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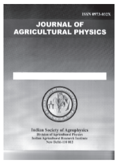

Research Article

Effect of No-tillage Practices on Carbon Management Indices in a Sandy Loam Soil of India

G.K. DINESH[1]*, D.K. SHARMA[1]*, S.L. JAT[2], K.K. BANDYOPADHYAY[3], PRAVEEN KADAM[2], SETHUPATHI NEDUMARAN[1], ARTI BHATIA[1], PRAMOD KUMAR[4], T.J. PURAKAYASTHA[5] AND ANJALI ANAND[6]

[1]Division of Environment Science, [2]Division of Agronomy, [3]Division of Agricultural Physics, [4]Division of Agricultural Economics, [5]Division of Soil Science and Agricultural Chemistry, [6]Division of Plant Physiology, ICAR-Indian Agricultural Research Institute, New Delhi-110012, India

ABSTRACT

After six years of continuous Conservation Agriculture practices, we investigated the impact of crop residue retention and GreenSeeker N fertiliser supply on soil carbon indices. The lability of carbon appears to be more in zero tillage without residues (ZTWoR) plots than zero tillage with residues (ZTWR). More carbon pools were observed in 33%N+GS and 50%N+GS treatments, and the trend was 33%N+GS > 50%N+GS > 70%N+GS or RDN. CMI was higher in the 15-30 cm layer than the 0-15 cm soil layer. CMI values were high in the residue-retained plots compared to non-residue retained plots. In ZTWR plots, CMI values ranged from 150.22±7.37 and in ZTWoR plots, values ranged from 145.33±1.09. From the study, Zero tillage with residue retention improves CMI values in the soil; hence it is recommended to improve the soil fertility and quality.

Key words: Carbon management indices, Carbon pools, Conservation agriculture, Maize-wheat-mung bean

Introduction

Soil organic carbon and its indices are a vital component of soil quality and aid climate change mitigation and food security. It has been estimated that around 30% of India's SOC content is lost due to crop residue loss. The loss of SOC concentration is a significant barrier to the Indian agricultural system. Unfortunately, in India, the increasing population is causing major pressure on agricultural systems in many world regions, frequently resulting in soil resource degradation (Blair *et al.*, 1995). Soil carbon is a fundamental indicator of agricultural system sustainability. Because of conventional tillage (CT), which is highly intensive, its continued use in crop production poses several agricultural challenges, including water and labour shortages (Jat *et al.*, 2021), loss of soil organic carbon (SOC) due to accelerated oxidation (Zhang *et al.*, 2008), increased greenhouse gas (GHG) emissions (Yan *et al.*, 2006), loss of vital plant-available nutrients (Alam *et al.,* 2014), poor soil health (Aggarwal *et al.*, 2017), and reduces agricultural sustainability (Memon *et al.*, 2018). Even though the quantity of soil organic carbon (SOC) in Indian soils is meagre, frequently less than 0.5 per cent, its impact on soil fertility and physical condition is significant (Swarup *et al.*, 2019). In this context, Conservation agriculture (CA) has gained importance and emerged as an effective technique to improve SOC and concerns about agricultural sustainability around the world. CA

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*Corresponding author,
Email: gkdineshiari@gmail.com

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techniques cover around 8% of the world's arable land (124.8 million hectares) (Bhattacharya *et al.,* 2020). The practice of zero tillage and CA has grown to roughly 1.5 million hectares in the last few years (Jat *et al.*, 2012). CA practices improve soil physicochemical and biological properties by increasing the soil micro and macrofauna (Sharma *et al.*, 2017).

Lefroy *et al.* (1993) advocated changes in soil carbon lability as a measure of sustainability. Effects of fresh crop residues added where visible in labile SOC fractions acquired during oxidation stages can be an effective tool for measuring changes in soil quality (Weil *et al.*, 2003; Luan *et al.*, 2010, 2014). Blair *et al.* (1995) and Bayer *et al.* (2009) advocated that soil carbon management indices are effective early predictors of soil quality. According to Weil *et al.* (2003), some fractions of SOC are essential determinants of soil quality. High CMI values are often correlated with high soil quality (Blair *et al.*, 1995; Bayer *et al.*, 2009). The Carbon Management Index is a sensitive assessment of the rate of change in the system's soil carbon dynamics compared to a more stable reference soil (Bronson *et al.*, 1998). Previous studies by Moharana *et al.* (2012) and Ghosh *et al.* (2018) found that CMI decreases with soil depth in a traditional pearl millet-wheat and maize-wheat cropping system. Hence, CMI is a better metric for assessing the competence of management methods that enhance soil quality. In a maize-wheat system, Gong *et al.* (2009) found that an 18-year-old field with organic fertiliser and N-fertilizer increases CMI.

There are few studies on the impact of residue retention and removal on changes in carbon management indices in the Maize-Wheat-Mung bean-based cropping system in South Asia. After six years of CA in the IGP in northwest India, the current study evaluated the impacts of crop residues and precision nitrogen management on carbon management indices in sandy loam soil.

