International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(5): 480-485

Received: 09-07-2017
Accepted: 10-08-2017

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Influence of tillage practices on soil physical chemical and biological properties under cotton maize cropping sequence

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Abstract
To study the soil quality changes in the important cropping sequence cotton maize under different tillage and land configuration methods, field experiments were conducted in Tamil Nadu Agricultural University during the year 2012-15. Tillage practices are minimum, conventional and zero tillage combined with land configuration methods *viz*., furrow irrigated raised bed (FIRB) and flat bed with permanently for both crops and for individual crops were the treatments. After three years of experimentation, analytical report of post harvest soil samples reveals, tillage practices do not have influence on soil physico chemical properties. But favorable physical environment of maximum porosity of 47.2 % was recorded in the minimum tillage (MT)-furrow irrigated raised bed (FIRB) which was on par with zero tillage (46.1%) and minimum tillage (MT)-flat bed (45.7%). Higher population of bacteria, fungi and actinomycetes of 74 cfu x 10^{-6} g/soil, 35 cfu x 10^{-4} g/soil and 21 cfu x 10^{-3} g/soil recorded respectively in the zero tillage. The zero tillage also recorded high dehydrogenase activity of 101 mg TPF/kg/24hours. The soil carbon pool reveals that minimum tillage with FIRB treatment recorded higher water soluble carbon (WSC). But zero tillage recorded higher potassium permanganate oxidisable organic carbon (PMOC) (797mg/kg) and WBC (6920 mg/kg). Among the treatments, zero tillage recorded higher carbon stock value of 13.12 Mg/ha These results indicated that zero tillage can be recommended for maintaining soil fertility as well as store more carbon to protect our environment.

Keywords: Tillage practices, land configuration methods, soil physical, chemical, biological properties, cotton-maize

Introduction

Tillage is the major farm operation which alters soil structure, exposing more organic matter to microbial attack while no/minimum tillage practices stimulate the formation of macro aggregates, which represent an important mechanism for protection and maintenance of soil organic matter (SOM) (Yang *et al*., 2005). The SOM decomposition is mediated by microorganisms, their activity is stimulated on tropical soils where temperature is higher than temperate climate. Soil management, which uses traditional plowing and disking to prepare the land may reduce soil organic matter (SOM) and microbial activity (Galantini *et al*., 2004) [10]. The excessive cultivation can cause decrease in the microbial biomass and its activity. Reports showed that activities of some enzymes were higher in No tillage than Conventional tillage in top 7.5 cm layer.

Soil quality is an important tool to assess the land quality which is used to evaluate soil resource ability to sustain yield. Linking physical, chemical and biological properties of soil by integrated approach will give more comprehensive solutions as compared to assessing each soil property individually. In the tropical soils, disturbing soil is the major phenomena which decide the nutrient resource mineralization and soil quality.

The important way that SOC improves the soil physical structure is by enhancing the water stability of macroaggregates (Tisdall and Oades 1982) [25]. The irregularly shaped macroaggregates fit together rather loosely, creating macropores between the aggregates (Magdoff and Van Es, 2000) [15]. This soil structure has several beneficial effects on crops. It increases the water infiltration rate, enhances the drainage, and allows for rapid gas exchange and easy root growth. Increase of SOC also increases the available water capacity of soils.

Soil organic carbon can also influence the soil chemical reactions, which affect the availability of nutrients to the crops and pH of the soil. There are two ways in which SOC can increase the availability of nutrients to the plant. The first way is that SOC is always associated with other elements such as N, sulphur, and phosphorus. When SOC is mineralized, it releases these nutrients in forms available for absorption by plants.

SOM is the most important indicator of soil quality and agronomic sustainability because of its significant role and impact in influencing the other physical, chemical and biological properties of the soil. SOM also improves the soil resilience capacity and impacts the ecosystem restoration. Maintenance of soil organic C (SOC) in cropped soil is important, not only for improvement of agricultural productivity but also for reduction in C emission (Rajan *et al*., 2012) [18]. However, short- and medium-term changes of SOC are difficult to detect because of its high variability temporally and spatially (Blair *et al*., 1995) [3]. Again these SOC can be divided into different carbon pools. The soil carbon pool dynamics under different cropping sequences are also reported (Smyrna, 2016) [22]. Soil organic carbon pools are comprised of labile, stable and recalcitrant pools with varying residence time. Some C pools like microbial biomass C, mineralizable C, dissolved organic C (DOC), water extractable organic C (WEOC), hot water soluble C (HWEOC), $KMnO_4$-oxidizable C, and organic C fractions of different oxidizability are used as indicators of organic matter lability (Blair *et al*., 1995 ; Sparling *et al*., 1998; Benbi *et al*., 2012) [3, 24, 2]. These pools are considered to respond to agricultural management and land use changes more rapidly than the total organic carbon and thus could be used as sensitive indicators of organic C dynamics in soils.

