

# Long-term Effect of Manure and Fertilizer on Soil Aggregates and Associated Carbon in Vertisol and Inseptisol in India

THESIS



*Submitted to the*

**Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya**

In partial fulfillment of the requirement for the degree of

**MASTER OF SCIENCE**

In

**AGRICULTURE**

**SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

*by*

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**College of Agriculture, Gwalior (M.P.)**

**2019**

## CERTIFICATE – I

*This is to certify that the thesis entitled “**Long-term effect of manure and fertilizer on soil aggregates and associated carbon in Vertisol and Inseptisol in India**” submitted in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE in AGRICULTURE (SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)** of **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** by **Mr. Sabe Singh, ID No. 16111305**, under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instruction.*

*No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of this investigation has been acknowledged by the scholar.*

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### **Abbreviations and Acronyms**

<b>Abbreviations/ Acronyms</b>	<b>Meaning</b>
Ag	Agriculture
C	Carbon
°C	Degree Celsius
cm	Centimeter
DHA	Dehydrogenase activity
DMRT	Dunccun multiple range test
EDTA	Ethylene diamine tetra acetic acid
EC	Electrical conductivity
et al.	And others
Etc	and the rest
Fig.	Figure (s)
FYM	Farm yard manure
Ha	Hectare
INM	Integrated nutrient management
IISS	Indian Institute of Soil Science

kg/ha <sup>-1</sup>	Kilogram per hectare
LTFE	Long Term Fertilizer Experiment
MBN	Microbial biomass nitrogen
Mg	Miligram
M	Molar
mM	Milimolar
mL	Milliliter
N	Nitrogen
NS	Non significant
NT	No tillage
OC	Organic carbon
P	Phosphorus
POMC	Particulate organic matter carbon
POC	Particulate organic carbon
POSC	Permanganate oxidizable soil carbon
R.V.S.K.V.V.	RajmataVijayarajeScindiaKrishiVishwaVidyalaya
SMBC	Soil microbial biomass carbon
SMBN	Soil microbial biomass nitrogen
SOC	Soil organic carbon

SOM	Soil organic matter
S.S.	Sum of Square
TC	Total carbon
TPF	Triphenylfarmazon
TTC	Tryphenylphenylteterazolium chloride
THAM	Tri-hydroxymethylaminomethane
Temp.	Temperature
WSA	Water stable aggregates
$\mu\text{g g}^{-1}$	Microgram per gram
$\mu\text{m}$	Microne meter
>	Greater than
<	Less than

## **Chapter – I**

### **INTRODUCTION**

To examine the sustainability of highly intensive farming on a long term basis, the Indian Council of Agricultural Research started the All India Co-ordinated Research Project long-term fertilizers Experiment during fourth plan period to examine as to what happens to soil fertility and productivity on a Long-term basis under high input soil management technology Incorporation of FYM along with optimal NPK dose improved soil physical properties and organic carbon status of soil (Dhakshinamoorthy et al., 2013).

Long term fertilizer experiments play an important role in understanding the changes in physical, physico-chemical and chemical properties and productivity of the crop. The decline in soil fertility due to the imbalanced fertilizers use has been recognized as one of the most important factors limiting crop yields (Nambiar and Abrol, 1989).

The crops are growing for many decades with different nutrient management practices according to the available input resources. Rice–wheat systems, as a result of several decades of continuous cropping and the contrasting edaphic requirements of the two cereals, have shown evidence of soil nutrient depletion and imbalances, low nutrient use efficiency, a general reduction in soil organic matter, and stagnating order clinging yields (Dawe *et al.* 2000 and Ladha *et al.* 2003). There may be various factors behind yield stagnation of both the crops such as edaphic constraints, infestation of insects and diseases, growing of local and susceptible cultivars, adverse and fluctuating climate conditions, conventional methods of sowing, rain fed cultivation of crop and low soil organic carbon coupled with nitrogen status in soil.

The use of high analysis fertilizer for immediate boosting of production potentials of crop plants cast the shadow on use of organic manures. This reflects

on degradation of soil quality and environments as well as sustainability of yield levels of crop plants (Virmani, *et al.* 1991).

Soil contains one of the Earth's most diverse assemblages of living organisms, intimately linked via a complex food web. It can be either sick or healthy, depending on how it is managed. Two crucial characteristics of a healthy soil are the rich diversity of its biota and the high content of non-living soil organic matter. If the organic matter is increased or maintained at a satisfactory level for productive crop growth, it can be reasonably assumed that a soil is healthy. Soil health has been defined as: "the capacity of soil to function as a living system. Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots, recycle essential plant nutrients, improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production"( IPCC. 2007).

The influence of soil organic pools on yield is both indirect and direct as the soil organic carbon plays multifunctional role such as buffering, restoring and supplying of plant nutrients etc. It is a storehouse of all soil micro-organisms inhabiting in soil; improve physical, chemical and biological properties of soil. However, total organic carbon estimation is not reflected the entire soil functions. Soil organic carbon is the fraction of carbon associated with organic matter in plant and soil. The organic carbon present in different fractions or pools in soil such as active pool, passive pool and slow pool etc. The active pool of C consists of labile or easily decomposed material and half-life of this pool is only a few days to one year. Organic matter in this pool has relatively high average C/N ratio (about 15-30) and included such organic matter fractions as living biomass, tiny pieces of detritus (POM), most of the polysaccharides and other non-humic substances. Active pool provides most of the readily accessible food for microbes and most of the readily mineralizable nitrogen. It can be readily increase by addition of fresh plant and animal residues into the soil and readily loss occurs if such additions are reduced or tillage is intensified. This pool rarely comprises > 10-20 % of total soil organic matter. The slow pool of soil organic carbon has intermediate properties between the active and passive pools. Probably includes the finest fraction of particulate organic matter that

are high in lignin and other slowly decomposable and chemically resistant components, half-life is typically measured in decades. This pool is an important source of mineralizable N and the plant nutrients as well as also responsible for structure stability, lead to enhance infiltration, resistance to erosion and ease of tillage practices. It also probably makes some contribution to the effects associated primarily with active and passive pools.

Passive pools of carbon consist of very stable material remaining in soil for hundred or even thousands of years. This includes most of the humus physically protected in clay-humus complexes. It accounts for 60-90% of the organic matter. The passive pool most closely associates with the colloidal properties of soil humus, and it is responsible for most of the cation and water holding capacities contributed to the soil by organic matter.

Quality of soil is a composite of and can be determined by physical, chemical and biological properties of the soil. These properties not only are important for the soil's function as a medium for plant growth, but also influence its services as a buffer in the formation and destruction of hazardous compounds (Larson and Pierce, 1994). They are essential attributes on which the soil's productive capacity and its role as an environmental moderator depend (Acton and Padbury, 1993; Bezdick *et al.*, 1996). Consequently maintenance and enhancement of soil quality are dependent upon improvement of physical, chemical and biological properties of the soil that are useful indicators of quality change (Doran & Parkin 1996).

In the face of regional energy crisis, increase in the cost of fertilizer and growing concern about deterioration of soil health and environmental quality, recycling of organic material is gaining significance in India. An integrated use of both organic manures and chemical fertilizers has emerged as a promising option not only for maintaining higher productivity but also for providing maximum stability to crop production in intensive farming systems. The interactive advantages of combining organic and inorganic sources of nutrients in integrated nutrient management have proved superior to the use of each component separately. Judicious use of organic manures, such as farmyard manure, green manuring and

rice straw along with chemical fertilizers improves soil physical, chemical and biological properties and enhance productivity in both the seasons. It is essential to identify such practices which bring more sustainability to the production system, besides improving the productivity of the system and soil health (Urkurkar *et al.*,2010).

There is a big gap between the removal of nutrients by crops and addition to soil. This deficit will have to be met through supplementary and complementary use of organic and biological sources of nutrients in integrated nutrient management system. The use of organic manure, crop residues, bio-fertilizers and green manuring have become essential because of limiting availability of chemical fertilizer and their high prices. Application of organic matter in any form reduces the loss of nitrogen fertilizer and increases fertilizer use efficiency. The crop residues can be recycled in soil by different methods such as *in situ* incorporation of organic matter or by organic mulch besides composting which eventually will improve physical, chemical and biological properties of soil resulting in higher crop productivity. The important questions to be addressed are national food security, nutritional security, and maintenance of soil health, enhancement of soil productivity and good management of plant nutrients. The ability of plant to produce more grain is dependent on the availability of adequate plant nutrients, there is need to add nutrients to the soil through the judicious use of nutrient sources as mineral fertilizer, organic manure in conjunction with bio fertilizers.

The continuous use of high levels of chemical fertilizers is affecting the sustainability of agricultural production adversely and causing environmental pollution (Virmani, *et al.*,1994). In coming decades, a major issue in designing sustainable agricultural system will be the management of soil organic matter and the rational use of organic inputs such as animal manures, crop residues, green manures and food industry wastes. However since organic manures cannot meet the total needs of modern agriculture, integrated use of nutrients from fertilizers and organic resources seem to be a need of the time.

Integrated nutrient management (INM) has shown its potential in increasing crop productivity may be due to the combined effect of nutrient supply, synergism and improvement in soil physical and biological properties and also in crop physiological processes. Therefore, it has realized that there is a need for an assessment on crop specific land quality so that the yield diminishing factors can be identified. The need for development of a land quality index with reference to type of land use was stressed by the Kerlen *et al.* (1997).

The depletion of soil organic carbon leads decreasing in yield in monocropping and double cropping system. There are several studies on long term effect of manures and fertilizers on soil organic pool has been done. The incorporation of organic manures, wheat straw and root residues are most effective for buildup of soil organic carbon while chemical N and P are not effective as compared to the organic matter addition (Manna *et al.* 2006; 2007; Fan *et al.* 2007; Bado *et al.* 2010). The continuous cultivation of rice-wheat crop without any fertilization decreases the various N from soil and deteriorates its health although, the total N content in soil increases with the addition of FYM, green manure and press mud along with the mineral fertilizer, while, Burnt rice husk has no positive effect on total N content (Sekhon *et al.* 2011). However some studies indicate that application of any of the nutrient enhances the SOC content in the soil (Bhattacharya *et al.* 2012) while some of the research shows that application of inorganic fertilizer alone is not sufficient to increase SOC and labile C fraction (Liang *et al.* 2012). In practice it is difficult to apply all nutrients through organic manures, thus application of recommended dose of NPK either through inorganic fertilizer or inorganic fertilizer NPK with FYM or crop residue or green manure to rice and wheat may improve the soil organic carbon, particulate organic carbon, microbial biomass carbon concentration, total SOC stocks and their sequestration rate (Nayak *et al.* 2012).

Soil quality is the major functional factor in alteration of production potential of crops. To overcome this problem the integrated nutrient management system (INM) is adopted in cropping system. The basic concept of the INM is to maintain soil fertility for sustained crop productivity on long-term basis and also reduce fertilizer input cost. At present the quantity of inorganic fertilizers is reduced by substituting

the various organic manures viz., FYM, vermincompost, green manuring and recycling of crop residues. The protection of environment and sustainability in yield levels can be achieved by the integrated nutrient management. This will be the noble approach toward organic farming.

Besides fertilization, cropping system is one of the major factors which affect the SOC content in soil. We hypothesized that continuous cropping of cereals may effect on the productivity, carbon pools and soil health. In double cropping system the loss of C occurs more if there is no effective measure to reduce it, therefore the better management practices are needed to mitigate its negative effect. The double cropping system of irrigated rice does not decrease the SOC levels if there recommended dose of fertilizer apply regularly (Bado *et al.*, 2010). However, such information is not available in this area. Similarly, declining in yield could be related to decline SOC fractions under different nutrient management system. However, the decline in yield of any crop is a result of combine effect of all factors which affect the plant growth and development. Seasonal rainfall, maximum and minimum temperature and SOC has jointly explained variation in rice production. A combination of ecosystem processes and wise use of mineral fertilizers forms the basis of a sustainable soil health management system that has the capacity to produce higher yields while, using fewer external inputs. Long-term experiments can be more useful for studying the changes in soil properties and processes over time and for obtaining information on sustainability of agricultural systems for developing future strategies to maintain soil health. Present investigation is planned with the following objectives:-

1. To determine the effect of long term manure and fertilizer application on soil aggregates
2. To estimate associated soil carbon under long term manure and fertilizer application
3. To assess the effect of long term manure and fertilizer application on activities of main hydrolytic enzymes involved in soil carbon cycling

## Chapter- II

### Review of literature

#### 2.1 To estimate associated soil carbon under long term manure and fertilizer application.

Tisdall and Oades (1982) study that soil structure and soil organic matter (SOM) are strongly related; organic matter binds mineral particles into aggregates and reduces soil erodibility. Some workers have investigated the effects of different management practices on the SOM content and aggregation. (Puget et al. 1998; Elliott 1986; Six et al. 1998).

