

Soil Organic Carbon Sequestration in Rice-Wheat System under Conservation and Conventional Agriculture in Western Chitwan, Nepal

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Abstract Soil organic carbon plays the crucial role in maintaining soil quality. The impact and rate of SOC sequestration in CA and conventional agriculture is still in investigation in this environment. A field experiment was initiated in 2011/12 and continued up to 2012/13 to compare the organic carbon buildup in the soil due to conservation and conventional agriculture. The soil organic carbon data represents the cumulative after five crop cycle. The treatments consisted conventionally tilled direct seeded rice followed by zero tilled wheat, conventionally tilled transplanted rice followed by conventionally tilled wheat, zero tilled direct seeded rice followed by zero tilled direct seeded wheat without residue retention, zero tilled direct seeded rice followed by direct seeded wheat with residue retention, permanent raised bed of rice followed by wheat without residue retention and permanent raised bed of rice followed by wheat with residue retention in randomized complete block design with three replications. About 4 t ha⁻¹ of standing rice and wheat crop and about 70% residue of moongbean was retained for succeeding crop in retained treatments. Soil samples from each treatments were collected from two soil depths (0-20 and 20-40cm) and analyzed. Result showed that, soil organic carbon buildup was affected significantly by tillage and residue level in upper depth of 0-20 cm but not in lower depth of 20-40 cm. Higher SOC content of 19.44 g kg⁻¹ of soil was found in zero tilled residue retained plots followed by 18.53 g kg⁻¹ in permanently raised bed with residue retained plots. Whereas, the lowest level of SOC content of 15.86 g kg⁻¹ of soil were found in puddled transplanted rice followed by wheat planted under conventionally tilled plots. Zero tilled residue retained plots sequestered 0.91 g kg⁻¹ yr⁻¹ SOC in the year 2012/13 which was 22.63% higher over the conventionally tilled residue removed plots after five seasons of experimentation. Therefore, CA in rice-wheat system can help directly in building-up of soil organic carbon and improve the fertility status of soil.

Keywords: soil organic carbon, CA, rice-wheat system, residue retention

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1. Introduction

Rice and wheat cropping system is very intensive (Tripathi, 2010) and more exhaustive (Beri *et al.*, 2002; Sharma and Behera 2011). Production and productivity of the system is very low (Regmi *et al.*, 2003). Declining or stagnant yield and impact on environment are major well known problems of cropping system (Khanal *et al.*, 2012).

Soil organic carbon is the fraction of organic matter; the decomposed plant and animal materials including microbial population. It is directly associated with nutrient availability, soil physical properties, and biological soil health and buffer actions over various toxic substances. Soil carbon level determined to the abundance of nutrient

and equilibrium of various nutrient elements (Bot and Benites, 2005). With the increase in the concentration of soil organic carbon, yield of the crop is increased directly especially in sandy loam soil (Rattan and Datta, 2011). The major cause of yield decline in this system is nutrient imbalance, which is associated with soil organic matter, declining over time where intensive cropping has been experienced (Ladha *et al.*, 2000).

The equilibrium level of SOC in the soil is the function of climate, soil and nature of vegetation (Rattan and Datta, 2011). The carbon content was decreased up to by 15% per unit increase in pH, increase by 1% per percent increase in clay content and decreased up to by 0.3% per percent increase in slope (Bronson *et al.*, 1997). It is the function of residue and roots (Bot and Benites, 2005).

Residue retention helps to maintain good soil structure, increase in biological activity in soil and supply important nutrient elements (Watson *et al.*, 2002). In general, rice residue after grain harvest has been used for animal feed, a valuable animal feed and wheat straw has been burned for the facilitation of summer ploughing. The rice straw feeding culture is more in case of small holder farmers especially. Farmers burn straw of rice-wheat field each year to facilitate the crop planting (Gupta and Seth, 2007).

Increasing level of soil organic carbon into soil not only enhance soil quality but also help to reduce GHGs emission; lowers climate change (Chan, 2008). About 8% of global energy used is used by agriculture in various farm operations including tillage, irrigation, harvesting and threshing; the rate has increasing (Tandon and Singh, 2009). Agriculture contributes about 20% of increase of annual GHGs emission by anthropogenic activity (Aydinalp and Cresser, 2008). Emission of carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) has major role in warming potential and this is mainly associated with rice based cropping system (Kumar and Ladha, 2011).