On the contrary, soil labile organic C fractions (i.e., microbial biomass carbon (MBC), dissolved organic carbon (DOC), and easily oxidizable C (EOC)) that turn over quickly can respond to soil disturbance more rapidly than total organic C (TOC) (Ghani *et al*., 2003) [11]. Therefore, these fractions have been suggested as early sensitive indicators of the effects of land use change on soil quality (Rudrappa *et al*., 2006) [20].

Due to increasing commercial crops cultivation of maize and cotton in Tamil nadu, farmers are going with different tillages viz., minimum, conventional even zero tillage to accommodate these crops also. Planting also carried out in flat bed or furrow irrigated raised bed to cope up with time. Due to shortage of time they are going with permanent FIRB some time or with flat bed. To improve the agricultural sustainability, agricultural practices on soil health have to be taken care of by the scientists. No tillage, planting with minimal soil disturbance combined with crop rotation protects the soil against degradation toward sustainability. Crop rotations can be an important step for maintaining and improving soil quality. Crop rotations change the soil habitat due to their difference in extract nutrients, depth of roots, amount of residue which remain in soil and difference in their components. Crop rotations can stimulate soil biodiversity and biological activity. Soil management such as no-tillage and crop rotations are important practices, which can reduce soil erosion, conserve organic matter and water and stimulate microbial activity. Tillage and crop rotations are important factors influencing soil quality.

Although a lot of information available on the relation between tillage, crop rotation and soil quality, very little is known about these effects under tropical condition like India. In this context, the measurement of soil quality could be an indicative of soil health. The soil quality parameters selected in this project are, physical properties such as soil bulk density, water holding capacity, chemical properties such as pH, EC, soil organic carbon and their pool *viz.,* pottasium permanganate oxidisable carbon, water soluble carbon, total carbon, available nutrients, soil biological indicators such as soil dehygrogenase enzyme activity, soil microbial population. It is hypothesized that no-tillage and soil disturbance by planting techniques would stimulate the soil quality. So studying influence of tillage and planting technique on soil quality under cotton maize cropping sequence, will give more information in this current scenario of environmental conservation

Materials and methods

To study the effect of tillage and land configuration methods on soil health, under intensive cropping system of maize - cotton the research project was undertaken. Treatments are T_1-CT-Flat (conventional tillage for both crops and planting on flat surface), T_2-CT-FIRB (conventional tillage for both crops and planting in FIRB(furrow irrigated raised bed),T_3-CT-permanentFIRB (conventional tillage once and planting on permanent FIRB), T_4 - MT-flat (Minimum tillage for both crops and planting on flat surface),T_5-MT-FIRB (Minimum tillage for both crops and planting in FIRB),T_6-MT-permanent FIRB (Minimum tillage once and planting in permanent FIRB), T_7-Zero tillage. Plot size is 200 m^2 (permanent). The post harvest soil samples of the experiment were collected after the harvest of cotton and maize and analysed for the pH and EC, available nutrients, organic carbon, physical properties, microbial population, dehydrogenase enzyme activities and different soil carbon pools. The common physical properties such as bulk density, particle density, water holding capacity and porosity were analysed by keen rockowski box method. The different soil carbon pools viz., water soluble fraction and potasium permanganate oxidisable carbon (labile fraction by Passive carbon can be calculated by subtracting labile carbon from total carbon. Soil organic carbon was determined by Walkey and Black's (1934) [26] rapid titration method. Potassium permanganate oxidisable carbon estimated by following i.e. three gram soil sample was treated with 25 ml of 33 $mMKMnO_4$ in centrifuge tubes with capand completely cover with aluminium foil to exclude ligh and was shaken for 6 hours on a reciprocal shaker. Same is repeated without soil as blank. After centrifuging at 2000 revolutions per minute for 5 minutes, the samples were filtered through a Whatman No.1 filter paper. A corresponding blank without soil was also prepared in the same manner. The 2 ml aliquot of $KMnO_4$ from each samples and blank were transferred using a Pipetman into 50 ml volumetric flask and diluted to volume. The absorbance of filtrate from samples and blank was measured at 565 nm in a spectrophotometer. The concentration of $KMnO_4$ from samples and blank was determined using standard calibration curve.Soil carbon stock worked out by multiplying SOC (%), bulk density and depth of soil.