Bellakki and Badanur (1997) studied in a long-term experiment with sorghum-safflower cropping sequence on Vertisol at Bijapur under dry land condition found that application of sun hemp straw in combination with fertilizer significantly improved the infiltration rate, water stable aggregates, porosity, field capacity, water holding capacity. The bulk density of soil decreased significantly with the application of FYM or sun hemp either alone or in combination with fertilizer.

Pulleman *et al.*, (2005) conducted a study on SOM concentrations are determined largely by land use and management. The study was found that The SOM content of agricultural soils can therefore be increased through the adoption of alternative management systems that increase the amount of organic inputs and/or slow down SOM turnover.

Pal *et al.*, (2006) conducted a long term field experiment since 1994-2004 in the rainfed upland red and laterite soils of dryland agriculture research farm, Phulbani, Orissa under rice (*Oryza sativa*) -horsegram (*Macrotyloma uniflorum*) cropping sequence. Soil physical properties showed that the bulk density declined in all treatments from the initial of 1.63 Mg/m<sup>3</sup>. The FYM treated soil recorded the lowest value of 1.15 Mg/m<sup>3</sup> and the water holding capacity was the highest in the FYM treated plots.

Sleutel *et al.* (2006) conducted a study on soil organic carbon (SOC) pools using physical fractionation in two long-term arable field experiments in Hungary (Martonvasár and Keszthely), which started in 1950 and 1963, respectively (clay loam and loam soil). The study was concluded that the considered SOC fractions were associated with different conceptual SOC pools. The study was found that the Calcic Chernozem soil at Martonvasár had a much higher SOC content than the Eutric Cambisol at Keszthely for all treatments, although both experiments were comparable in management and crop rotation. OC content of the bulk soil samples increased with both mineral fertilizer and manure applications as compared to the control for both sites.

Shreshta *et al.* (2006) observed a large difference in  $\text{KMnO}_4$  - oxidizable soil organic C (KOC) due to the effect of cultivation length and cropping system. During a 3-year study period, large changes in soil C were observed for  $\text{KMnO}_4$  - oxidizable C but not for total carbon (TC), indicating the usefulness of the  $\text{KMnO}_4$  - oxidized fraction for detecting a relatively short-term increase or decrease in soil C pool.

Behara *et al.* (2009) conducted a study on the effect of continuous cropping with maize and wheat on soil characteristics and various forms of micronutrient cations in an Inceptisol over the years was studied in an ongoing long-term experiment in New Delhi, India. The study concluded that the pH, electrical conductivity (EC), and calcium carbonate ( $\text{CaCO}_3$ ) content of the soil varied from 8.28 to 8.53, 0.40 to 0.43  $\text{dSm}^{-1}$ , and 0.92 to 1.05%, respectively. OC content ranged from 0.38 in the control to 0.67% in 100% NPK + farmyard manure (FYM). (DTPA)-extractable Fe and Mn (but not Zn and Cu) in soil declined from their respective initial of intensive cropping for more than three decades. The study was found that decreases in the concentrations of all the four metallic cations bound to organic matter, in addition to Fe and Zn, Continuous cropping and fertilizer use for more than three decades has resulted in decreases in the concentrations of all the four metallic cations bound to organic matter and: Fractions of Fe, Mn, Cu, and Zn in surface soil.

Verma *et al.*(2010) studied long-term effect of integrated nutrient management on properties of Typic Haplustept under maize-wheat cropping system reported that after harvest of maize as well as wheat crops, the treatments receiving FYM alone (T8 receiving FYM @ 20t ha<sup>-1</sup> ) exhibited significantly lower bulk density compared to all the chemical fertilizer and control treatment.

Liang *et al.* (2012) conducted a study on soil organic carbon (SOC) and its labile fractions are strong determinants of chemical, physical, and biological properties, and soil quality. The study concludes that thus, a 15-year experiment was established to assess how diverse soil fertility management treatments for winter wheat (*Triticum aestivum* L.) and summer maize (*Zea mays* L.) cropping system affect SOC and total N (TN) concentrations in the North China Plain. The study was found that despite the higher crop yields over unfertilized control(CK), application of inorganic fertilizers(INF) neither increased the SOC nor the labile C fractions particulate organic C(POC) (18.0–45.8% of SOC) and hot-water extractable C(HWC) (2.0–2.8%).

Dong *et al.* (2012) research that appropriate fertilizer application is an important management practice to improve soil fertility and quality in the red soil regions of China. The study concludes that soil pH, soil organic carbon (SOC), total nitrogen (TN), C/N ratio and available nutrients contents in the plowed layer (0–20 cm) of paddy soil. The study concludes that the soil pH was the lowest with an average of 5.33 units in no fertilizer (CK) and was significantly higher in NPK (5.89 units) and OM (5.63 units) and SOC and TN concentrations (72.5% and 51.2%). The study was found that improve soil fertility in this region and K fertilizer should be simultaneously applied considering the soil K contents which increase soil fertility.

Yuan *et al.* (2013) investigated that the 19 years of continuous application of organic manure along with mineral fertilizers promoted SOC accumulation, while in contrast, there is no significant improvement in SOC level in plot receiving mineral fertilizer alone compared with the unfertilized control. Mere chemical fertilizer additions did not affect the weight proportion of aggregates and associated C

content, while integrated use of manure and chemical fertilizer improved macroaggregation and macroaggregates protected carbon over the control. The increment of organic C in macroaggregates following organic manure + mineral fertilizer amended was primarily located in the intra-aggregate particulate organic matter (iPOM) fraction.

Geisseler and Scow (2014) conducted a study on a long-term impacts in managed ecosystems affect not only plant communities but also associated soil microbial communities. Studies carried out in predominantly unmanaged ecosystems have found that increasing nitrogen (N) inputs generally decrease soil microbial biomass. The study was found that mineral fertilizer application led to a 15.1% increase in the microbial biomass.

Nunan *et al.* (2015) conducted a study on along-term barefallow soils were analysed and compared with those of the microbial communities from their cultivated counterparts. Found that the differences between bare-fallow and cultivated plots were significant ( $P < 0.01$ ) along both of the first two ordination axes of all the PCA. The values of the first two principal components accounted for 90%, 59% and 89% of the total variance.

Tian *et al.* (2015) conducted a study on along-term field experiments published from 1980 to 2012 was used to characterize the changes in SOC under different fertilization treatments and residue management practices in China's paddy soils. The reported the study applied a consistent SOC measurement protocol and the initial and final SOC measurements were clearly. The study was found that greatest potential for C sequestration in agricultural soil and produced the longest SOC sequestration duration (45–51 yr).

Das *et al.* (2016) conducted a study on a long-term experiment has been conducted for 18 years at the Indian Council of Agricultural Research-Indian Institute of Farming Systems Research, Modipuram, India. Continuous use of imbalanced fertilizers under intensive rice-wheat cultivation over the years has gradually degraded the soil structure, and the organic C and nutrient-supplying capacity of these soils have depleted. The study was found that Irrespective of the nutrient management

practices, BD was lower in the top 0–15 cm soil layer compared to the 15–30 cm soil layer.

Zou *et al.* (2018) conducted a study on a Flue-cured tobacco production in China is typically over-fertilized and mono-cropped. The study was concludes that study investigated the effect of rotation, fertilizer rate, and manure amendment on the proportion of water stable aggregates and aggregate-associated soil organic carbon (SOC). The study was found that fertilizer management and rotation all significantly affected whole-soil and small macroaggregate and microaggregate associated SOC, while fertilizer and rotation had no significant effect on SOC in large macroaggregates and the silt-clay size class fraction.

Mazumdar *et al.* (2018) conducted a study on a long-term fertilizer experiment initiated in 1971 in sandy loam soil (*Eutrochrept*) of Barrackpore, West Bengal to study the effects of applying organic and inorganic sources of nutrients on yield of jute-rice-wheat system and soil health. The study concluded that the unfertilized soil supported yields of 0.8 t ha<sup>-1</sup> of jute fibre, 1.5 t ha<sup>-1</sup> of rice grain and 0.7 t ha<sup>-1</sup> of wheat grain (average yield of 42 years). Application of 150% recommended NPK through chemical fertilizers produced maximum yields of jute (2.1 t ha<sup>-1</sup>), rice (3.8 t ha<sup>-1</sup>) and wheat (2.8 t ha<sup>-1</sup>). The study was found that increase in DTPA extractable micronutrient, DHA activity, soil microbial biomass by applying FYM+NPK fertilizer with increase soil fertility.

Microbial biomass C represent vital components of ecosystem cycling with a turnover time from days to years (Hu *et al.*, 1997) and serve as a source (mineralization) or a sink (immobilization) of labile nutrients. Studies have shown that microbial biomass responded quickly to change in soil perturbation by tillage (Carter 1986) and soil moisture (Skopp *et al* 1990). Brookes (1995) agreed on the use of microbial biomass C as indicator of soil quality, owing to its high sensitivity to changes in land use and management practices. Ladd *et al* (1994) added that microbial biomass C is a good measure of the state of edaphic environment and its inclusion in a soil quality index leads to reduction in the number of properties that need to be considered.

Soil microbial biomass carbon (MBC) on an average, constitutes only about 1 percent of the soil organic carbon (Moore *et al* 2000), yet it may comprise up to 44 percent of the active pool of soil nitrogen (Liang *et al* 1999). Therefore, the size of soil MBC pool and its turnover have significant bearing on the overall productivity of soils. Application of mineral N fertilizers and manures has been reported to significantly influence the build-up and dynamics of soil microbial biomass (Mahmood *et al* 1997). Microbial biomass, which is a relatively small component of soil organic matter, plays an important role in nutrient cycling and organic matter stabilization in soils (Jedidi *et al* 2004). Microbial biomass immobilized 2.32-2.57 percent of the soil carbon and 4.08-4.48 percent of the soil nitrogen in tree-based systems (Kaur *et al* 2000).

## **2.2 To determine the effect of long term manure and fertilizer application on soil aggregates**

Mathan & Mahendra (1994) recorded that the soil organic matter content and aggregate stability coefficients were greater in the forested watershed and this was reflected in a lower soil erodibility compared to the cropped watershed. Sediments resulting from erosion in the forested watershed were clay rich whereas in the cropped watershed the sediment was sand (coarse and fine sand) rich.

Elliott *et al.* (1996) conducted a study on the current hypothesis of the aggregate hierarchy concept is that free primary particles are bound together into microaggregates (50–250 $\mu$ m) by persistent binding agents (e.g. humified OM). These stable microaggregates are bound together into macroaggregates. Microaggregate stability is higher and less dependent on agricultural management than macroaggregate stability. Since long it has been an aspiration to integrate these mechanisms of the physical protection of SOM within aggregates.

Huggins *et al.* (1997) reported significant increases in aggregate stability under perennial crops, but no appreciable change in soil organic carbon. They found that the particulate organic carbon increased as cropland was converted to conservation reserve programme land. Increases in particulate organic carbon were in the range of 2 to 3 t C ha<sup>-1</sup>.

Rhoton and Lindho (1997) assessed soil quality and aggregate stability with depth. Stable aggregates varied at all effective soil depths. The percentage of water stable aggregates increased with increase in effective soil depth.

Aoyama *et al.* (1999) conducted a study on a effects of long-term applications of manure and NPK fertilizer on the labile organic matter (OM) and its protection in water-stable aggregates were investigated in a Le Bras silt loam (HumicGleysol). The study was concluded that manure application contributed to the accumulation of macro aggregate-protected C and N. The study was found that mineral fertilizers increased the protected-N pool only. Macroaggregates can provide a mechanism for the protection of labile soil OM. Crushing the macroaggregates enhanced mineralization of C by 14 to 35% and N by 17 to 103%. Additional C and N rendered mineralizable by crushing represents a fraction of the macroaggregate-protected OM. Manure application increased the protected pools of C (up to threefold) and N (up to fourfold) located in the small macroaggregates (250–1000  $\mu\text{m}$ ).

Franzluebbers *et al.*, (2000) studied on soil aggregation and stated that it is important for maintaining soil surface integrity and allowing water to infiltrate, rather than runoff and cause erosion. Total glomalin of the 1.0- to 4.75-mm dry-stable aggregate class was highly related to whole soil organic C content, but neither of these properties was particularly well related with water- stable macroaggregation, mean-weight diameter, or their stabilities. We conclude, overall, that grazing of pastures in the Southern Pied- mont USA has little detrimental effect on soil aggregate distribution freshly deposited and stability and is comparable in soil conservation with other land gone conservation strategies.