Materials and Methods

Description of the experimental site and climate

A field experiment was undertaken at a permanent site in Block 9B of the research farm, ICAR-Indian Agricultural Research Institute, New Delhi, India, over six years (2012-2018). (28°40′ N, 77°12′ E, 228.6 m altitude). The experimental site has sandy loam soil (Typic Haplustept), a hot and dry summer environment, and a cold winter climate, with an average annual rainfall of 650 mm. Soil samples were taken in triplicate across the treatment. They were collected before the commencement of the 2018 growing season before maize was planted. First, the basic properties of soil were investigated. The parameters are soil organic carbon (Walkley and Black 1934), available soil nitrogen (Subbaiah and Asija 1956), available phosphorus (Olsen *et al.* 1954), and available potassium (Prasad 1998). The pH of the soil is 7.8, the electrical conductivity is 0.42 dS m^{-1}, the soil organic carbon content is 4.69 mg kg^{-1}, the available nitrogen is 162.8 kg ha^{-1}, available phosphorus is 15.2 kg $ha^{-1,}$ and available potassium is 152.2 kg ha^{-1}.

Experimental layout and management practices

The research lasted two years and included three seasons: 2018-19 and 2019-20. With a split-plot experiment design and a conventional plot size of 6 x 5 m, the experiment comprises two main plots and four subplot treatments with three plot replications. Maize (cv. PMH 1) was planted in mid-July, wheat (cv. HD 2967) in the first week of November, and summer mung bean (cv. Pusa Vishal) in mid-April. Residue management practices as main plot [ZTWoR, zero tillage without residue and ZTWR, zero tillage with residue retention], and 4-precision nitrogen management options for sub-plot treatments [Recommended dose of fertiliser with 3-splitting (RDN), 33% basal RDN followed by Green Seeker N application (33%N+GS), 50% basal RDN followed by Green Seeker N application (50%N+GS), 70% basal RDN followed by Green Seeker N application (70%N+GS)] as sub-plot treatments. The amount of fertiliser applied was 150:60:40, 120:60:40, 18:46:0 (kg ha^{-1}) for Maize-Wheat-Mung bean, respectively.

Collection and processing of soil samples

To get composite and homogeneity samples, each sample from each plot was obtained at three random sites in July 2018 and 2019. The samples were collected from 0-15 cm and 15-30 soil depths. A core sampler was used to collect samples from all 24 plots (with replications). The collected soil samples are grounded and passed through a 0.2-mm sieve before being used to determine soil characteristics (Page, 1982; Ghosh *et al.,* 1983).

Analysis of soil parameters

Carbon indices

Various standard formulas were used to estimate the Carbon management index (CMI), Lability of carbon (LOC), Carbon Pool Index (CPI), and Lability Index of C (LIC) (Blair *et al.,* 1995; Majumder *et al.,* 2007, 2008).

$$Lability\ of\ carbon\,(LOC) = \frac{VLSOC + LSOC}{NLSOC}$$

The loss of C from an extensive carbon pool soil is less effective than the loss of the same volume of Carbon from a Carbon pool soil already exhausted or started with a smaller total C pool. Likewise, the more carbon deficient soils are, the harder it is to rehabilitate. The reference soil is sandy loam in Indo-Gangetic Plain (Jat *et al.,* 2019a). Carbon Pool Index is estimated to account for this as:

$$Carbon\ Pool\ Index\,(CPI) = \frac{Sample\ total\ SOC}{Reference\ total\ SOC}$$

The consequence of the depletion of labile C is greater than that of nonlabile C. Carbon Lability Index is measured to account for this as:

$$Lability\ Index\ of\ Carbon\,(LIC) = \frac{VLSOC \times 3}{TOC} + \frac{LSOC \times 2}{TOC} + \frac{LLSOC \times 1}{TOC}$$

The Carbon Management Index is an evaluation model that indicates how specific land-use influences soil quality compared to reference soil (Sainepo *et al*., 2018). The sustainability of the C supply depends on the overall size of the pool, all of which must be considered when the carbon management index is derived (Blair *et al.*, 1995). Therefore, there is no advisable CMI value. However, CMI can be used in experimental plots to track variations in the dynamics of soil C between treatments and over time.

$$Carbon\ management\ index = CPI \times LI \times 100$$

Statistical analysis

The degree of significance, p-values, and correlation values created using r-program version 1.4.1103 (R Core Team, 2013) were evaluated (Gomez and Gomez, 1984; Rangaswamy, 2018). At a 5% level of significance ($P \leq 0.05$), the least significant difference test was employed to determine the effects of treatments (Zhu, 2016; Buchan, 2020).

Results and Discussion

Carbon pools

The ZTWoR 70%N+GS treatment had the greatest non-labile carbon pool (2.92 g kg^{-1}), and the lowest was observed in the ZTWoR 33% N+GS treatment (1.22 g kg^{-1}). Non-labile carbon pools were greater in ZTWR plots than in ZTWoR plots in general. Due to the constant retention of the previous crop residues in the past six years, the lower soil layer (15-30 cm) showed the same pattern in very labile carbon pools in the research year 2018. (Fig. 1). The topsoil layer (0-15 cm) with very labile and labile carbon pools follows nearly the same pattern in the second research year (*i.e.*) 2019. (Fig. 2). In the second study year, the non-labile carbon pool in ZTWR plots was about double that of ZTWoR plots at both soil layers. The very labile carbon pools were lowest in the bottom soil layer (15-30 cm) when treated with ZTWoR 50% N+GS (1.03 g kg^{-1}) and greatest in ZTWR 33% N+GS (1.44 g kg^{-1}). ZTWR 33% N+GS treatment (2.02 g kg^{-1}) had the greatest non-labile carbon pool (2.02 g kg^{-1}), and ZTWoR 50% N+GS treatment had the lowest (1.054 g kg^{-1}).