Emission of CO₂ and NO_x can be decreased by adopting reduced tillage and residue management (Lumpkin and Sayre, 2009) and nitrous oxide gas emission is greatly reduced in residue retained rice field (Bhattacharyya *et al.* 2012). Grace *et al.* (2003) reported the reduction of methane gas emission by adopting water and fertilizer management with selection of cultivars emits less methane. Singh and Sharma, (2005) showed up to 70 kg ha⁻¹ yr⁻¹ CO₂ emission from rice-wheat field to environment has reduced by adopting zero tillage in place of conventional tillage.

Conservation agriculture is holistic approach of crop production (Venkateswarlu *et al.*, 2009) and viable alternative to current crop production system which is sustainable, technically successful and economic (Derpsch and Friedrich, 2009b). CA technique provides equal or more productivity, improve soil health and higher farm profitability in sustainable way in comparison to conventional practice (Jat *et al.*, 2009). Former researchers in this reason Regmi *et al.* (2003), Ghimere *et al.* (2012) suggested the further researches to conclude about SOC sequestration in rice-wheat system under conventional and conservation agriculture. Therefore, with the aforementioned situation, aspects and needs, research had conducted with the objective to find out the SOC sequestration in the rice-wheat system under conventional and conservation agriculture.

2. Materials and methods

2.1 Experimental site and Cropping History

The experiment was conducted on research farm of Institute of Agriculture and Animal science (IAAS) Rampur, Chitwan. The trial was initiated during 2011 and treatments setup was started since May, 2011. Two crops, rice and wheat were planted during 2011/12. The fallow period between wheat and rice was utilized by growing moongbean other than conventional plots. 30% residue of rice and wheat was retained on some of the CA plots. In the experiment of 2012/13, 75% of moongbean residue on rice and 30% of Rice residue on wheat experiment was

retained on residue retained treatments. Therefore, data of soil organic carbon increase denotes five crop cycles.

The mean maximum temperature during the experimental period ranged from 21°C in January, 2013 to 35.1°C in June, 2012. The mean minimum temperature during the cropping period ranged from 1.83°C in January, 2013 to 28°C in August, 2012. No rainfall was recorded during November and December, 2012 and February, 2013. The highest rainfall during the experimental period was 485.5 mm in July, 2012. The total rainfall during the rice season was 1015.35 mm and maximum (485.55 mm) occurred during July. The average relative humidity during the experimental period ranged from 83.6% in April, 2012 to 99.6% in December, 2012.

The experiment was laid out in a randomized complete block design (RCBD) with three replications and 6 treatments. The net plot size was (6m x 6m) 36 m². Treatments were Conventional tilled dry direct seed Rice followed by Zero tilled wheat (CTDSR+ ZTW), Transplanted rice followed by conventional tilled wheat (TPR+CTW), Zero tilled rice followed by wheat without residue retention (ZTR-ZTW+RH), Zero tilled rice followed by wheat with residue retention (ZTR-ZTW+RR), permanent raised bed rice followed by wheat without residue retention (BPR-BPW+RH) and permanent raised bed rice followed by wheat without residue retention with residue retention (BPR-BPW+RR). Seeds were sown with 20cm spacing in continuous row in the treatments of direct seeded (conventional, zero and bed planting) rice and wheat but puddled transplanted rice, three seedlings per hill were transplanted in 20 x 20 cm² geometry. In bed planting, two continuous rows of rice and wheat seeds per bed were seeded directly on each bed. Manually operated locally made furrow opener was used for direct seeded rice while, manual transplanting was done in puddled transplanted treatment.

Composite samples were collected randomly from five different spots in each plot before and after each crop planted at two different depths of 0-20 cm and 20-40 cm using screw auger to record the initial and final physiochemical properties of the research field. The samples were shade/air dried, grounded and sieved in 2 mm sized sieve and then subjected to physical and chemical analysis. The sample taken was also used to analysis of texture, nitrogen, phosphorous, potash and pH for descriptive purpose.