Nimmo and Perkins (2002) reported that, wet analysis may be more appropriate to evaluate or predict erosion due to rainfall impact and runoff. The stability of wet aggregates can be related to surface seal development and field infiltration, as water-stable fractions may restrict water entry and form surface seals (Loch, 1994).

Franzluebbers *et al.*,(2002) Soil aggregation is an important factor for plant growth and directly affects water infiltration, the structure of the microbial community, soil biodiversity, soil biomass dynamics, nutrient adsorption and desorption, oxygen availability to the roots, and soil erosion (Denef *et al.*, 2001;; Six *et al.*, 2004; Madari *et al.*,2005; Souza *et al.*, 2009; An *et al.*, 2010).

Six *et al.*(2004) added that all of these processes greatly affect soil organic matter (SOM) dynamics and nutrient cycling. Soil aggregation is directly related to soil management practices.(Bronick and Lal, 2005).

Angers *et al.* (2005) conducted a study on a measured the incorporation of carbon (C) and nitrogen (N) derived from crop residues in water-stable aggregate fractions of a silty soil in a field experiment in Northern France using  $^{13}\text{C}^{15}\text{N}$ -labelled wheat straw (*Triticum aestivum* L.). The study was concludes that When incorporated in soil, plant residues and their decomposition products are in close contact with mineral particles with which they can be bound to form aggregates. The macro aggregates represented only < 20% of the soil mass and at any one time, they accounted for <25% of the residual  $^{13}\text{C}$  in the soil. The proportion of  $^{13}\text{C}$  recovered in the <50- $\mu\text{m}$  and 50–250- $\mu\text{m}$  fractions increased during decomposition of the residues; at day 574, the 50–250- $\mu\text{m}$  fraction accounted for close to 50% of the residual  $^{13}\text{C}$ . The study was found that in this silty soil the 50–250- $\mu\text{m}$  stable aggregates appear to be involved in the storage and stabilization of C from residues.

John *et al.* (2005) studied the effect of land use and soil cultivation on organic matter stabilization in silty soils under wheat, maize, grassland and spruce. Macro-aggregates (>250  $\mu\text{m}$ ) had high organic carbon content and wider C:N ratio than micro-aggregates (1000  $\mu\text{m}$ . they further reported that the major part (86-9 %) of the soil organic carbon was associated with the heavy mineral fraction at the grassland, maize and wheat site.

Gajic and Zivkovic (2006) evaluated the aggregate composition and structural stability under cropland, pasture and forest. The study was concludes that The stability of aggregates in terms of MWD was higher in soils under forest (5.24 mm) followed by pasture (4.4 mm) and cropland (4.2 mm), while higher soil structure

coefficient values were recorded under pasture (10.5) and lower under cropland (2.6). It was clearly demonstrated that tillage decreases the organic binding agents by exposing it to microorganism, weakening the soil structure stability and decreasing the proportion of agronomically most valuable aggregates (0.25-10 mm).

Hati *et al.* (2007) showed that the aggregation, water retention, micro porosity and available water capacity of the soil were increased while the bulk density was reduced significantly with the 100% NPK+FYM treatment over all other treatments. However, the use of imbalanced (100% N) and suboptimal rate of inorganic fertilizer (50% NPK) as compared to the unfertilized control showed no significant effect on the physical properties of soil.

Lopez *et al.* (2007) found that soil management, particularly tillage operations, affected the erodible fraction more than the intrinsic soil characteristics. The tillage operations were found to affect the erodible fraction directly through breakdown of coarse aggregates and their transformation into smaller ones (Six *et al* 1998, Gale *et al* 2000, Six *et al* 2000, Hevia *et al* 2003), or indirectly by decreasing soil organic matter content (Six *et al* 1998, Wright and Hons 2004).

Zhu *et al.* (2008) investigated a study on the effects of lignin content, acetyl content, and biomass crystallinity on the 1-, 6-, and 72-h digestibilities with various enzyme loadings were investigated. To eliminate the cross effects among structural features, selective pretreatment techniques were employed to vary one particular structural feature during a pretreatment, while the other two structural features remained unchanged. The study was found that lignin content and biomass crystallinity dominated digestibility whereas acetyl content had a lesser effect. Lignin removal greatly enhanced the ultimate hydrolysis extent. Crystallinity reduction, however, tremendously increased the initial hydrolysis rate and reduced the hydrolysis time or the amount of enzyme required to attain high digestibility. To some extent, the effects of structural features on digestibility were interrelated. At short hydrolysis periods, lignin content was not important to digestibility when crystallinity was low.

Colazo and Buschiazzo (2010) investigated the Dry stable aggregates stability DAS of cultivated and uncultivated soils in medium textured soils. The DSA were found to be lower in soils under cultivation 5 (74.5%) than in uncultivated (86.5%) soils, indicating that cultivation reduced the soil's capacity to resist wind erosion and increase the erodible fraction.

Ferro *et al.* (2010) conducted a study on a physico-chemical and physical mechanisms of soil structural stability in a longterm experiment in north-eastern Italy. The study concludes that to investigate subtle structural changes in aggregates and their hydraulic properties (intrinsic permeability). The study demonstrated the central role of organic carbon on aggregate stabilization. The study was found that organic carbon positively affects soil microporosity, reducing the widening effect towards small pores. This is also confirmed by the positive relationship ( $p < 0.05$ ) between SOC and ultra micro pores (5-0.1  $\mu\text{m}$ ).

Singh and Kundu (2010) determined the physical chemical and hydraulic characteristics and soil water function, relationship development. Most of fine textured soils belongs to Inceptisols, Vertisols and coarse textured soils belongs to Alfisols and Entisols subgroups. Clay content varies from 12.4 per cent in Typic Ustipasmments to 62.8 per cent. In Typic Haplustepts silt content varies from 4.9 per cent to 47.1 per cent and sand fraction varied from 7.3 per cent to 82.7 per cent.

Chatterjee *et al.* (2011) conducted a study on the wet stability of aggregates and wet aggregate size distribution under different land uses in typical ustochrepts of northwest India. The study was concluded that the soils under grassland had the highest WSA >2 mm (17.3%) and lowest in eroded lands (0.85%). The effect of land use on the extent of different sized water stable aggregates (WSA) was more pronounced in WSA >2 mm and WSA <2 mm. The study was found that higher proportion of macro aggregates in soil under forest than in cultivation soils so that disturbance induces increase in macro aggregate turnover.

Saha *et al.* (2011) while studying the land use impacts on SOC fractions and aggregate stability in typical ustochrepts of northwest India, observed that the

aggregate associated organic carbon (AAOC) was quantitatively the most dominating fraction followed by particulate organic carbon (POC), labile carbon (LC) and hot water soluble carbon (HWC). The difference in the amount of these fractions due to land use was highest in LC followed by POC, HWC and least in AAOC. The LC was 91.6 per cent lower in eroded lands from that in grasslands, and the difference decreased to 41.5 per cent in AAOC. This indicates that LC responds to a greater extent to the change of land use compared to other fractions. Research shows that LC is characterized by rapid mineralization due to labile nature of its constituents and lack of protection by soil colloids (Turchenek and Oades 1979). The amount of POC and AAOC decreased with decrease in size of water stable aggregates, this could be due to the fact that the larger aggregates are composed of smaller aggregates plus organic binding agents.

Long *et al.* (2015) conducted a study on a the trial was conducted in Wuqiao County, Hebei Province, China. The study was concluded that to evaluate the effects of organic materials on soil aggregate stability, along with the total organic carbon (TOC). The organic materials were incorporated at an equal rate of C, and combined with a mineral fertilizer. The study was found that organic material incorporation increased soil aggregation and stabilization. On average, the soil macroaggregate proportion increased by 14%, the microaggregate proportion increased by 3%, and mean-weight diameter (MWD) increased by 20%. TOC, N, and the quality of organic material. Soil silt and clay particles contained the largest part of TOC, whereas the small macroaggregate fraction was the most sensitive to organic materials.

Davoud *et al.* (2016) demonstrated the extent and rate of decrease of SOC fractions following a change of forest and pasture land use to agriculture. The total organic carbon(TOC) and labile pools of SOC including microbial biomass carbon(MBC), POXC, CWEOC and HWEOC decreased in the order: forest > pasture > forest to agriculture > pasture to agriculture. Among the studied land uses, pasture soils showed a better and different quality of organic carbon than other land use systems, which was indicated by the highest proportion of MBC (3.3%), particulate organic matter (POXC) (4.8%), cold water extractable organic carbon(CWEOC)

(0.55%) and hot water extractable organic carbon(HWEOC) (3.7%). The SOC storage decreased by 36.6 and 34.3 per cent following a change of forest and pasture land use to agriculture. The soils under forest were spotted with the highest amount of SOC stocks ( $42.1 \text{ Mg ha}^{-1}$ ) followed by pasture ( $29.7 \text{ Mg ha}^{-1}$ ), forest to agriculture ( $26.7 \text{ Mg ha}^{-1}$ ) and pasture to agriculture ( $19.5 \text{ Mg ha}^{-1}$ ) land use systems.

Vladimir *et al.* (2016) determined the impact of forest and cropland on water extractable organic carbon (WEOC) fractions and their interaction with soil properties in three types of soils. Forest lands contain a higher concentration and portion of labile WEOC fractions than arable land in all three soil types. The concentration of CWEOC fractions in three soil types under forest ranged from  $0.14$  to  $0.46 \text{ mg g}^{-1}$  while arable lands had lower CWEOC concentrations ( $0.10$ – $0.17 \text{ mg g}^{-1}$ ) in the surface (0–30 cm) horizon. The HWEOC of forest soils contained  $0.53$ – $0.98 \text{ mg g}^{-1}$  of HWEOC and arable soils ranged from  $0.29$  to  $0.35 \text{ mg g}^{-1}$ . The strong and positive correlations were established between the CWEOC and HWEOC fractions with mean weight diameter ( $R^2 = 0.70$ ,  $R^2 = 0.88$ ). The WEOC fractions are uncomplexed, readily mineralizable, and consist mainly of carbohydrates derived from plant roots, microorganisms, amino acids, humic substances and rarely from phenol and lignin monomers, proteins and chitin. This implies that a higher concentration of WEOC leads to more favourable aggregate stability.

Rao *et al.* (2017) studied under continuous use of various inorganic fertilizers and organic manure in a Vertisol. The soil pH and EC did not change significantly but markedly changed the organic carbon and available nutrient contents of the soil. Thus, the balanced use of fertilizers continuously either alone or in combination with organic manure revealed that soil pH was slightly increased from initial to harvest stage. There was a reduction in soil pH when compared to the initial (1991-92) value of 8.4. However, the treatment differences were non-significant. considerable decrease in the soluble salt content of soil which was relatively less compared to the initial (1991-92) value of  $0.60 \text{ dS m}^{-1}$ .

### **2.3 To assess the effect of long term manure and fertilizer application on activities of main hydrolytic enzymes involved in soil carbon cycling**

Liu *et al.* (2010) studies of this site showed that manure is more effective in building soil carbon than straw; yields and water-use efficiency declined significantly with lapse of time, but long-term additions of organic fertilizers to soil could increase the size of water-stable aggregates, the soil water-holding capacity, and the soil enzymatic activity.

Saha *et al.* (2010) studied the effect of continuous six year organic and mineral fertilization on chemical and biological soil properties. They revealed that soils amended with organic manure showed significantly higher  $\beta$ -glucosidase activities as compared to mineral fertilizer amended soils.

Chang *et al.* (2014) conducted a study on a field experiment was conducted to examine the long-term effects of different kinds of organic matter in combination with inorganic nitrogen (N) fertilizer on chemical and biological properties of soils. The study concluded that continuous treatment for 12 years and with cultivation of 24 crops on the same area, soils were sampled for analyses of chemical and biological properties, enzymatic activities and phospholipid fatty acid (PLFA) profiles.. The study was found that a peat application led to the highest increase in SOC content compared to compost and green manure; however, compost-treated soil had a higher microbial population and higher microbial and enzyme activities, while the effects of both green manure and chemical N fertilizer on soil properties

Järvan, *et al.*(2014) conducted a study on a study was to compare the effect of farming methods on soil microbial communities and dehydrogenase activity (DHA). The study concluded that total bacteria and cellulose decomposing bacteria were determined as a number of colony forming units per g of dry soil. Soil DHA was determined in accordance with Tabatabai (1982). The study was found that Solid cattle manure applied in the ORGFYM rotation increased significantly ( $P < 0.05$ ) the number of total bacteria and cellulose decomposing bacteria (by 19.4% and 45.3%, respectively), and DHA by 22.7%.

