarly demonstrated that the combined use of inorganic fertilizers with organic materials increases soil organic carbon compared with fertilizer-only treatments (Saha et al, 2012; Ghosh et al, 2012). In particular, integrated nutrient management has been reported to improve soil organic carbon and its fractions because organic materials provide direct carbon inputs while balanced mineral nutrition promotes greater crop biomass production and consequently greater carbon return to the soil (Bharadwaj et al, 2012).

3. Cold-water extractable organic carbon (CWOC)

The CWOC content ranged from 28.47 to 52.40 mg kg^{-1}, with the maximum value recorded under organic lowland (52.40 mg kg^{-1}), followed by INM upland (47.75 mg kg^{-1}), conventional lowland (46.43 mg kg^{-1}), conventional upland (38.94 mg kg^{-1}) and INM lowland (28.47 mg kg^{-1}) (Table 1; Figure 1). The differences among growing practices were significant at the 5% level, with a CD value of 8.34 mg kg^{-1}. The greater CWOC under organic lowland suggests enhanced accumulation of relatively labile and water-extractable carbon compounds resulting from the continuous addition and decomposition of organic materials. Water-extractable carbon represents a relatively dynamic fraction of soil organic carbon and can respond rapidly to changes in organic matter inputs and microbial activity. Similar findings have shown that organic amendments and integrated nutrient management enhance active carbon pools in rice soils, particularly through increased availability of decomposable carbon substrates (Benbi et al, 2015; Mi et al, 2016). Long-term INM studies have also demonstrated that the addition of organic materials with mineral fertilizers improves soil organic carbon fractions and carbon sequestration compared with mineral fertilization alone (Bharadwaj et al, 2012).

4. Hot-water extractable organic carbon (HWOC)

The HWOC content ranged from 53.34 to 66.20 mg kg^{-1}, and the highest value was recorded under organic lowland (66.20 mg kg^{-1}), followed by conventional lowland (64.36 mg kg^{-1}), INM lowland (61.12 mg kg^{-1}), conventional upland (57.05 mg kg^{-1}) and INM upland (53.34 mg kg^{-1}) (Table 1; Figure 1). The differences were significant at the 5% level, with a CD of 5.75 mg kg^{-1}. The higher HWOC under organic lowland may be attributed to the greater supply of easily decomposable organic substrates and enhanced microbial transformation of organic residues. Hot-water extractable carbon is considered a sensitive fraction of soil organic matter because it responds to changes in organic inputs and microbial decomposition. The present findings are in agreement with long-term rice–wheat studies showing that organic manure and residue incorporation increase hot-water-soluble and other labile carbon fractions compared with inorganic fertilizer management alone (Benbi et al, 2015). Similarly, integrated application of organic amendments and NPK has been reported to increase labile soil carbon fractions, reflecting enhanced carbon cycling under organic and integrated nutrient management systems (Mi et al, 2016; Chaudhary et al, 2017).

5. Readily oxidizable carbon (ROC)

The ROC content varied from 116.98 to 194.76 mg kg^{-1}, with the maximum value observed under organic lowland (194.76 mg kg^{-1}), followed by INM upland (191.28 mg kg^{-1}), conventional upland (179.74 mg kg^{-1}), INM lowland (157.74 mg kg^{-1}) and conventional lowland (116.98 mg kg^{-1}) (Table 1; Figure 1). Although the numerical variation was considerable, the differences among the growing practices were non-significant at the 5% level, with a CD value of 49.77 mg kg^{-1}. The greater ROC under organic lowland and INM upland indicates a tendency toward greater accumulation of readily decomposable and oxidizable carbon under systems receiving organic or integrated nutrient inputs. Readily oxidizable carbon is a sensitive indicator of changes in soil organic matter quality and is generally enhanced by continuous organic material addition, residue return and improved crop growth. Long-term studies have demonstrated that integrated application of organic manures and inorganic fertilizers can increase labile and oxidizable carbon pools by increasing carbon inputs and promoting microbial transformation of plant residues (Benbi et al, 2015; Chaudhary et al, 2017). Similarly, long-term INM in rice-based systems has been reported to enhance active carbon fractions and carbon sequestration, particularly where organic sources are combined with balanced mineral fertilization (Bharadwaj et al, 2012; Saha et al, 2021).

CONCLUSION

Overall, the results indicate that organic lowland consistently maintained higher organic carbon and most of the active carbon fractions, particularly CWOC, HWOC and ROC, whereas the differences in inorganic carbon and total organic carbon were not statistically significant. The stronger response of the labile fractions suggests that these pools were more sensitive to differences in paddy-growing practices than the comparatively stable carbon pools. This agrees with long-term rice-based experiments showing that labile carbon fractions respond more readily to organic amendments and integrated nutrient management than total soil carbon, and that combining organic materials with balanced mineral fertilization can improve soil carbon sequestration and soil quality (Bharadwaj et al, 2012; Benbi et al, 2015; Chaudhary et al, 2017).