Results and discussion

Tillage is the important farm operation which influence the soil condition especially soil physical condition inturn it will affect soil fertility, enzyme activities and different soil carbon pools. The soil samples collected after 2015 of maize were analysed for chemical, physical properties, microbial population, enzyme activity and organic carbon pools.

Soil chemical properties

The result of tillage practices effect on soil chemical properties under cotton maize cropping sequence is presented in the table (1). The soil samples analysed after completing three years of cropping sequences revealed that, the tillage practices do not have influence on soil physico chemical properties viz. pH and EC (table1). The data on SOC indicated that zero tillage (ZT) recorded higher value of 0.88 % which is statistically on par with minimum tillage –FIRB (0.78 %).This might be due to undisturbed condition, reduced C loss as well as residue addition in ZT would have improved the SOC status.Fig1 showed zero tillage has registered higher SOC than minimum and conventional tillage practices irrespective of land configurations. Regarding the availability of nutrients, the minimum tillage with flat bed planting recorded higher available N (260 kg/ha) and available K (788 kg/ha). The reduced N loss by minimum disturbance might be the reason for improved N status. But higher available P (24.2 kg/ha) recorded in minimum tillage with furrow irrigated raised bed treatments. Regarding available K, higher value of 812 kg/ha recorded in zero tillage followed by MT flat planting (788 kg/ha). The substances released from residues of zero tillage might be responsible for increased available P and K. Similar report was obtained by Powell (1986) [17] and Reganold and Palmer (1995) [19].

Soil physical properties

Some soil physical properties are more amenable for tillage practices. The treatments do not have influenced on soil bulk density (BD) and particle density. Though non significant response observed for bulk density and particle density, numerically lower BD was observed in minimum tillage received treatments. But maximum porosity of 48.1 % was recorded in the MT-FIRB which was on par with zero tillage(46.1%) and MT-flat (45.7%). Fig(2) also depicts that, zero tillage recorded higher porosity and water holding capacity than other two tillage practices irrespective of land configuration methods. Improved porosity in the above treatments might be due to increased SOC registered in the same treatment of present investigation. Higher maximum water holding capacity of 58.2 % in T7, 57.5 % in T5 registered also due to improved SOC contents (Table2). Similar results was reported by Dam *et al*. (2005) [6]. The SOC is the important chemical quality in the soil which decides the physical and biological characteristics of the soils. It has positive effects on soil physical properties and promotes water storage and drainage. It is directly related to the maintenance of soil structure, presence of different groups of microorganisms, mineralization of organic matter, and nutrient availability. The increased SOC in the zero tillage evidenced in the present study might be the reason for improved physical properties.

Soil biological properties

Influence of tillage practices on soil biological parameters viz., bacteria, fungi, actinomycetes population and soil dehydrogenase activity is given in the table3. Higher population of bacteria, fungi and actinomycetes recorded higher values of 74 cfu x 10^{-6} g/soil, 35 cfu x 10^{-4} g/soil and 21 cfu x 10^{-3} g/soil respectively in the zero tillage which is followed by MT-FIRB of treatment i.e bacteria, fungi and actinomycetes recorded 63 cfu x 10^{-6} g/soil, 29 cfu x 10^{-4} g/soil and 15 cfu x 10^{-3} g/soil respectively. Irrespective of land configuration methods, zero tillage recorded more microbial population than conventional and minimum tillage practices (fig3). The enzyme activities especially soil dehydrogenase activity is the indicator of total microbial population also influenced by tillage practices. The zero tillage recorded high dehydrogenase activity of 101 mg TPF/kg/24hours followed by minimum tillage with FIRB of 101 mg TPF/kg/24hours (fig 3).The improved biological activity might be due to higher SOC level in the same treatment of present investigation. Residue inputs tend to increase the amount of organic matter available for microbial decomposition, and thus soils with greater residue inputs are expected to have larger microbial populations than soils that receive less residue (Collins 1992) [5]. The residue addition had a positive effect on SOC was reported by Bama *et al*. (2015) [1].