Mangalassery *et al.* (2015) investigated the DHA activity in agricultural land use consisting of no till (NT) and conventional tillage treatments (CT) in the east midland of UK. The DHA was observed to be higher by 60 per cent in NT soil as compared to CT. Lower activity under CT was attributed by lower organic matter content and higher rate of mineralization of soil organic matter; with the increase in depth the enzyme activity decreased significantly.

Benbi *et al.* (2015) also reported significantly higher DHA activity ( $6.5 \text{ mg kg}^{-1} \text{ soil h}^{-1}$ ) in uncultivated land use than cultivated soils, while no significant difference was observed in other land uses such as agroforestry and cropping system consist of maize-wheat, rice- wheat and sugarcane. Arnab (2012) observed significantly higher dehydrogenase enzyme activity in the grassland and eroded soils as compared to agriculture and agroforestry lands.

Gałązka *et al.*(2017) conducted a study on a effects of long-term maize monoculture and crop rotation on biological activities of soil, especially soil enzymatic activities and microbial communities. experiment conducted from 2004 to 2012 in the Experimental Station in Grabów (MazowieckieVoivodship) on podzolic soil (very good rye soil). The study concluded that the biological activity of the soil was based on the determination of the number of basic groups of soil microorganisms and enzyme activities. The study was found that the statistically significant increase in soil enzymatic activity and total number of bacteria and actinomycetes in soil.

## Chapter-III

### METHODS AND MATERIALS

All India Coordinated Research Project (AICRP) on Long-term fertilizer experiment (LTFE) at ICAR- Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore (West Bengal) under Rice – Wheat – Jute fibre cropping system in soil order *Inceptisol*, where LTFE started in 1971. All India Coordinated Research Project (AICRP) on LTFE at Mahatma PhuleKrishi Vidyapeeth (MPKV), Parbhani (Maharashtra) under Soybean – Safflower cropping system in soil order *Vertisol*, where LTFE started in 1996. The present study entitled “**Long-term effect of manure and fertilizer on soil aggregates and associated carbon in Vertisol and Inceptisol in India**” was carried out in the Soil Biology Division, ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh. The details of the materials used in experimental techniques and analytical methods adopted during the investigation are presented in the chapter under the following heads.

#### 3.1 Experimental site and Situation:

- 1) All India Coordinated Research Project (AICRP) on Long term fertilizer experiment (LTFE) at ICAR- Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore (West Bengal) under Rice – Wheat – Jute fibre cropping system in soil order *Inceptisol*, where LTFE started in 1971.
- 2) All India Coordinated Research Project (AICRP) on LTFE at Mahatma PhuleKrishiVidyapeeth (MPKV), Parbhani (Maharashtra) under Soybean – Safflower cropping system in soil order *Vertisol*, where LTFE started in 1996.

#### 3.2 Geographical location

The experimental site of CRIJAF Barrackpore (W.B.) is situated at 88°26' E, 22°45'N and elevations of 9 m which falls under hot sub-humid to humid eco-region with alluvium-derived soil. The experimental site of MPKV Parbhani (Maharashtra) is situated at 19°15' N latitude and 76°45' E longitude at an elevation of about 407 m above mean sea level which falls under hot semi-arid eco-region.

### 3.3 Weather condition

The climate of the experimental site of Barrackpore is humid (rainfall >1600 mm) with a distinct wet monsoon, summer, and a cool winter season. Average annual temperatures varies from 19.7 °C to 36.9 °C. Whereas, Parbhani falls under hot dry summer and cool winter climate. The mean annual rainfall is about 900 - 960 mm, of which 80-90 per cent is received between June and September months. The daily average minimum temperature varies from 4.4 to 28.6 °C and during summer, the maximum temperature varies from 22.2 °C to 45.5 °C.

### 3.4 Soil characteristics

The soil of experimental site was classified as follows:

Order	Inceptisols	Vertisols
Suborder	Ochrept	Ustert
Great group	Eutrochrept	Haplusterts
Sub group	TypicEutrochrept	TypicHaplusterts

### 3.5 Soil sampling and analysis

Soil samples were collected before sowing of *kharif* crops from three LTFE sites from 0-15 cm depth by the process of random sampling and analysis was conducted at the laboratory of Division of Soil Biology, ICAR-Indian Institute of Soil Science (IISS), Bhopal, Madhya Pradesh.

### 3.6 Experimental details

**Plot size:**10m x30m<sup>2</sup>      **Treatments:**06

**Replications:**03**Design:**Randomized Block Design (RBD)

## Treatment Details

S. No.	Treatment
1.	Fallow
2.	100% N
3.	100% NP
4.	100% NPK
5.	100% NPK + FYM
6.	Control

\*100% NPK(NPK for maize 120:26:75 and NPK for wheat 90:39:38). FYM application @ 5 t ha<sup>-1</sup> on oven dry basis which was 10 t ha<sup>-1</sup>, After harvesting of *Kharif* crops.

### 3.7 Analysis of basic physico-chemical and biochemical parameters of experimental soils

#### 3.7.1 pH

Soil pH was determined using a digital pH meter having glass electrode in 1: 2.5 soil-water suspensions (Jackson, 1973). The pH meter was calibrated using buffer solutions of pH 4.0, 7.0 and 9.2.

#### 3.7.2 Electrical Conductivity

The electrical conductivity (EC) was determined in 1:2.5 soil-water suspensions (Jackson, 1973) by a conductivity meter. The electrical conductivity meter was adjusted at temperature 25°C and calibrated with the standard solution 0.01N KCl solution conductivity 1.41 (dSm<sup>-1</sup> at 25°C).

### 3.7.3 Estimation of Organic carbon (%)

Soil organic carbon was analysed as per the method given by Walkley and Black Method (1934). 1 g soil sample was treated with 10 mL of 1N  $K_2Cr_2O_7$  and 20 mL concentrated  $H_2SO_4$  and mixed by gentle shaking. The flask is allowed to stand for 30 minutes and thereafter 200 mL of distilled water and 10 mL of  $H_3PO_4$  were added. After that the solution was titrated with 0.5 N ferrous ammonium sulphate (FAS) in presence of diphenylamine indicator which changed its colour from blue violet to green at the end point.

### 3.7.4 Estimation of Available N

Available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). 1 g of soil was treated with excess alkaline  $KMnO_4$ . The organic matter present in the soil was oxidized by nascent oxygen liberated by  $KMnO_4$  in presence of sodium hydroxide. Ammonia thus released was absorbed in known volume of standard acid (2% boric acid), excess of which was titrated with standard alkali using methyl red as indicator.

$$\text{Mineralizable N (kg ha}^{-1}\text{)} = R \times 31.36$$

Where, R = volume of 0.02 N  $H_2SO_4$  required for titration.

31.36 = Correction factor

### 3.7.5 Estimation of available phosphorus

Available P was extracted from soil with 0.5 M  $NaHCO_3$  (pH 8.5) as described by Olsen *et al.* (1954) and determined by Ammonium Molybdate Blue Colour method using Spectrophotometer at 882 nm.

$$\text{Available P (kg ha}^{-1}\text{)} = \frac{R \times \text{Volume of extract}}{\text{Volume of aliquot}} \times \frac{2.24 \times 10^6}{\text{wt. (g) of soil} \times 10^6}$$

Where, R =  $\mu\text{g P}$  in the aliquot from standard

### 3.7.6 Estimation of available potassium

The soil was equilibrated with 1N neutral ammonium acetate and available K in the soil extract was estimated using systronic type 120 Flame photometer (Hanway and Heidel, 1952).

$$\text{Available K (kg ha}^{-1}\text{)} = \frac{R \times \text{Volume of extract} \times 2.24}{\text{Weight of soil taken}}$$

Where, R = ppm of K in the extract (obtained from the standard curve)

### 3.7.7 Estimation of soil dehydrogenase activity

Soil dehydrogenase activity (DHA) was determined by the method proposed by Casida *et al.* (1964). The intensity of pink coloured Tri- Phenyl Formazan (TPF) formed due to the reduction of 2, 3, 5-Triphenyl Tetrazolium Chloride (TTC) under anaerobic conditions was measured using spectrophotometer at a wavelength of 485 nm against methanol as a blank. The amount of Tri-Phenyl Formazan (TPF) formed was calculated from the standard curve drawn in the range of 10 to 90 µg TPF ml. The dehydrogenase activity was expressed in terms of µg TPF g<sup>-1</sup>soil h<sup>-1</sup>.

### 3.7.8 Estimation of soil bulk density

Bulk density was measured as per method given by Black (1965) Bulk density was determined by removing natural undisturbed core sample from soil by core sampler. The sample were oven dried at 105°C to a constant weight. Bulk density was calculated by the following formula.

$$\text{Bulk density (gm/cm}^3\text{)} = \frac{\text{Weight of dried soil (gm)}}{\text{Volume of soil (cm}^3\text{)}}$$

### 3.8 Aggregate size distribution

The size distribution of aggregates was measured by wet sieving method (Yoder 1936) using a nest of sieves of 2000, 250, 53  $\mu\text{m}$  mesh size. The bulk soil samples were passed through 2 mm sieve were used for analysis. For wet sieving method, a 50 g sample of aggregates (2 mm) was placed on the top sieve (2 mm) of the sieve set. The water level in the container was adjusted so that the base of the top sieve just touched the water and aggregates were allowed to saturate by capillary rise of water to avoid immersion of aggregates in water and minor explosion due to rushing out of air from the aggregates. After saturating the soil for 5 minutes, the nest of sieve were removed carefully from the water, and aggregate retained on each was back washed and then dried in oven at 60°C for 24 h. After drying, weight of soil aggregate on each sieve was weight.

### 3.9 Water soluble carbon (WSC)

Water soluble organic carbon in soil was determined as per the procedure outlined by McGill et al. (1986). 10 gram freshly drawn field-moist soil sample was shaken with 20 mL distilled water (1:2:: soil : water) distilled water by 30 minutes centrifugation at 10,000 rpm. The supernatant was then filtered with whatman no. 42 then do syringe filter (size= 0.22 $\mu\text{m}$ ) after that store the filtrates at -20°C and 10 ml aliquot was taken in conical flask and treated with 10 mL 1N  $\text{K}_2\text{Cr}_2\text{O}_7$ , 20 mL concentrated  $\text{H}_2\text{SO}_4$  after that swirl a little and keep on an asbestos sheet for 30 minutes and 10 ml ortho-phosphoric acid. Thereafter, add slowly 200mL of distilled water and 1mL of diphenylamine indicator was added and titrated against 0.5 N ferrous ammonium sulphate prepared in 0.4 M  $\text{H}_2\text{SO}_4$  till the appearance of green colour as end point. Simultaneously a blank was also run. WSC was calculated as follows:

$$\text{WSC (\%)} = \frac{(B-S) \times 0.035 \times 0.003 \times 100 \times 10}{\text{Weight of soil}}$$

Where:

0.035 = Normality of ferrous ammonium sulphate

0.003 = Normality of potassium dichromate

B = Quantity of ferrous ammonium sulphate consumed in blank titration

S = Quantity of ferrous ammonium sulphate consumed in sample titration.

### **3.10 Total glomalin (TG) extraction method (Wright and Upadhyay, 1998)**

The total glomalin (TG) extraction method for glomalin extraction. Take 0.25 g of soil in 50 mL centrifuge tube with 2 mL 50 mM sodium citrate. Cap tubes and vortex to have appropriate soil solution contact. Autoclave for 60 min at 121°C. Centrifuge at 5000rpm for 10 min immediately after extraction. Repeat steps 2-4 until the extract is straw-colored. Measure total volume of extract with a graduated cylinder and transfer 1mL to a micro titer tube. The concentrations (mg per g of dry soil) of BRSP fractions were measured by Bradford assay using a standard of bovine serum albumin (1974). The standard curve and linear regression equation was prepared to calculate the concentration of TG-BRSP. Based on the total volume of the supernatants collected, the protein concentration was calculated for one gram culture medium ( $\mu\text{g/g}$ ).

### **3.12 $\text{KMnO}_4$ extractable carbon (Blair et al., 1995)**

Take 3 gram of air dry soil (<2mm) in 50mL centrifuge tube .Add 30 ml of 20 mM  $\text{KMnO}_4$  to soil in centrifuge tube and run a without taking soil. Shake the contents for 15 minutes and centrifuge for 5 minute at 2000 rpm. Transfer 2 mL aliquot of supernatant into 50 ml volumetric flask. This volume makeup by distilled water. Read the absorbance at 560-565nm and determine concentration of  $\text{KMnO}_4$  from standard calibration curve (plot of concentration Vs Absorbance).