The four carbon pools were evenly distributed throughout the soil profile's two depths. As a result, compared to ZTWoR plots, ZTWR plots feature larger SOC pools (Tigga *et al.,* 2020). Tillage and residue management substantially impacted various SOC fractions at the surface soil depth (0-15 cm), but significant variations between treatments were identified in the 15-30 cm layer. The highly unstable topsoil layer (0-15 cm) was marginally higher in the ZTWR plots than in the ZTWoR plots in the research year 2018. (Fig. 1). This is due to crop leftovers left on the field from previous crops (Jat *et al.,* 2019b).

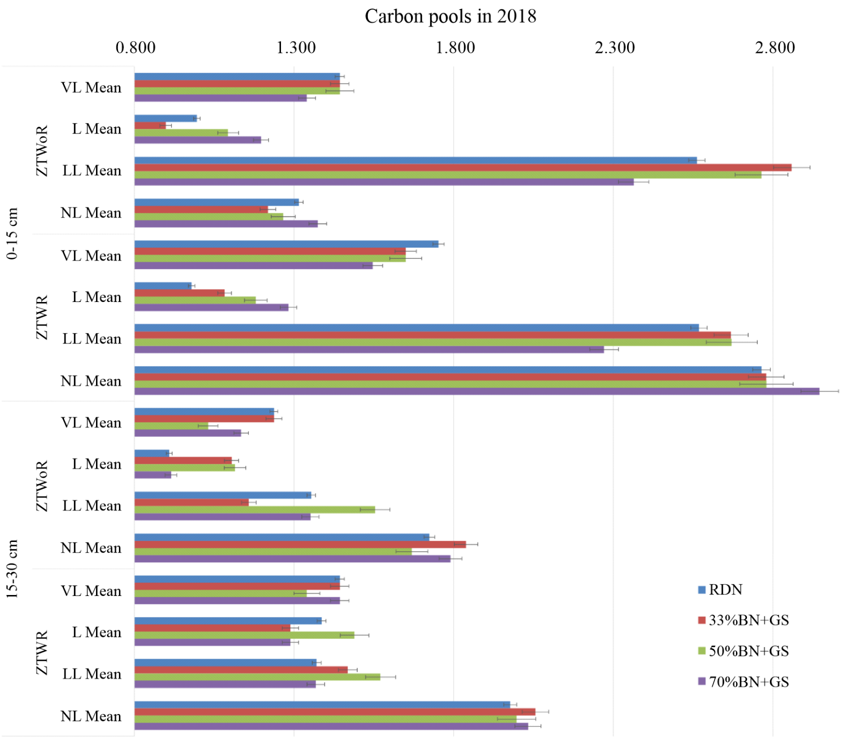

Fig. 1. Effect of residue and precision nutrient management on the carbon pools in 2018

Notes: RDN = The recommended dose of fertilizer with 3 (Ad-hoc) splitting; 33+GS = 33% basal RDN followed by Green Seeker N application; 50+GS = 50% basal RDN followed by Green Seeker N application; 70% basal RDN followed by Green Seeker N application; ZTWoR = Zero Tillage Without Residue; ZTWR = Zero Tillage with Residue; CA = Conservation Agriculture; RM = Residue management; NM = Nutrient Management

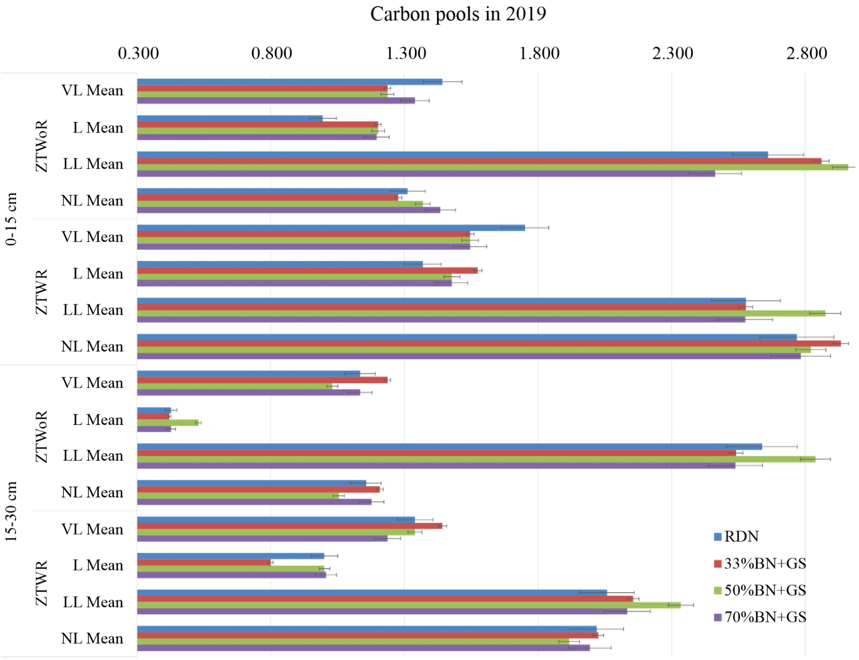

Fig. 2. Effect of residue and precision nutrient management on the carbon pools in 2019