Soil organic matter determination by Loss on Ignition method is considered as standard method since long time having relatively more recovery efficiency. Soil sample from carefully weighed 1 g sample was heated to 600°C for 4 hour. The weighing balance was 0.001g setting. Reduced weight from heated sample was soil organic matter. Organic matter contains 58% soil organic carbon (Schumacher, 2002). Hence, in this way soil organic carbon from all samples was calculated. The soil samples were subjected to comparative soil organic carbon analysis by Walkley-Black procedure for the verification of LOI analysis.

3. Results

3.1. Physicochemical Properties of Soil

The soil of the experimental field was sandy loam in texture and acidic in reaction. It contains medium rating organic matter on upper 20 cm depth and low in lower depth of 20-40 cm. The level of Nitrogen was medium but phosphorous and potash was low in rating.

3.2. Soil Organic Carbon Content of the Field (g kg^{-1} Soil)

The status of soil organic carbon at two different depths was analyzed (Table 1) to accomplish the annual soil organic carbon deposition under various treatments of the continuous trial of rice-wheat system. The mean soil organic carbon content at the upper 0-20 cm depth was 17.25 g kg^{-1} soil before rice season at 2012 and 17.58 g kg^{-1} soil after wheat season at 2013. The soil organic carbon at upper 0-20 cm depth was significantly influenced by conventional and conservation agricultural practices. But the soil of lower depth, 20-40 cm, organic

carbon content was relatively lower and statistically similar among the treatments.

At every sampling, zero tilled residue retained treatment contained significantly higher amount of soil carbon followed by permanent raised bed residue retained treatment than other treatments at 0-20cm depth. Before rice season, ZTR-ZTW+RR contained higher soil carbon (18.53 g kg^{-1} soil), statistically similar with BPR-BPW+RR (18.23 g kg^{-1} soil). The trend was similar till the end of the experiment. Similarly after wheat season, ZTR-ZTW+RR contained higher (19.44 g kg^{-1}) soil carbon followed by permanent BPR-BPW+RR (18.96 g kg^{-1}). The soil organic carbon content was significantly lowest in TPR-CTW. It was 15.86 g Kg^{-1} of soil before rice season which became 15.85 g Kg^{-1} of soil after wheat season. It was statistically similar to all other treatments except ZTR-ZTW+RR and BPR-BPW+RR.

Table 1. Soil organic carbon content as affected by conservation and conventional agricultural practice of continuous rice-wheat trial at Rampur soil, 2012/2013

Treatments	Before rice season	After wheat season	Before rice season	After wheat season
	0-20 cm	0-20 cm	20-40 cm	20-40 cm
CTDSR-ZTW	16.62 ^{bc}	16.76 ^b	12.25	12.33
TRP-CTW	15.86 ^c	15.85 ^b	12.2	12.12
ZTR-ZTW+RR	18.53 ^a	19.44 ^a	12.91	13.03
ZTR-ZTW+RH	17.62 ^{abc}	17.69 ^{ab}	12.62	12.75
BPR-BPW+RH	16.63 ^{bc}	16.78 ^b	13.00	13.02
BPR-BPW+RR	18.23 ^{ab}	18.96 ^a	12.52	12.75
Grand mean	17.25	17.58	12.58	12.67
LSD (0.05)	1.77	1.75	NS	NS
SEm (\pm)	0.56	0.56	0.87	0.80
CV (%)	5.63	5.47	11.91	11.00

Treatment means followed by common letter(s) in the column are not significantly different among each other based on DMRT at 0.05. NS= non significant. CTDSR+ ZTW= Conventional tilled dry direct seed Rice followed by Zero tilled wheat. TPR+CTDSW= Transplanted rice followed by conventional tilled wheat. ZTR-ZTW+RH= Zero tilled rice followed by wheat without residue retention. ZTR-ZTW+RR= Zero tilled rice followed by wheat with residue retention. BPR-BPW+RH= permanent raised bed rice followed by wheat without residue retention. BPR-BPW+RR= permanent raised bed rice followed by wheat without residue retention with residue retention