#### **Standard curve of $\text{KMnO}_4$**

20mM  $\text{KMnO}_4$  reagent is prepared by dissolved 3.16 gram of AR grade  $\text{KMnO}_4$  in 1000ml distilled water. Adjust pH to 7.2 and store it in amberedcolour bottle. Extract concentration of  $\text{KMnO}_4$  reagent is determined by titration against a known mass (0.10gram) of  $\text{Na}_2\text{C}_2\text{O}_4$  (acidic hot solution) Concentration of  $\text{KMnO}_4$ ( M molar) +gram of  $\text{Na}_2\text{C}_2\text{O}_4 \times 2985/\text{mL}$  of  $\text{KMnO}_4$ .

### **Standard calibration curve :**

Transfer aliquots of 0.0, 0.5, 1.0, 1.5, 2.0 and 2.5 mL standard  $\text{KMnO}_4$  to 50 mL volumetric flask and dilute to volume read absorbance to obtain a standard calibration curve.

### **3.13 Particulate organic carbon (POC)**

The POC was determined by the method as described by Cambardella and Elliot (1992). The POC contained in the whole soil and in each aggregate fraction was separated by dispersing the 10 g of aggregate and whole soil sample with 150 mL of 0.5% sodium hexametaphosphate solution by shaking for 15 h on a reciprocal shaker. The dispersed soil sample was passed through 250  $\mu\text{m}$  and 53  $\mu\text{m}$  sieves. The material retained on 53  $\mu\text{m}$  sieve was rinsed several times with distilled water and dried at 50°C overnight. It (53  $\mu\text{m}$  -250  $\mu\text{m}$ ) was properly ground and analyzed for carbon.

### **3.14 Soil microbial biomass carbon**

The soil microbial biomass carbon was estimated by Chloroform Fumigation Incubation (FI) method of Vance et al., 1987. The soil was sieved through 2 mm mesh sieve to remove stones, coarse roots and all visible litters. 5g of each sample was taken in a beaker and was placed in a vacuum desiccator containing 30 ml of alcohol free chloroform in a shallow dish. The lid was closed and sealed and the vacuum was used till the last trace of chloroform evaporated and thereafter the desiccator was kept in the dark for 10 days at 25°C. Next, weighed another 10g of each sample for unfumigated extraction. The sample was then kept in a conical flask (250mL) and extracted directly without fumigation with 10 mL of 0.5 N NaOH small plastic bottle put in conical flask and sealed this for 10 days. After 10 days sealed NaOH added in 100 mL conical flask. The plastic bottle of NaOH is rinsed by distilled water 2-3 times. Add 3 mL of 2N  $\text{BaCl}_2$  in 100 mL conical flask by pipet. In the digested sample added 1-2 drops of phenolphthalein indicator in 100 mL conical flask after then seen the pink colour of sample. The sample was then titrated with 0.5 N HCl. The end point was a colour change from pink to white. Then we have note

down the titration reading. Three replicates were maintained in each case. For blank, 10 mL of 0.5 N NaOH solution was added in place of sample filtrate solution.

$$SMBC = (\mu\text{g C}^{-1}\text{g soil}) = \frac{E_{CF} - E_{CNF}}{E_{EC}}$$

Where,

$E_{CF}$  = extractable carbon in the fumigated soil sample

$E_{CNF}$  = extractable carbon in the non fumigated soil sample

$E_{EC} = 0.25 + 0.05$  it represent the efficiency of extraction of SMBC Microbial biomass carbon ( $\mu\text{g} / \text{g soil}$ ) =  $(E_{CF} - E_{CNF}) / 0.25$ .

### **3.15 $\beta$ Glucosidase assay**

Assay of  $\beta$  glucosidase enzyme was carried out by the method described by Eivazi and Tabatabai (1988). Taken 1 gm soil (< 2mm sieved) in 50 mL volumetric flask Added 0.25 mL toluene, 4 mL of MUB pH 6.0, 1 mL PNG solution and swirled the flask and placed in an incubator at 37 °C for 1 hour. After incubation removed the stopper and added 0.5 M  $\text{CaCl}_2$  and 4 mL of 0.1 M (tris[hydroxymethyl] aminomethane) THAM buffer, pH 12. Swirled the flask for few seconds and filtered the suspension through Whatman no.2 filter paper measured the yellow colour intensity in spectrophotometer with 420 nm wave length. Calculated the p-nitrophenol content of the filtrate by reference to calibration curve. The activity of  $\beta$ -glucosidase was expressed as  $\mu\text{g}$  (PNP) p-nitrophenyl-phosphate  $\text{g}^{-1}$  soil  $2 \text{ hr}^{-1}$ .

Calibration of standard curve: To prepare a graph with standards containing 0, 10, 20, 30, 40 and 50  $\mu\text{g}$  of p-nitrophenol, dilute 1 mL of standard p-nitrophenol solution to 100 mL in volumetric flask and mix the solution thoroughly. Then pipetted 0, 1, 2, 3, 4 and 5 ml aliquots of this diluted standard solution into 50 mL volumetric flasks and adjusted the volume to 50 mL by addition of distilled water and proceed as described for p-nitrophenol analysis of the incubated soil sample. The standard curve was plotted on a graph paper taking  $\mu\text{g}$  of PNP readings against absorbance of 420 nm.

### **3.16 Statistical analysis**

The obtained experimental data were statistically analyzed by applying analysis of variance (ANOVA) technique. To measure specific differences between pairs of means post hoc test called Duncan's Multiple Range test (DMRT) has been done using SPSS software.

## Chapter-IV

### RESULTS

The results of the present investigation entitled "Long-term effect of manure and fertilizer on soil aggregates and associated carbon in Vertisol and Inceptisol in India have been presented under the following sections.

4.1 Determination of effect of long term manure and fertilizer application on soil aggregates.

4.2 Estimation of associated soil carbon under long term manure and fertilizer application.

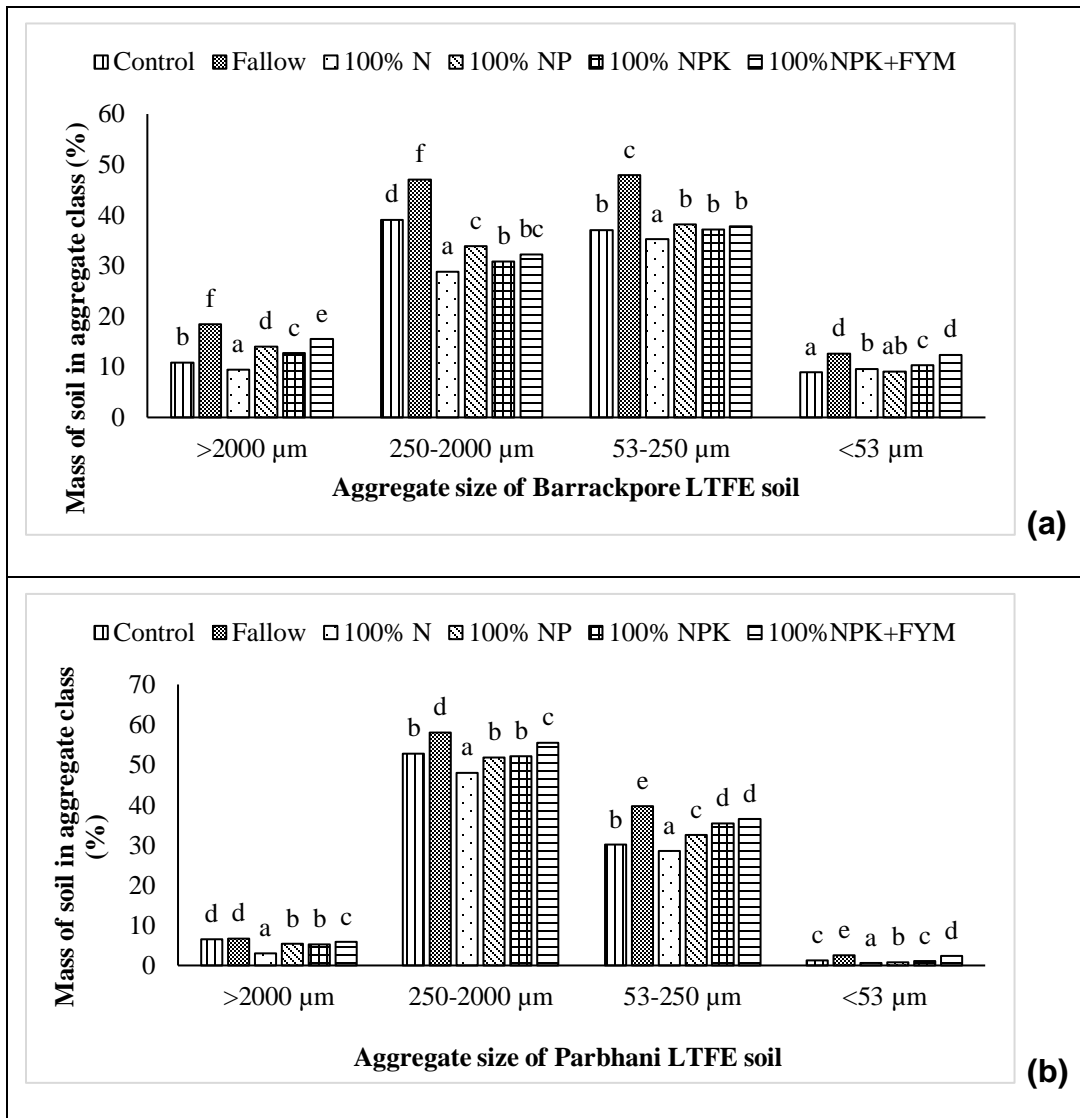
4.3 Assessment of effect of long term manure and fertilizer application on activities of main hydrolytic enzymes involved in soil carbon cycling.

4.1 Determination of effect of long term manure and fertilizer application on soil aggregates

The effect of long-term use of farmyard manure (FYM) and inorganic fertilizers in Inceptisol (Rice–Wheat-Jute rotation) and Vertisol (Soybean-Safflower) has been investigated for aggregate size distribution, aggregate-carbon, particulate organic matter carbon, water soluble organic carbon, KMnO<sub>4</sub> extractable carbon and aggregate-glomalin content in the soil samples of LTFE Barrackpore and LTFE Parbhani. The targeted treatments are fallow, control, 100% N, 100% NP, 100% NPK, 100% NPK + FYM.

Significant variations in aggregate size distribution were noticed among different treatments in LTFE Barrackpore (Fig. 1a). Both the 250-2000µm macroaggregates and 53-250µm microaggregates contributed almost equally in aggregate size distribution and accounted for 28.7 to 47.01% and 35.2 to 47.9% of the dry weight of soil, respectively. Among all the treatments fallow had the highest % contribution to each aggregate size class and it was followed by the 100% NPK+FYM treatment. In contrast, in LTFE Parbhani the highest contributing aggregate class was 250-2000 µmacroaggregates which accounted for 48.05 to 58.04% of dry weight of soil, whereas, 53-250µm microaggregates accounted for 28.5 to 39.75% of dry weight of

soil (Fig. 1b). The relative weight of soil increased with decrease in aggregate size classes, and significant differences due to fertilizer treatments were observed in all aggregate size classes except for the silt-clay fractions (<53  $\mu\text{m}$ ) in LTFE-Barrackpore and microaggregates in LTFE-Parbhani. Amongst treatments, fallow showed better aggregate stability than cultivated soil in both the Inceptisols and Vertisols. Continuous application of 100% N, 100% NP, and 100% NPK significantly reduced larger macroaggregates (>2000  $\mu\text{m}$ ).



#Means followed by different letter are significantly different as per DMRT

Fig. 1. Aggregate size distribution (a) Barrackpore LTFE soil (b) Parbhani LTFE soil.

**Table 4.1** Effect of long term application of fertilizer and manure on soil aggregate proportion Mass of soil in aggregate class (%) Barrackpore and Parbhani soil.