Soil carbon pools

Different soil carbon fractions viz.Water Soluble Carbon (WSC), Potassium Permanganate Oxidisable organic Carbon (PMOC), Walkley and Black method of organic carbon content (WBC) changed with respect to tillage operation (table4). Among different treatments higher WSC was recorded in CT-FIRB (56 mg/kg) which was followed by MT-FIRB (51 mg/kg). In this study irrespective of land configuration methods, conventional tillage recorded more WSC than zero and minimum tillage (Fig4). The increase in conventional tillage might be due to disturbances caused by tillage which would have releases easily dissolvable organic carbon. Haynes (2000) [12] studying arable and pastoral soil in New Zealand, indicated that soil organic matter content is affected by soil management, but changes in total SOC content from land use may be difficult to detect, therefore labile organic fractions, represented by dissolved organic carbon is more sensitive property.

In the TOC higher value of 6920 mg/kg was observed with zero tillage followed by MT-FIRB (6630 mg/kg) which is on par with all other treatments (Fig 4). Increased WBC in zero tillage attributed by minimum disturbances, more residue addition and microbial population and enzyme activity. Soil properties associated with soil organic matter (SOM) have been recognized as key indicators and to have an effect on other properties (Doran *et al*.,1996) [8]. Deen *et al*. (2003) [7] reported that, SOM content is affected by intermediate grazing intensity, incorporation of crop residues or the addition of organic matter fractions and by soil management practices such as minimum or conservation tillage.

In the labile carbon higher value of 797mg/kg was registered in zero tillage which was on par with MT-permanent FIRB (776 mg/kg) and MT-flat (772 mg/kg) (table4 and fig 5). Irrespective of land configuration methods, zero tillage recorded higher PMOC than conventional and minimum tillage practices. Blair *et al*. (1995) [3] suggested $KMnO_4$-oxidizable C as a measure of labile C in soil. The method has been used in several studies under a variety of soils and land uses. $KMnO_4$ –C has been reported to be more sensitive indicator compared to total SOC for quantifying the impact of agricultural management on SOM (Sodhi *et al*., 2009) [23]. Tillage methods often have an effect on the size of the labile C (Haynes 2005) [13]. Soils are known to have increased respiration rates immediately after tillage events, and the respiration rate then falls below the original rate of the undisturbed soil (Hussain *et al*., 1999) [14]. This implies that tillage destroys the physical protection that has been partially preserving the labile pool.

The soil organic carbon stock was calculated by multiplying SOC (%) with Soil BD (Mg/m3) and soil sampling depth (cm). Among the treatments, zero tillage recorded higher carbon stock value of 13.12 Mg/ha which is followed by minimum tillage with permanent FIRB T5(12.79 Mg/ha). In the fig 6, zero tillage recorded higher soil carbon stock than minimum and conventional tillage practices irrespective of land configuration methods. The soil carbon stock value indicated the capacity of the soil to hold the carbon.

Table 1: Soil chemical properties under tillage practices and land configuration methods in a cotton maize cropping sequences

Treatments		pH	EC(dS/m)	OC (%)	Available nutrients (kg /ha)		
					N	P	K
T_1	CT-Flat	8.72	0.57	0.70	252	23.1	722
T_2	CT-FIRB	8.65	0.62	0.68	235	23.4	705
T_3	CT-permt FIRB	8.77	0.50	0.61	232	20.1	763
T_4	MT-flat	8.78	0.65	0.66	260	22.3	788
T_5	MT-FIRB	8.75	0.42	0.78	221	24.2	754
T_6	MT-permt FIRB	8.62	0.58	0.72	202	24.2	746
T_7	Zero tillage	8.71	0.59	0.88	252	26.2	812
SEd		NS	NS	0.07	11	Ns	18
CD (5 %)				0.15	23		38

Table 2: Soil physical properties under tillage practices and land configuration methods in a cotton maize cropping sequences