3.3. Annual Change in Soil Organic Carbon ($\text{g kg}^{-1} \text{ yr}^{-1}$ Soil)

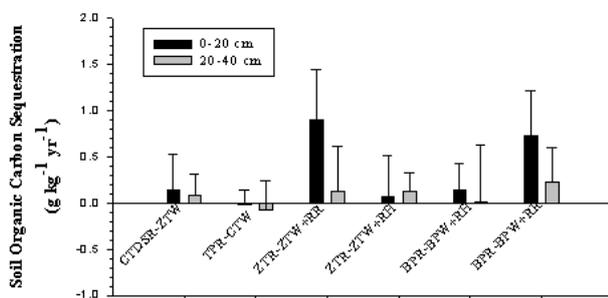


Figure 1. Change in soil organic carbon as influenced by conservation and conventional practice at Rampur, Chitwan, Nepal, 2012/13. CTDSR+ ZTW= Conventional tilled dry direct seed Rice followed by Zero tilled wheat. TPR+CTDSW= Transplanted rice followed by conventional tilled wheat. ZTR-ZTW+RH= Zero tilled rice followed by wheat without residue retention. ZTR-ZTW+RR= Zero tilled rice followed by wheat with residue retention. BPR-BPW+RH= permanent raised bed rice followed by wheat without residue retention. BPR-BPW+RR= permanent raised bed rice followed by wheat without residue retention with residue retention

Residue management and tillage clearly showed the change in soil organic (Figure 2). ZTR-ZTW+RR had higher increase in soil carbon ($0.91 \text{ g kg}^{-1} \text{ yr}^{-1}$ soil) followed by BPR-BPW+RR ($0.73 \text{ g kg}^{-1} \text{ yr}^{-1}$ soil) on upper depth 0-20cm. During experiment higher organic carbon increase in BPR-BPW+RR among the treatments in lower depth 20-40cm but effect was very insignificant. Carbon content was decreased in TPR-CTW for both depths.

3.4. Comparison of Soil Carbon Content among the Treatments

Soil organic carbon content over TPR-CTW of the field after five crop cycle is depicted on figure 3 and presented on appendix 4. Upper depth had significantly different soil organic carbon change but lower depth was not. Highest soil organic carbon change (122.63%) was found in ZTR-ZTW+RR plots followed by BPR-BPW+RR plots (111.61%). The use of ZTR-ZTW+RR and BPR-BPW+RR for five crop cycle increased soil organic carbon by 22.63% and 11.61% more than that of TPR-ZTW respectively. These treatments were statistically similar and significantly higher from all other treatments except ZTR-ZTW+RH.

Significant contrast was observed in conventional versus zero tillage and residue retention versus residue harvested practices while there was no significant difference in between zero tillage versus bed planting.

More carbon was observed in zero tillage and residue retention practice over alternative practices after five crop cycles.