Table (4.1.1) - Barrackpore soil

Treatment	Aggregate size class			
	>2000 $\mu\text{m}$	250-2000 $\mu\text{m}$	53-250 $\mu\text{m}$	<53 $\mu\text{m}$
Control	10.840(b)	39.097(d)	37.086(b)	8.984(a)
Fallow	18.400(f)	47.013(f)	47.947(c)	12.633(d)
100% N	9.420(a)	28.773(a)	35.207(a)	9.593(b)
100% NP	13.940(d)	33.813(c)	38.173(b)	9.073(ab)
100% NPK	12.700(c)	30.773(b)	37.213(b)	10.313(c)
100%NPK+FYM	15.500(e)	32.253(bc)	37.827(b)	12.413(d)

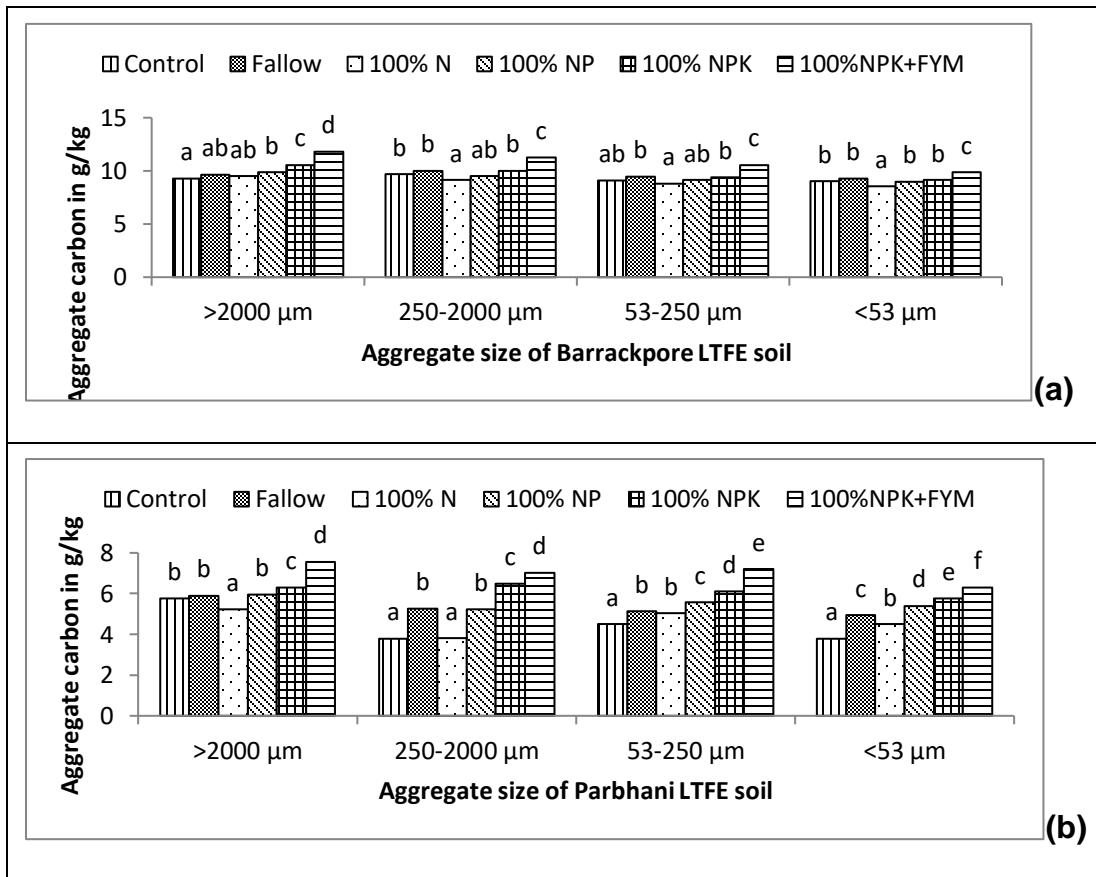
Table (4.1.2) -Parbhani soil

Treatment	Aggregate size class			
	>2000 $\mu\text{m}$	250-2000 $\mu\text{m}$	53-250 $\mu\text{m}$	<53 $\mu\text{m}$
Control	6.540(d)	52.773(b)	30.060(b)	1.213(c)
Fallow	6.720(d)	58.046(d)	39.757(e)	2.477(e)
100% N	3.080(a)	48.053(a)	28.502(a)	0.647(a)
100% NP	5.360(b)	51.785(b)	32.470(c)	0.813(b)
100% NPK	5.260(b)	52.121(b)	35.357(d)	1.127(c)
100%NPK+FYM	5.880(c)	55.507(c)	36.441(d)	2.356(d)

## 4.2 Estimation of associated soil carbon under long term manure and fertilizer application

### (a) Soil organic carbon associated with soil aggregates

In both LTFE soils of Barrackpore and Parbhani, overall associated carbon concentrations were greater in macroaggregates (>2000  $\mu\text{m}$ ) followed by small macroaggregates (250–2000  $\mu\text{m}$ ) >microaggregates (53-250  $\mu\text{m}$ ) > silt–clay fractions (<53  $\mu\text{m}$ ). Irrespective of aggregate size classes, the concentration of carbon was significantly higher in the 100% NPK+FYM treatment followed by 100% NPK and fallow soils (Fig. 2a, 2b). Significant variation in aggregate size classes was also observed between 100% N and 100% NP treatment and control. The least carbon was present in the <53  $\mu\text{m}$  size class for all the treatments in both the soil orders



#Means followed by different letter are significantly different as per DMRT

**Fig. 2. Aggregate carbon (a) Barrackpore LTFE soil (b) Parbhani LTFE soil.**

**Table 4.2** Effect of long term application of fertilizer and manure on soil aggregate carbon in(g/kg)LTFE Barrackpore and LTFE Parbhani soil

Table(4.2.1)- Aggregate carbon in Barrackpore soil

Treatment	Aggregate size class			
	>2000 $\mu\text{m}$	250-2000 $\mu\text{m}$	53-250 $\mu\text{m}$	<53 $\mu\text{m}$
Control	9.277(b)	9.680(d)	9.08(b)	9.010(a)
Fallow	9.635(f)	9.978(f)	9.441(c)	9.256(d)
100% N	9.487(a)	9.129(a)	8.771(a)	8.5204(b)
100% NP	9.845(d)	9.487(c)	9.129(b)	8.966(ab)
100% NPK	10.561(c)	10.024(b)	9.3796(b)	9.129(c)
100%NPK+FYM	11.814(e)	11.277(bc)	10.561(b)	9.845(d)

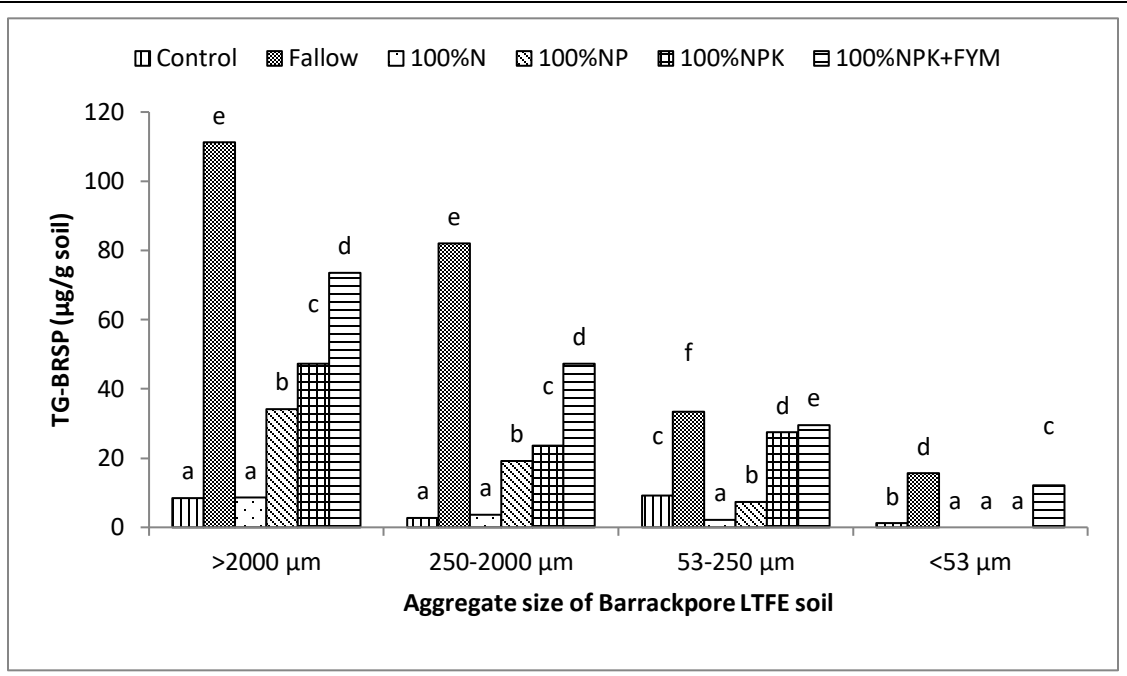
Table-(4.2.2)-Aggregate carbon in Parbhani soil

Treatment	Aggregate size class			
	>2000 $\mu\text{m}$	250-2000 $\mu\text{m}$	53-250 $\mu\text{m}$	<53 $\mu\text{m}$
Control	6.540(b)	52.773(a)	30.060(a)	1.213(a)
Fallow	6.720(b)	58.046(b)	39.757(b)	2.477(c)
100% N	3.080(a)	48.053(a)	28.502(b)	0.647(b)
100% NP	5.360(b)	51.785(b)	32.470(c)	0.813(d)
100% NPK	5.260(c)	52.121(c)	35.357(d)	1.127(e)
100%NPK+FYM	5.880(d)	55.507(d)	36.441(e)	2.356(f)

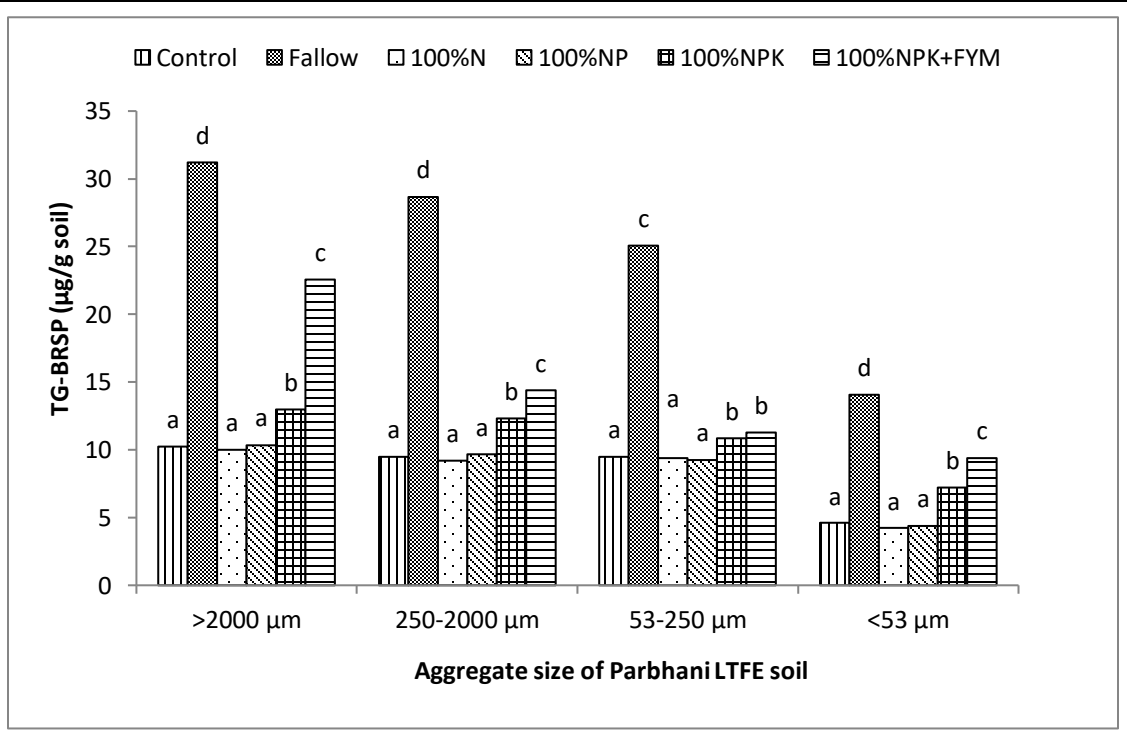
***(b) Total glomalin associated with soil aggregates***

Glomalin, a fungal glycoprotein, play a significant role in soil aggregation (Wright and Upadhyaya, 1996). Total glomalinbradford related soil protein (TG-BRSP) concentrations ( $\mu\text{g g}^{-1}$ ) across all treatments are shown in Fig.3a & b. Significant amounts of bovine serum albumin (BSA) persisted after the extraction process were detected by the Bradford method. Regardless of soil type, fallow treatment showed significantly higher TG-BRSP over other treatments. In Barrackpore LTFE soil, significant difference in TG-BRSP content was observed amongst soil aggregates. Highest TG-BRSP was recorded in fallow treatment and in soil aggregates size  $>2000 \mu\text{m}$  followed by  $250-2000 \mu\text{m}$ ,  $53-250 \mu\text{m}$  and  $< 53 \mu\text{m}$  in both Barrackpore and Parbhani LTFE soils. However, there is no significant difference between control, 100% N and 100% NP treatments in Parbhani LTFE soil.