Treatments		BD (Mg/m^3)	PD (Mg/m^3)	Total porasity (%)	MWHC (%)
T_1	CT-Flat	1.26	2.45	45.4	44.8
T_2	CT-FIRB	1.28	2.49	44.1	52.4
T_3	CT-permanent FIRB	1.28	2.49	41.5	51.3
T_4	MT-flat	1.25	2.44	45.7	53.3
T_5	MT-FIRB	1.23	2.44	47.2	57.5
T_6	MT-permanent FIRB	1.25	2.49	44.6	52.0
T_7	Zero tillage	1.28	2.44	48.1	58.2
SEd		NS	NS	0.85	1.6
CD (5%)				2.1	3.1

Table 3: Soil biological properties under tillage practices and land configuration methods in a cotton maize cropping sequences

reatments		Bacteria (cfu x 10^{-6}) g/soil	Fungi (cfu x 10^{-4}) g/soil	Actinimycetes (cfu x 10^{-3}) g/soil	Soil dehydrogenase activity mg TPF/kg/24 hrs
T_1	CT-Flat	52	25	10	77.0
T_2	CT-FIRB	58	25	11	85.4
T_3	CT-permt FIRB	52	27	13	81.8
T_4	MT-flat	54	23	12	83.3
T_5	MT-FIRB	63	29	15	92.0
T_6	MT-permt FIRB	55	24	10	85.2
T_7	Zero tillage	74	35	21	101.8
SEd		3	1.4	1.1	3.1
CD (5%)		6	3	2	6.3

Table 4: Soil carbon pools under tillage practices and land configuration methods in a cotton maize cropping sequences

Treatments		Water soluble carbon (WSC) (mg/kg)	Walkley and Black carbon (WBC) (mg/kg)	Potassium permanganate oxidisable carbon (PMOC) (mg/kg)	Passive carbon (mg/kg)	Soil C stocks (t/ha^{-1})
T_1	CT-Flat	37	6520	631	5852	12.32
T_2	CT-FIRB	56	6500	702	5742	12.63
T_3	CT-permt FIRB	37	6540	705	5798	12.60
T_4	MT-flat	43	6520	679	5797	12.52
T_5	MT-FIRB	42	6610	772	5796	12.79
T_6	MT-permt FIRB	51	6630	776	5923	12.83
T_7	Zero tillage	42	6920	797	5782	13.12
SEd		2	NS	24		0.08
CD (5%)		4		52		

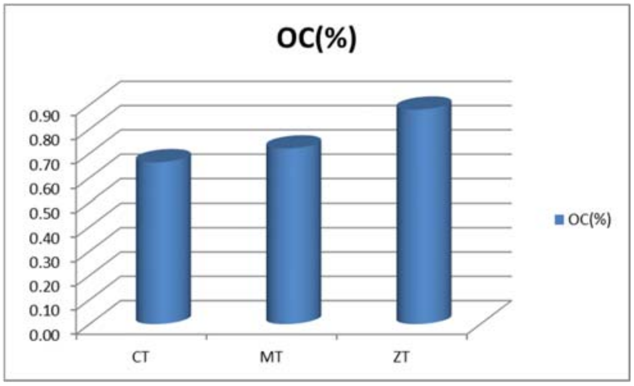

Fig 1: Soil organic carbon under tillage practices in a cotton maize cropping sequences

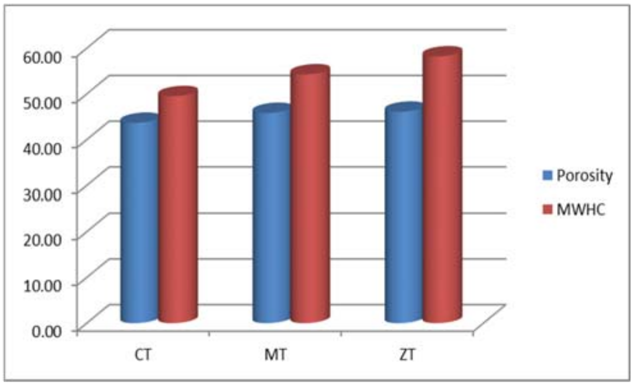

Fig 2: Soil physical properties (%) under tillage practices in a cotton maize cropping sequences