Table 1. Carbon pools at maturity stage of Paddy in various growing practices

Paddy Growing Practice	Inorganic carbon	Organic carbon	CWOC	HWOC	ROC
	g kg-1		mg kg-1		

Conventional Lowland	18.9	5.29	46.43	64.36	116.98
Organic Lowland	24.0	6.28	52.40	66.20	194.76
INM Lowland	21.5	6.11	28.47	61.12	157.74
Conventional Upland	24.8	5.15	38.94	57.05	179.74
INM Upland	21.0	6.20	47.75	53.34	191.28
SE (m)+-	0.73	0.52	2.83	1.95	16.87
CD at 5%	NS	NS	8.34	5.75	49.77

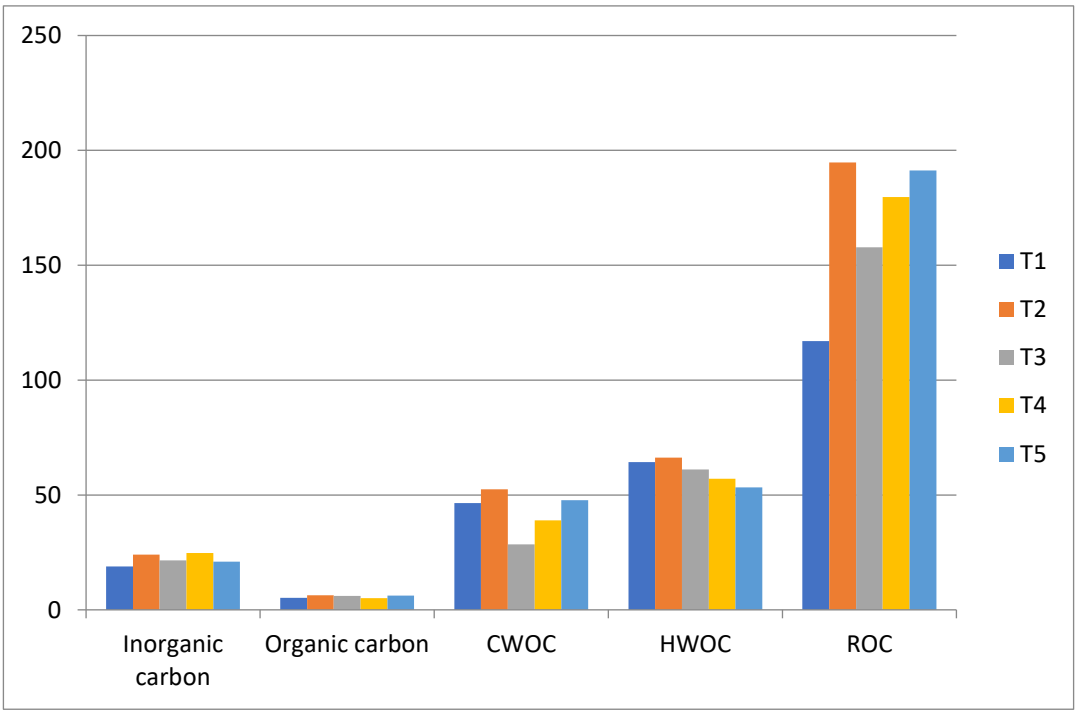


Figure 1.Carbon pools at maturity stage of Paddy in various growing practices

REFERENCES

1. Benbi, D. K., Kiranvir, B. R. A. R., & SHARMA, S. (2015). Sensitivity of labile soil organic carbon pools to long-term fertilizer, straw and manure management in rice-wheat system. Pedosphere, 25(4), 534-545.
2. Blair, G. J., Lefroy, R., Whitbread, A., Blair, N., & Conteh, A. (2001). The development of the KMnO4 oxidation technique to determine labile carbon in soil and its use in a carbon management index. Assessment methods for soil carbon, 323-337.
3. Chaudhary, S., Dheri, G. S., & Brar, B. S. (2017). Long-term effects of NPK fertilizers and organic manures on carbon stabilization and management index under rice-wheat cropping system. Soil and Tillage Research, 166, 59-66.
4. Cheshire, M. V. and C. M. Mundie, 1966. The hydrolytic extraction of carbohydrates from soil by sulphuric acid. Journal of Soil Science, 17: 372-381.
5. Ghimire, R., Lamichhane, S., Acharya, B. S., Bista, P., & Sainju, U. M. (2017). Tillage, crop residue, and nutrient management effects on soil organic carbon in rice-based cropping systems: A review. Journal of integrative agriculture, 16(1), 1-15.
6. Ghosh, M., Ashiq, W., Bhogilal Vasava, H., Gamage, D. N. V., Patra, P. K., & Biswas, A. (2021). Short-term carbon sequestration and changes of soil organic carbon pools in rice under integrated nutrient management in India. Agriculture, 11(4), 348.
7. Liu, Y., Ge, T., Zhu, Z., Liu, S., Luo, Y., Li, Y., ... & Kuzyakov, Y. (2019). Carbon input and allocation by rice into paddy soils: A review. Soil Biology and Biochemistry, 133, 97-107.
8. Mc Gill, W. B., K. R. Cannon, J. A. Robertson and F. D. Cook, 1986. Dyanamics of soil microbial biomass and water soluble organic carbon in Breton 1 after 50 years of cropping in to two rotations. Journal of Soil Science 66: 17-19.
9. Mi, W., Wu, L., Brookes, P. C., Liu, Y., Zhang, X., & Yang, X. (2016). Changes in soil organic carbon fractions under integrated management systems in a low-productivity paddy soil given different organic amendments and chemical fertilizers. Soil and Tillage Research, 163, 64-70.
10. Zhu, L., Li, J., Tao, B., & Hu, N. (2015). Effect of different fertilization modes on soil organic carbon sequestration in paddy fields in South China: a meta-analysis. Ecological indicators, 53, 144-153.