It is evident from the figure 3, that more amount of total glomalin has been extracted from Inceptisols (Barrackpore LTFE soils) than Vertisols (Parbhani LTFE soils). It was also observed that amongst aggregates, significant and consistent decrease was seen from macroaggregates to microaggragates in Inceptisols. But, in Vertisols the decrease was not very much significant.



(a)



(b)

#Means followed by different letter are significantly different as per DMRT

**Fig. 3. Total glomalinbradford related soil protein (TG-BRSP) (a) Barrackpore LTFE soil (b) Parbhani LTFE soil.**

**Table 4.3** Effect of long term application of fertilizer and manure on soilTotal glomalinTG-BRSP ( $\mu\text{g/g}$  soil) in LTFE Barracpore and LTFE Parbhani soil.

Table(4.3.1) -Total glomalin in Barracpore soil

Treatment	Aggregate size class			
	>2000 $\mu\text{m}$	250-2000 $\mu\text{m}$	53-250 $\mu\text{m}$	<53 $\mu\text{m}$
Control	8.52(a)	2.72(a)	9.19(c)	1.16(b)
Fallow	111.21(e)	81.99(e)	33.33(f)	15.59(d)
100%N	8.54(a)	3.61(a)	2.16(a)	0(a)
100%NP	34.18(b)	19.11(b)	7.38(b)	0(a)
100%NPK	47.36(c)	23.55(c)	27.44(d)	0(a)
100%NPK+FYM	73.48(d)	47.31(d)	29.57(e)	12.05(c)

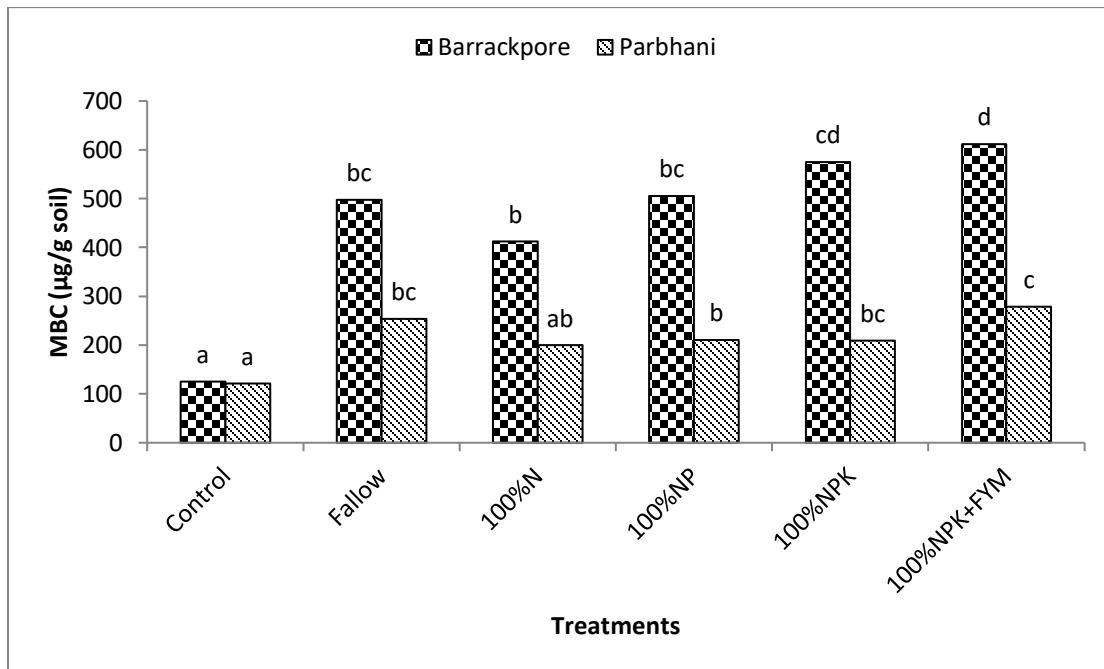
Table(4.3.2) -Total glomalin in Parbhani soil.

Treatment	Aggregate size class			
	>2000 $\mu\text{m}$	250-2000 $\mu\text{m}$	53-250 $\mu\text{m}$	<53 $\mu\text{m}$
Control	10.240(a)	9.499(a)	9.499(a)	4.596(a)
Fallow	31.200(d)	28.666(d)	25.066(c)	14.074(d)
100%N	10.020(a)	9.199(a)	9.388(a)	4.222(a)
100%NP	10.350(a)	9.666(a)	9.266(a)	4.399(a)
100%NPK	12.980(b)	12.333(b)	10.866(b)	7.200(b)
100%NPK+FYM	22.570(c)	14.399(c)	11.266(b)	9.399(c)

**(c) Soil microbial biomass carbon**

The soil microbial biomass is an essential component of nutrient cycling in the agroecosystems. The long-term effect of fertilizer and manure on soil microbial biomass carbon (MBC) was significant (Fig. 4). Application of FYM along with NPK significantly increased the MBC over other treatments. The mean MBC (in  $\mu\text{g/g}$  soil) observed in individual treatments in decreasing order were: 100% NPK+FYM (612) > 100% NPK (574) > 100% NP (505) > fallow (497) > 100% N (411) > control (125) in Inceptisols (Barrackpore LTFE soils) and 100% NPK+FYM (278) > fallow (254) > 100% NP (210) > 100% NPK (209) > 100% N (199) > control (121) in Vertisols (Parbhani LTFE soils).

It was also observed that soil microbial biomass carbon was recorded almost twice or more in Inceptisols than in Vertisols, in all treatments except for control.



#Means followed by different letter are significantly different as per DMRT

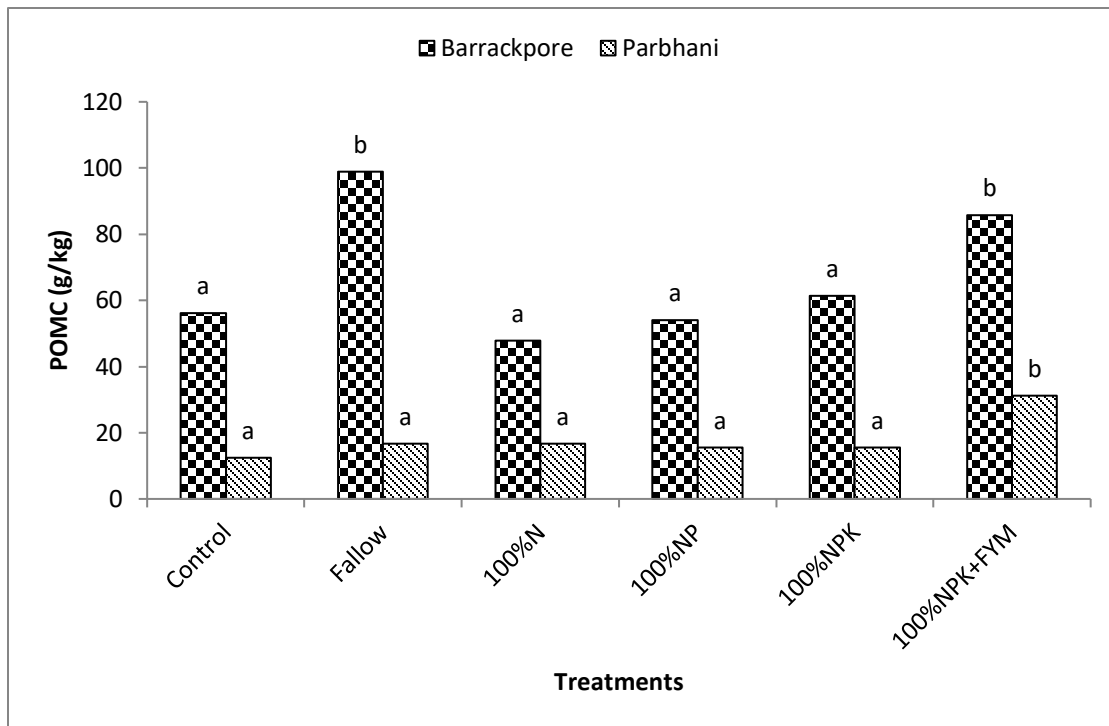
**Fig. 4. Soil Microbial Biomass Carbon (MBC) at LTFE-Barrackpore and LTFE-Parbhani soils.**

**Table 4.4** Effect of long term application of fertilizer and manure on Microbial biomass carbon (MBC) ( $\mu\text{g g}^{-1}$  soil)

Treatment	Microbial biomass carbon(MBC)( $\mu\text{g g}^{-1}$ soil)	
	Barrackpore	Parbhani
Control	125.4(a)	121.5(a)
Fallow	497.8(bc)	254.1(bc)
100% N	411.7(b)	199.7(ab)
100% NP	505.7(bc)	210.8(b)
100% NPK	574.9(cd)	209.4(bc)
100%NPK+FYM	612.2(d)	278.5(c)

***(d) Particulate organic matter carbon***

The particulate organic matter carbon(POMC) is an indicator of soil quality for any land use management and tillage practice and its disruption rate is primarily affected by soil aggregates (Cambardella and Elliott, 1992; Kuo et al., 1997). In LTFE-Barrackpore, as cultivation continued with unbalanced fertilization, there was an extensive depletion of particulate organic matter carbon (POMC) (Fig.5). POMC was recorded highest in fallow treatment followed by 100% NPK + FYM. Whereas in LTFE-Parbhani, POMC was significantly highest in the treatment with 100% NPK + FYM. But, in other treatments no significant difference has been observed.



#Means followed by different letter are significantly different as per DMRT

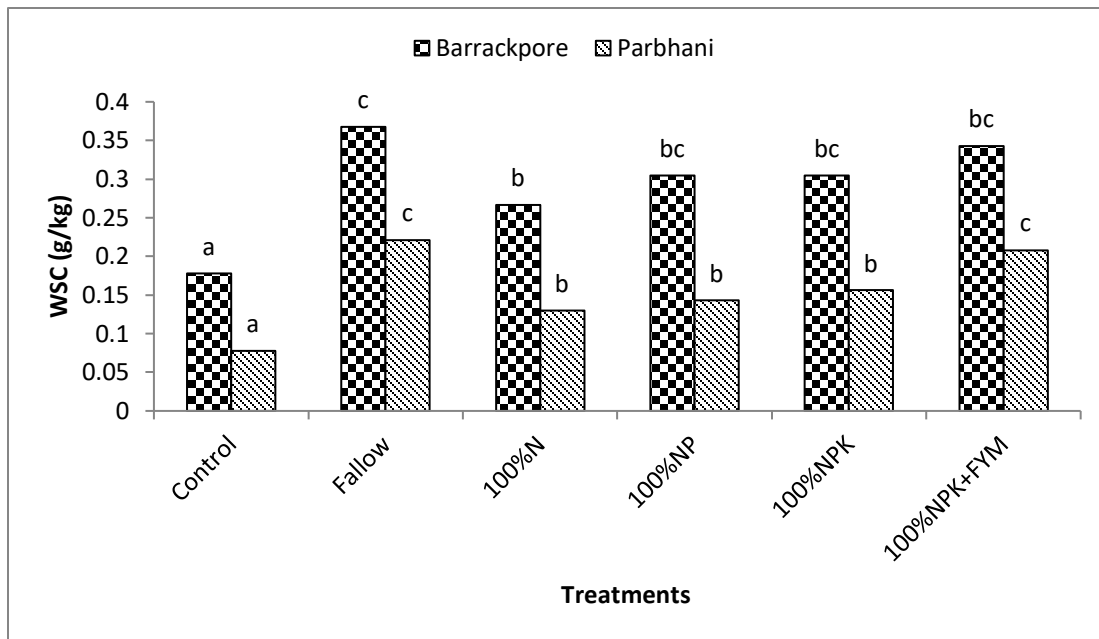
Fig.5. Particulate Organic Matter Carbon at LTFE-Barrackpore and LTFE-Parbhani.

**Table 4.5** Effect of long term application of fertilizer and manure on soil Particulate organic matter carbon (g/kg) in Barrackpore and Parbhani soil.