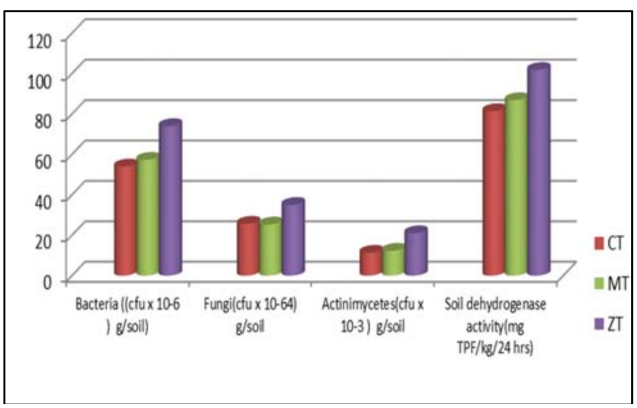

Fig 3: Soil biological properties under tillage practices in a cotton maize cropping sequences

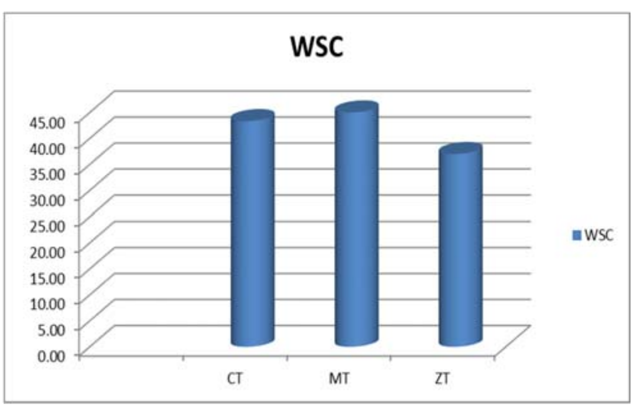

Fig 4: Water soluble carbon (mg/kg) under tillage practices in a cotton maize cropping sequences

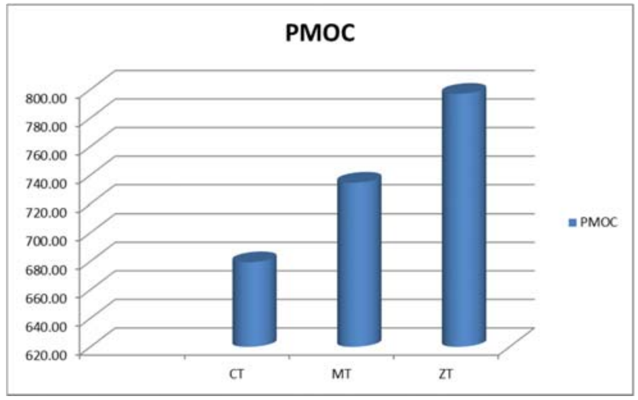

Fig 5: potassium permanganate oxidisable carbon (mg/kg) under tillage practices in a cotton maize cropping sequences

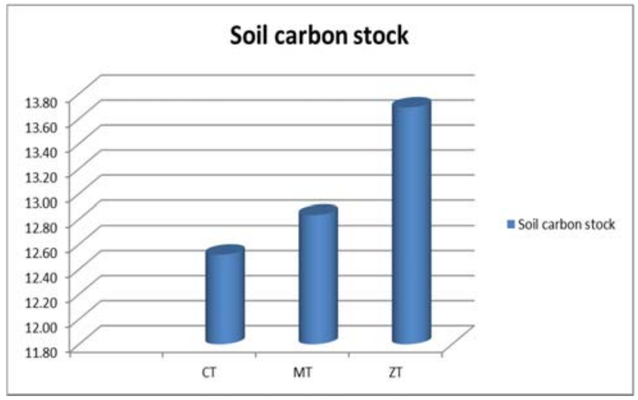

Fig 6: Soil carbon stock (Mg/ha) under tillage practices in a cotton maize cropping sequences

Conclusion

Among the different tillage practices and land configuration methods, zero tillage recorded more favorable physical environment of higher total porosity, water holding capacity, soil microbial population, dehydrogenase activity, available nutrients, soil carbon and carbon stock. The different carbon pools responds to tillage treatments with varied nature i.e, WSC was more in conventional tillage whereas PMOC and WBC more in zero tillage.In all the parameters zero tillage performed better in expressing all quality parameter, for environmental point of view zero tillage can be recommended. From soil fertility point of view, T5 minimum tillage for both cotton and maize and planting in FIRB can be recommended.

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