Notes: RDN = The recommended dose of fertilizer with 3 (Ad-hoc) splitting; 33+GS = 33% basal RDN followed by Green Seeker N application; 50+GS = 50% basal RDN followed by Green Seeker N application; 70% basal RDN followed by Green Seeker N application; ZTWoR = Zero Tillage Without Residue; ZTWR = Zero Tillage with Residue; CA = Conservation Agriculture; RM = Residue management; NM = Nutrient Management

Lability of carbon (LOC)

Lability refers to the measurement of lability, a ratio of the labile carbon to the non-labile carbon (Chatterjee *et al*., 2018). The loss of labile C is of more significant consequence than the loss of nonlabile Carbon (Blair *et al.,* 1995; Whitbread *et al.,* 1996). To account for this, a carbon Lability Index is calculated as SOC lability, which refers to the relative ease and pace of decomposition, relies on chemical recalcitrance and physical protection against microorganisms (McLauchlan and Hobbie 2004). Bhattacharyya *et al*. (2012) and Dey *et al*. (2018) reported significantly higher C under CA than CT. In general, LOC values are higher in 2018 than in 2019. In 2019, ZTWoR plots had less LOC values than in 2018 (Fig. 3).

There is no noticeable difference among different nitrogen treatments with respect to the lability of carbon. In general, to our experiment, the lability of carbon appears to be more in zero tillage without residues (ZTWoR) plots than zero tillage with residues (ZTWR). To account for this, because the turnover of labile carbon releases nutrients and the labile carbon portion of SOM appears to be of particular importance in affecting soil physical factors (Whitbread 1995). In general, the contribution of active SOC to the surface soil was higher, while there was a transition in the lower depth to passive pools (Fig. 3). The same results were reported by Tigga *et al*. (2020).

Labile soil organic matter originated primarily from the decomposition of plant and faunal biomass, root exudates, and microbial biomass (Bolan *et al*., 2011). The addition of Organic matter to the surface soil layer and minimised tillage can improve labile organic carbon within soils (Cooper *et al.,* 2016). Furthermore, Mandal *et al*. (2019) and Panettieri *et al*. (2015) reported that these approaches could increase C and N cycling and soil aggregation, among the critical processes that organic carbon is stored in the soil.

Carbon Pool Index (CPI)

Carbon Pool Index (CPI) provides information about the change in the carbon pools compared to reference soil data. In this analysis, the authors

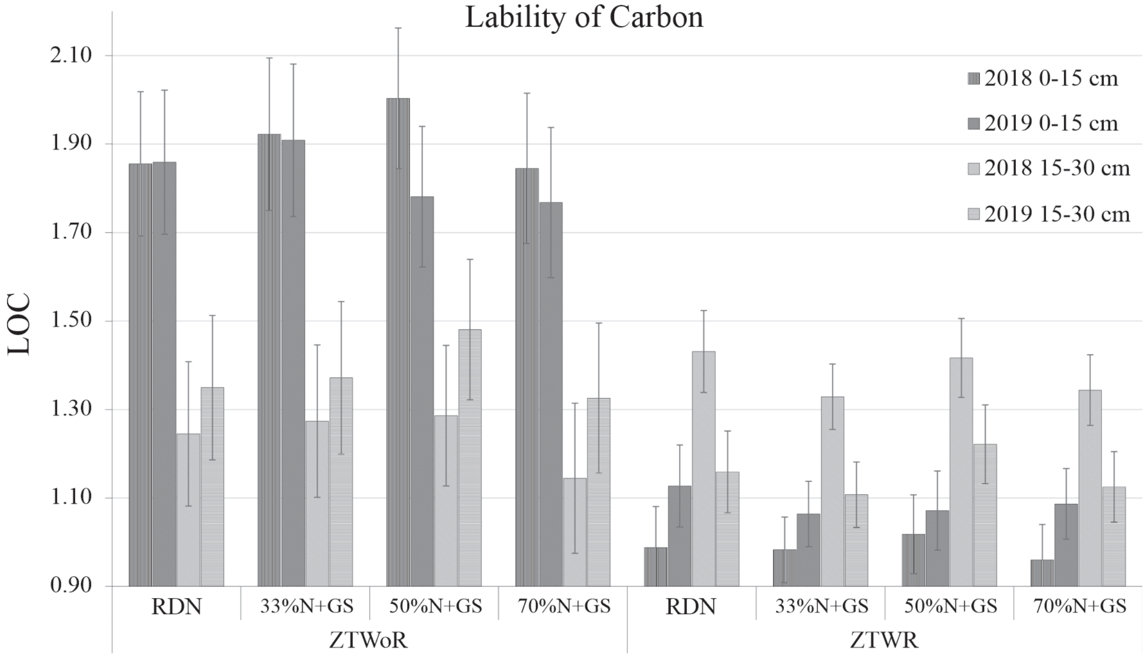

Fig. 3. Effect of residue and precision nutrient management on the lability of carbon

Notes: RDN = The recommended dose of fertilizer with 3 (Ad-hoc) splitting; 33+GS = 33% basal RDN followed by Green Seeker N application; 50+GS = 50% basal RDN followed by Green Seeker N application; 70% basal RDN followed by Green Seeker N application; ZTWoR = Zero Tillage Without Residue; ZTWR = Zero Tillage with Residue; CA = Conservation Agriculture; RM = Residue management; NM = Nutrient Management adopted the reference data from Jat *et al*. (2019). The carbon Pool Index showed that more Carbon pools were noticed in residue plots (ZTWR) than non-residue plots (ZTWoR) (Fig. 4).