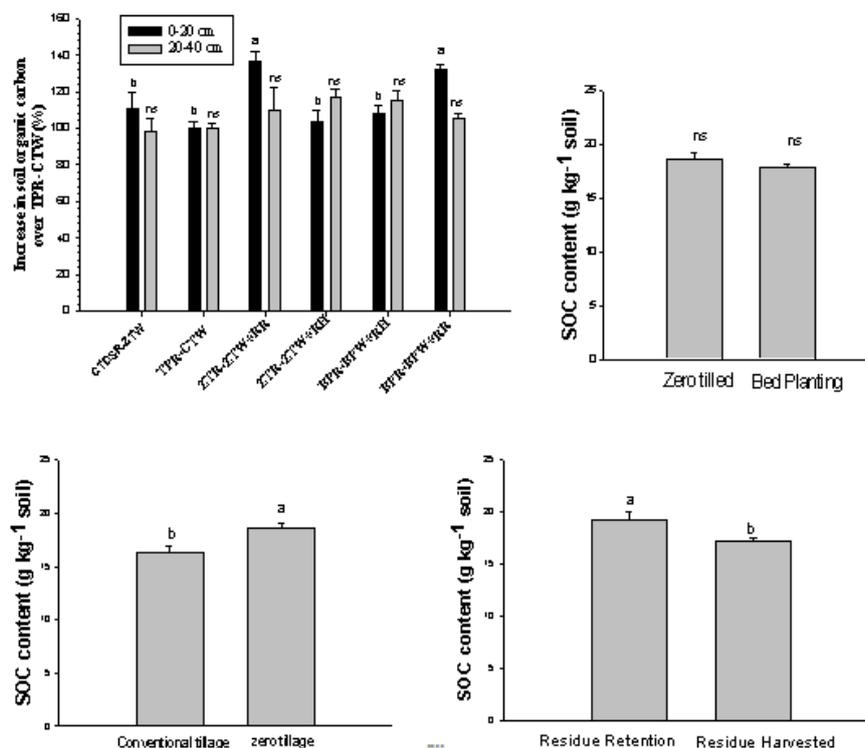


Figure 2. Increase in soil organic carbon (%) assuming 100% for TPR followed by conventional tilled wheat influenced by conservation and conventional practice and contrast of upper depths between different practices at Rampur, Chitwan Nepal from 2011/12-2012/13. Treatment means followed by common letter(s) in the column are not significantly different among each other based on DMRT at 0.05. NS= non significant. CTDSR+ZTW= Conventional tilled dry direct seed Rice followed by Zero tilled wheat. TPR+CTDSW= Transplanted rice followed by conventional tilled wheat. ZTR-ZTW+RH= Zero tilled rice followed by wheat without residue retention. ZTR-ZTW+RR= Zero tilled rice followed by wheat with residue retention. BPR-BPW+RH= permanent raised bed rice followed by wheat without residue retention. BPR-BPW+RR= permanent raised bed rice followed by wheat without residue retention with residue retention

4. Discussion

Tillage, residue management and establishment method affects carbon pool of the soil in this cropping system. In this cropping system, more increase in carbon content of soil in zero tilled residue retained plots. The percentage increment was smaller (22% more than CT) than findings (64.6% more than CT) of Calegari *et al.* (2008). Higher soil organic carbon content in residue retention could be attributed to more annual nutrient recycling in respective treatments and decreased intensity of mineralization (Kaisi and yin, 2005). Carbon input in the form of crop residue had primary factor for stabilization of soil carbon (Singh, 2011; Chivenge *et al.*, 2007). The microbial activity was found more on residue retained plots (Mandal *et al.*, 2004) so that soil organic carbon level increased with the residue retention (Duiker and Lal, 1999). It might also be associated to less emission of soil carbon in the form of GHGs.

Less carbon sequestration in bed planting than zero tillage in same level of residue retention in this cropping system might be due to earlier dryness, less microbial population and less decomposition in bed during wheat season. The variation of soil organic carbon sequestration also depends on difference in microbial populace, moisture and temperature fluctuation (Govaerts *et al.*, 2009). Residue retention and tillage has key role in soil

carbon conservation (Duiker and Lal, 1999; Anyanzwa *et al.*, 2010; Du *et al.*, 2009; Corsi *et al.*, 2012).

Conventional methods of crop establishment and residue harvested treatments add no more carbon which might be ascribed due to continuous nutrient removal from the plot. But, the level of soil organic carbon was not much decreased in conventional or residue harvested plots also as suggested by various literatures (Anyanzwa *et al.*, 2010; Ghosh *et al.*, 2010), it was found as similar to initial level and sometime slightly increased. This might be due to initial low carbon content in soil and maintaining by roots (Du *et al.*, 2009). Lack of nutrient recycling is considered to be major cause of declining soil carbon in lower depth of conventional planting (Ram *et al.*, 2005).

5. Conclusion

The results obtained from the investigation indicate that conservation agriculture have the ability to add soil organic carbon. Residue retention and no-tillage can facilitate soil carbon buildup. The effective SOC sequestration in upper depth (0-20 cm) is due to continuous nutrient recycling as crop residue in conservation agriculture. Less carbon content and changed in conventional methods of establishment likely due to continuous losses of carbon during tillage and no recycle of carbon via residue. But, the effect on lower depth (20-

40 cm) is insignificant in conservation agriculture also. Only two years of research might be very short period to conclude about soil organic carbon sequestration. Therefore, it needs long term study about SOC sequestration using various types of crops in different soil types and climate. Study using different rates of residue management is also essential in this region.

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