In the first study year 2018, at the topsoil layer, ZTWoR plots have CPI 1.04±0.04 and ZTWR plots having 1.17±0.03, which is 13% higher than ZTWoR plots (fig 2). In the bottom soil layer, ZTWoR plots have 1.11±0.04 CPI, and ZTWR plots have 1.17±0.03, which is 6% higher. It is mainly due to the retention of previous crop residues in the field, and if it is incorporated rather than retained, CPI may increase in the bottom soil layers. The same trend follows in the second study year, 2019, in ZTWR plots. CPI is higher by 16% in the topsoil layer and 8% in the bottom soil layer, with the values ranging from 1.20 to 1.21. Thus, CPI values are generally higher in ZTWR plots by 6 to 16% than ZTWoR plots.

More carbon pools were observed in 33% N+GS and 50% N+GS treatments, and the trend will be 33% N+GS > 50% N+GS > 70% N+GS and RDN. In general, when compared to 2018, more Carbon Pool was observed in 2019 compared to non-residue retained plots. More CPI values were observed in ZTWR plots by 5 to 15% than without residue and residue plots. It is due to the addition of crop residues after the harvesting of every crop (Jat *et al*., 2019).

Plots under ZTWR had a higher labile SOC concentration than that under ZTWoR. The enormous amount of residue retention also exceeds the potential of microbes for their humification or decomposition into CO_2; hence upsurge in labile SOC pools is thus expected in ZTWR plots (Dey *et al.,* 2018).

On the other hand, prolonged soil non-disturbance under ZTWR guarantees moistened conditions that are congenial to developing a passive carbon pool (Jat *et al.,* 2019a; Parihar *et al.,* 2020). The labile SOC has enough time to convert to non-labile SOC pools, eventually upgrading both the labile and non-labile pools (Dey, 2016; Dey *et al*., 2018). These resulting developments in labile and

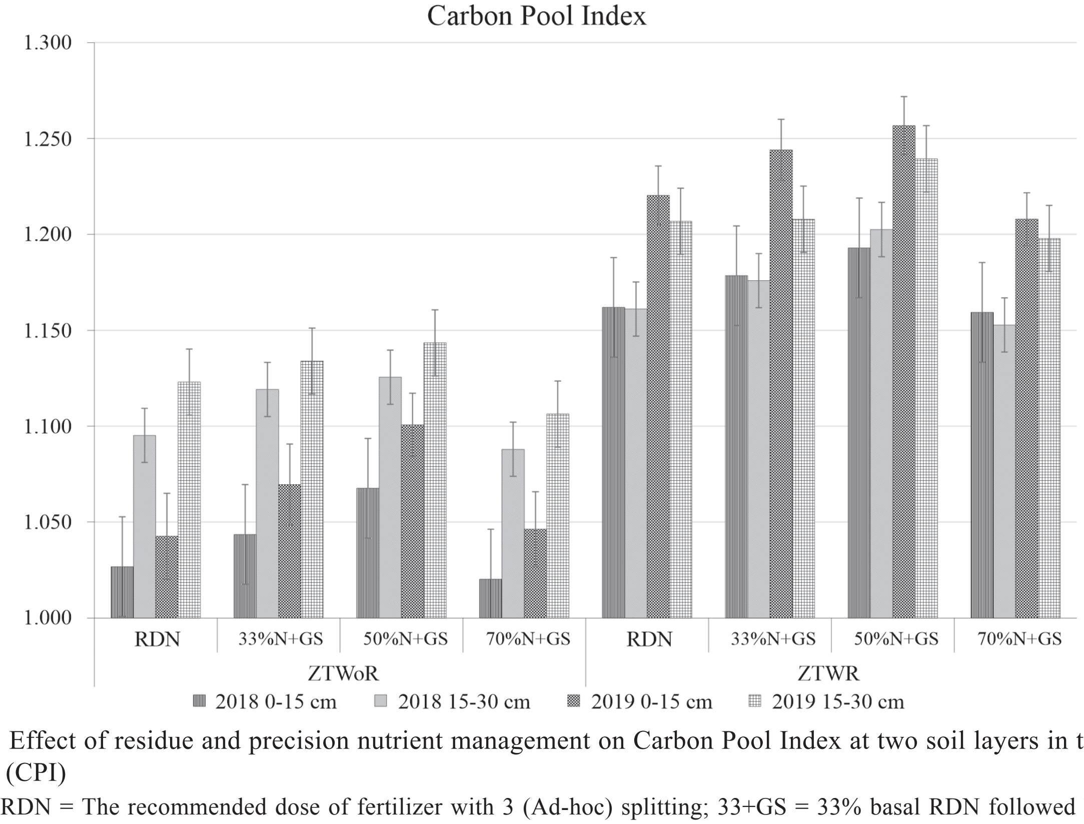

Fig. 4. Effect of residue and precision nutrient management on Carbon Pool Index at two soil layers in the study period (CPI)

Notes: RDN = The recommended dose of fertilizer with 3 (Ad-hoc) splitting; 33+GS = 33% basal RDN followed by Green Seeker N application; 50+GS = 50% basal RDN followed by Green Seeker N application; 70% basal RDN followed by Green Seeker N application; ZTWoR = Zero Tillage Without Residue; ZTWR = Zero Tillage with Residue; CA = Conservation Agriculture; NM = Nutrient Management; Y = Year passive SOC. While most rhizodeposits enhance labile SOC pools, Non-labile SOC has contributed to root biomass (Manzoni *et al.,* 2010; Cotrufo *et al.,* 2013).

Lability Index of Carbon (LIC)

More Lability Index of Carbon (LIC) values was observed in ZTWoR main plots than ZTWR main plots. In ZTWoR plots, compared to 2018, LIC values were comparatively lower in 2019, implying lability was high and soil was more prone to lability and became unstable. In subplot N treatments, there is no noticeable trend observed (Fig. 5). In the topsoil layer (0-15 cm), ZTWOR plots were slightly high LIC values in 2018, reducing in 2019. However, in ZTWR plots, the LIC values are nearly 11% higher in 2019 (1.37±0.03) compared to 2018 (1.22±0.03).

In the bottom soil layer (15-30 cm), in both ZTWoR and ZTWR plots, LIC values decreased in 2019 compared to 2018. However, the variation in decreasing LIC values are higher in ZTWR plots than ZTWR plots, and it is due to residue retention of the previous season crop (Tigga *et al.,* 2020).

Carbon Management Index (CMI)

The Carbon Management Index (CMI) is based on the SOC and C lability content and may represent soil management activities in promoting soil quality (Yang *et al.,* 2018). Furthermore, in a few pieces of literature, Carbon Management Index (CMI) was also mentioned as Carbon Pool Management Index (CPMI) (Zhang *et al.,* 2020). Therefore, to determine SOC variance rates in response to soil management activities, the carbon pool management index (CPMI) is essential.

The data shows that more carbon management is needed for 0-15 cm soil depth as fewer carbon fractions. CMI was higher in the 15-30 cm layer than the 0-15 cm soil layer (Table 1). Similar results were reported by Fang *et al*. (2015). Comparing main plot treatments, ZTWR main plots require less Carbon management practices when compared to ZTWoR

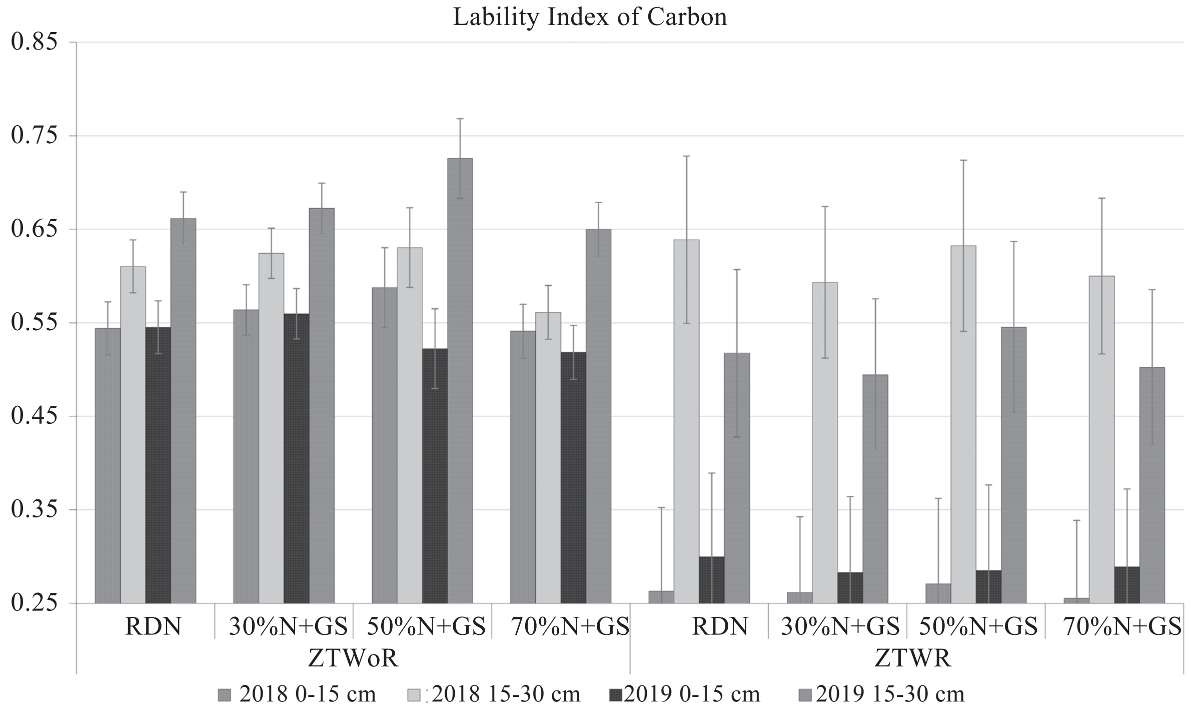

Fig. 5. Effect of residue and precision nutrient management on Lability Index of Carbon

Notes: RDN = The recommended dose of fertilizer with 3 (Ad-hoc) splitting; 33+GS = 33% basal RDN followed by Green Seeker N application; 50+GS = 50% basal RDN followed by Green Seeker N application; 70% basal RDN followed by Green Seeker N application; ZTWoR = Zero Tillage Without Residue; ZTWR = Zero Tillage with Residue; CA = Conservation Agriculture; NM = Nutrient Management; Y = Year

Table 1. Effect of residue and precision nutrient management on Carbon Management Index

RM	PNM	2018		2019	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
ZTWOR	RDN	144.4	144.3	146.1	144.5
	33%N+GS	146.1	148.4	146.0	148.8
	50%N+GS	150.9	144.2	147.6	146.6
	70%N+GS	142.7	138.0	144.3	142.5
ZTWR	RDN	141.0	159.3	152.4	151.9
	33%N+GS	140.9	157.4	149.4	152.0
	50%N+GS	143.8	161.1	150.9	157.1
	70%N+GS	136.5	155.5	146.6	147.7
MP mean	ZTWoR	146.03	143.72	145.98	145.58
	ZTWR	140.56	158.33	149.80	152.19
SP Mean	RDN	142.71	151.78	149.21	148.23
	33%N+GS	143.52	152.91	147.68	150.39
	50%N+GS	147.34	152.63	149.23	151.85
	70%N+GS	139.62	146.77	145.45	145.09

Notes: RDN = The recommended dose of fertilizer with 3 (Ad-hoc) splitting; 33%N+GS = 33% basal RDN followed by Green Seeker N application; 50%N+GS = 50% basal RDN followed by Green Seeker N application; 70%N+GS = 70% basal RDN followed by Green Seeker N application; ZTWoR = Zero Tillage Without Residue; ZTWR = Zero Tillage with Residue.

main plots. However, interesting and noticeable results were observed in CMI. In the residue retained plots, CMI values were high compared to non-residue retained plots, mainly due to the retention of previous crop residues. (Blair *et al.,* 2006) found that residues combined with inorganic fertiliser significantly boosted CMI in a long-term experimental trial. To get the maximum yield and productivity, carbon management is crucial in non-residue plots (Blair *et al.,* 1995). Hence, further Carbon management practice is not required in residue-retained plots as the residue retained in the soil is fair enough to achieve the desired maximum yield by increasing the soil carbon and its pools. In concise, more carbon management is necessary for the bottom 15-30 cm soil layer and non-residue retained plots. In ZTWR plots, CMI values ranged from 150.22±7.37 and in ZTWoR plots, values ranged from 145.33±1.09. The highest CMI value, 161.1, was observed in the 50%N+GS ZTWR plot of the bottom 15-30 cm soil layer (Table 1), but this is in contrast to the studies done by Venkatesh *et al.* (2013). According to the study, agricultural residues enhanced the CMI in surface soils more than the subsurface layer, but the rise in CMI found in inorganic fertilizer plots was almost the same at both soil levels. This is because of the yearly increase in C input, affecting carbon to transform into an oxidised form (Tirol-Padre and Ladha, 2004). However, supporting our results, the maize-wheat study conducted in China by Jiao *et al.* (2020), rice-wheat straw incorporation study in North-Western India by (Sharma *et al.,* 2020) and rice-based study in the eastern plateau region of India by (Saha *et al.,* 2021) reported increased CMI values with soil depths. Residue retained plots are in excellent condition, and it may lead to an increase in yield and good soil quality in upcoming years, and the lowest CMI (138.0) was observed in the 70%N+GS ZTWoR plot (Table 1). High CMI levels may be linked to the usage of fertilisers in fields (Sainepo *et al.,* 2018). It has been discovered that using nitrogen-based fertilisers increases biomass, and consequently, soil organic matter also increases. These findings are similar to those of Vieira *et al.* (2007), who found that adding fertiliser and stubble to maize production systems increases the lability of SOM by 12-46 per cent and ultimately increases the CMI (Liu *et al.*, 2014). Because CMI is dependent on land use, there is no definite standard. Blair *et al.* (1995b) argued that higher CMI values imply carbon restoration, whereas lower CMI levels indicate carbon degradation. Furthermore, according to Benbi *et al.* (2015), proper land use with a higher CMI gives better C restoration alternatives.

Effect of Soil organic carbon pools as affected by nitrogen management

Very labile and less labile pools seemed to react more to nitrogen than other SOC fractions. High biomass output from increased N levels resulted in larger concentrations of fresh organic crop leftovers, effectively adding to SOC. Large dosages of basal N improve soil mineral N at harvest. High N fertiliser doses guarantee adequate soil N after crop and microbial absorption and early soil N loss, which raises SOC and establishes a long-term stable SOC (Chen *et al.,* 2009; Cotrufo *et al.,* 2013). According to Jat *et al.* (2019b), the massive quantity of aboveground biomass assured a tremendous amount of substrate for soil bacteria. Partial oxidation enhanced VLSOC, LSOC, and LLSOC in N-fertilized plots. Less mechanical work and better protection under N-fertilized plots promote C-sequestration. The N-fertilized plots had greater CPI and CMI values than the unfertilized plots (Jat *et al.,* 2019b). Carbon levels rise with crop residue and adequate inorganic fertiliser doses. The maximal N dosages at short time exhibited a considerable unfavourable influence on SOC build-up. In general, residue retention under PB increased SOC stability, but recalcitrant wheat residues contributed to LLSOC and NLSOC (Jat *et al.,* 2019b).

Pearson's Correlation analysis

In 2018 CMI values are highly positively correlated with 2018 LIC value (0.74), 2018 LOC (0.88), and it is negatively correlated with 2019 CPI value (-0.51) and 2018 CPI (-0.52) (Fig. 6). The 2018 LOC values are highly positively correlated with 2019 LIC values (0.83), 2018 LIC values (0.92) and negatively correlated with 2019 CPI values (-0.78) and 2018 CPI values (-0.79). The 2019 LIC values are highly positively correlated with 2018 LIC values (0.97) and both CPI values. 2019 CPI values have a perfect correlation with 2018 CPI values (1.0) CMI values are highly positively correlated with CPI values. 2019 CPI values have a very strong statistical significance level (P ≤ 0.001) with 2018 CPI values. LIC values have a very strong statistical significance level (P ≤ 0.001) with CPI values. In the bottom soil layer (15-30 cm), 2019 LIC values were negatively correlated with other soil indices (Fig. 7).

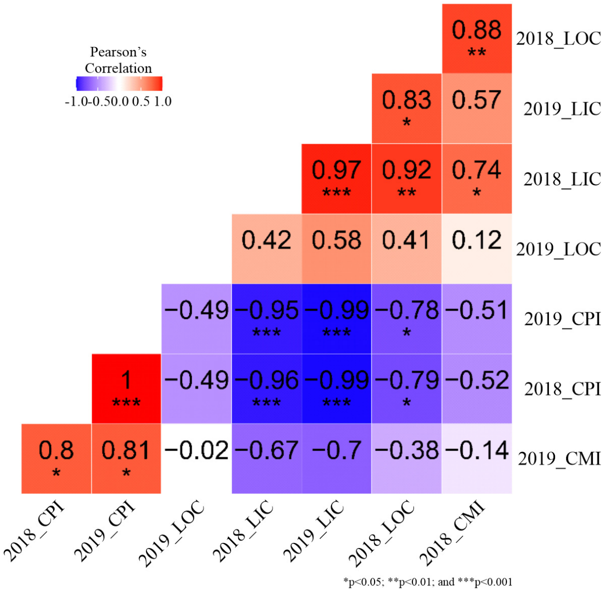

Fig. 6. Pearson's correlation analysis between various carbon indices in the topsoil layer

Notes: LoC – Lability of carbon; LIC - Lability Index of carbon; CPI – Carbon Pool Index; CMI – Carbon Management Index; *P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001

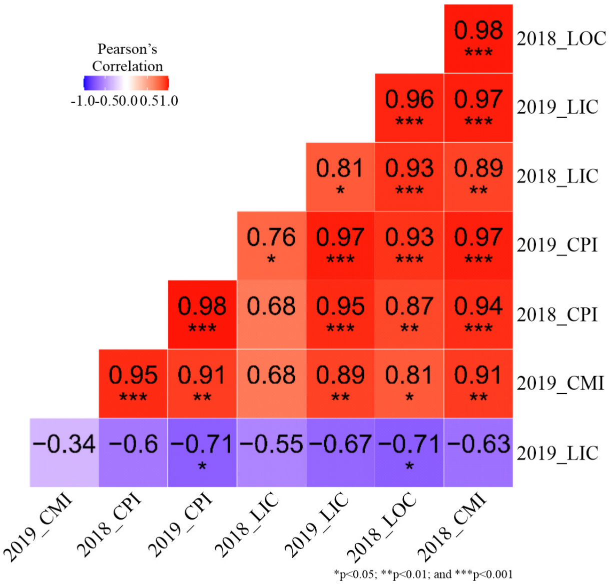

Fig. 7. Pearson's correlation analysis between various carbon indices in the bottom soil layer

Notes: LoC – Lability of carbon; LIC - Lability Index of carbon; CPI – Carbon Pool Index; CMI – Carbon Management Index; *P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001

Conclusion

The present study conclude that zero tillage with residue retention plots has more carbon pools and may build up recalcitrant carbon pools over a long period. Carbon lability appeared higher in zero tillage plots without residues (ZTWoR) than with residues plots (ZTWR). In ZTWoR plots, the range in decreasing lability index of carbon (LIC) values is more significant than in ZTWR plots. In addition, CMI values were lower in non-residue-retained plots than in residue-retained plots. The best CMI values registered in precision nitrogen treatment are 33%N+GS followed by 50%N+GS, 70%N+GS or RDN. Compared to non-residue retained plots, the residue-retained plots are outperformed better in terms of carbon pools and indices. Hence, conservation agriculture should utilize previous crop residues as a sustainable practice.

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