Treatment	Particulate organic matter carbon (g/kg)	
	Barrackpore	Parbhani
Control	56.16(a)	12.48(a)
Fallow	98.8(b)	16.64(a)
100% N	47.84(a)	16.64(a)
100% NP	54.08(a)	15.6(a)
100% NPK	61.36(a)	15.6(a)
100%NPK+FYM	85.8(b)	31.2(b)

**(e) Water soluble carbon**

Water soluble carbon represents the labile fraction of carbon from the soil, which is also important source for microorganisms. Water soluble carbons (WSC) of both the soils are represented in Fig. 6. Perusal of the data shows that the WSC was recorded significantly highest in fallow treatment irrespective of the soil order. In LTFE- Barrackpore, WSC in 100% NP, 100% NPK and 100% NPK+ FYM was non-significant followed by 100% N and lowest in control. In LTFE-Parbhani, WSC in 100% NPK+ FYM treatment is at par with fallow treatment, whereas, 100% N, 100% NP and 100% NPK were non-significant. Lowest WSC was observed in control.



#Means followed by different letter are significantly different as per DMRT

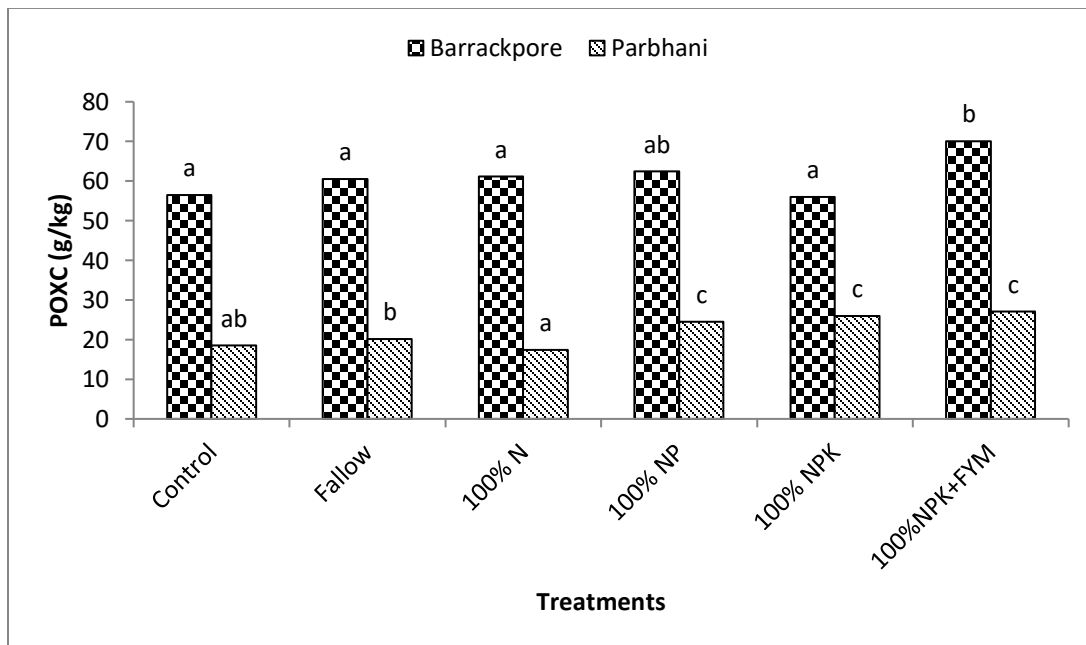
Fig.6. Water Soluble Carbon (WSC) at LTFE-Barrackpore and LTFE-Parbhani.

**Table 4.6** Effect of long term application of fertilizer and manure on soil water soluble carbon(g/kg) in Barrackpore and Parbhani soil.

Treatment	water soluble carbon(g/kg)	
	Barrackpore	Parbhani
Control	0.177(a)	0.078(a)
Fallow	0.367(c)	0.221(c)
100% N	0.266(b)	0.13(b)
100% NP	0.304(bc)	0.143(b)
100% NPK	0.304(bc)	0.156(b)
100%NPK+FYM	0.342(bc)	0.208(c)

### (f) Potassium permanganate oxidizable carbon

The potassium permanganate oxidizable carbon (POXC) significantly increased due to fertilization in both the soil orders and recorded significantly highest in 100% NPK + FYM treatment (Fig.7). In LTFE-Barrackpore, other treatments showed non-significant difference. Whereas, in LTFE-Parbhani, 100%NP and 100% NPK values are at par with 100% NPK + FYM. These again signified the superiority of balanced fertilization over other nutrient management treatments (Sandeep et al. 2016).



#Means followed by different letter are significantly different as per DMRT

**Fig.7. Potassium Permanganate Oxidizable Carbon (POXC) at LTFE-Barrackpore and LTFE-Parbhani.**

**Table 4.7** Effect of long term application of fertilizer and manure on soil (POXC) Potassium permanganate oxidizable carbon (g/kg) in Barrackpore and Parbhani soil.

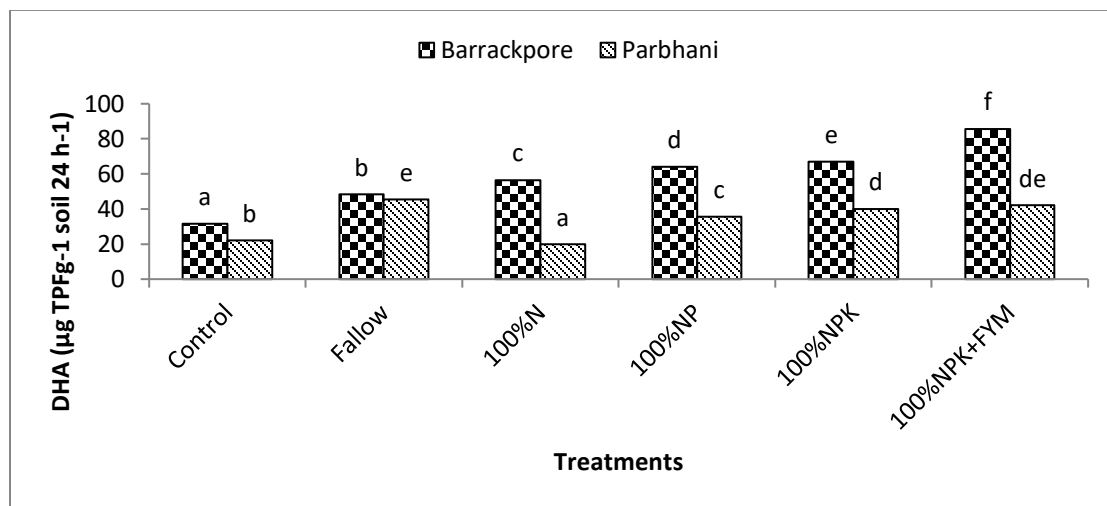
Treatment	Potassium permanganate oxidizable carbon (g/kg)	
	Barrackpore	Parbhani
Control	56.52(a)	18.59(ab)
Fallow	60.5(a)	20.13(b)
100% N	61.09(a)	17.37(a)
100% NP	62.43(ab)	24.43(c)
100% NPK	55.97(a)	25.92(c)
100%NPK+FYM	70.09(b)	27.03(c)

### 4.3 Assessment of effect of long term manure and fertilizer application on activities of main hydrolytic enzymes involved in soil carbon cycling

#### (a) Dehydrogenase enzyme

Dehydrogenase activity (DHA) is thought to reflect the total range of oxidative activity of soil microflora and may be a good indicator of microbial activity (Nannipieri et al., 1990). In LTFE-Barrackpore, optimum and balanced application of nutrients (100% NPK + FYM) led to significant increase in DHA (Fig.8). However, in the most heavily fertilized treatment (100% NPK), significant reduction in dehydrogenase activity was observed followed by 100% NP > 100% N > fallow > control.

In contrast to Inceptisols, in LTFE-Parbhani (Vertisols), dehydrogenase activity was recorded significantly more in fallow treatment followed by 100% NPK + FYM > 100% NP > 100% N > control.



#Means followed by different letter are significantly different as per DMRT

Fig.8. Dehydrogenase Activity (DHA) at LTFE-Barrackpore and LTFE-Parbhani.

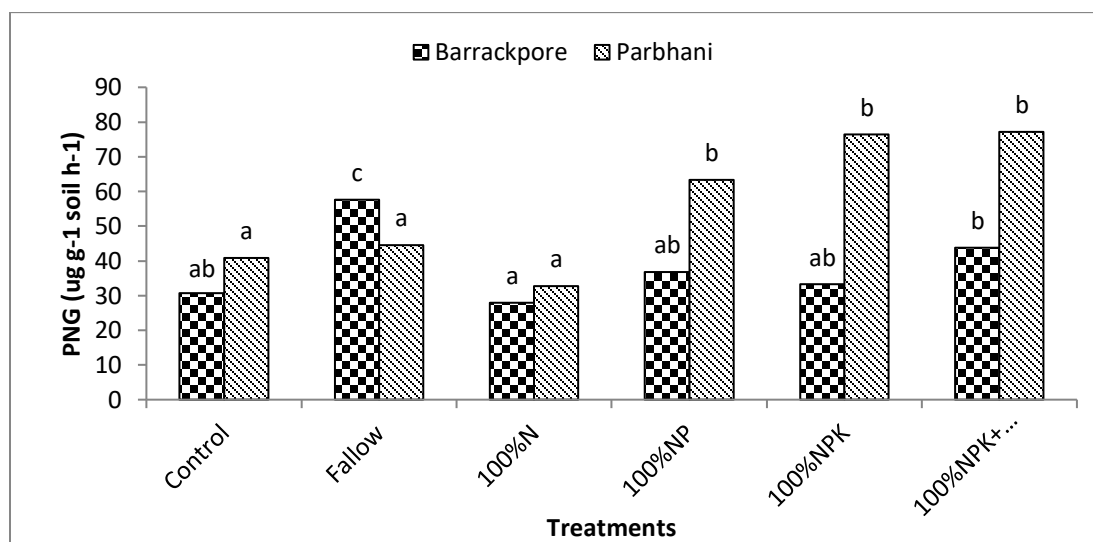
**Table 4.8** Effect of long term application of fertilizer and manure on soil LTFE Barrackpore and parbhani soil Dehydrogenase activity (DHA) DHA ( $\mu\text{g TPFg}^{-1}$  soil  $24 \text{ h}^{-1}$ )

Treatment	Dehydrogenase activity DHA ( $\mu\text{g TPFg}^{-1}$ soil $24 \text{ h}^{-1}$ )	
	Barrackpore	Parbhani
Control	31.72(a)	22.7(b)
Fallow	48.35(b)	45.3(e)
100% N	56.55(c)	19.8(a)
100% NP	64.21(d)	35.7(c)
100% NPK	66.9e(e)	40.1(d)
100%NPK+FYM	85.54(f)	42.1(de)

## (b) $\beta$ -Glucosidase enzyme

In LTFE-Barrackpore,  $\beta$ -Glucosidase activity was observed significantly highest in fallow followed by 100% NPK + FYM. The treatments 100% NPK, 100% NP and control showed non-significant difference. Lowest enzyme activity was observed at 100% N treatment (Fig.9).

Whereas, in LTFE-Parbhani (Vertisols),  $\beta$ -Glucosidase activity was recorded significantly more in 100% NPK + FYM, 100% NPK and 100% NP treatment followed by fallow, control and 100% N.



#Means followed by different letter are significantly different as per DMRT

Fig.9.  $\beta$ -Glucosidase Activity at LTFE-Barrackpore and LTFE-Parbhani.

Table 4.9 Effect of long term application of fertilizer and manure on soil LTFEBarrackpore and Parbhani soil  $\beta$ -Glucosidase Activity PNG ( $\mu\text{g g}^{-1} \text{soil h}^{-1}$ )

Treatment	$\beta$ -Glucosidase Activity PNG ( $\mu\text{g g}^{-1} \text{soil h}^{-1}$ )	
	Barrackpore	Parbhani
Control	30.68(ab)	40.9(a)
Fallow	57.64(c)	44.6(a)
100% N	27.99(a)	32.8(a)
100% NP	36.81(ab)	63.4(b)
100% NPK	33.28(ab)	76.5(b)
100%NPK+FYM	43.87(b)	77.2(b)

## Chapter-V

### DISCUSSION

Results from long-term experiments can help in establishing cause-and-effect relationships between organic pools and nutrients. The present study entitled **“Long-term effect of manure and fertilizer on soil aggregates and associated carbon in Vertisol and Inceptisol in India”** was carried out in the Soil Biology Division, ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh. This chapter deals with the discussion of the results obtained from the study. The investigation provided an opportunity to evaluate long-term effects of 100% N, 100% NP, 100% NPK and 100% NPK + FYM and fallow treatments compared with control on aggregation, associated carbon, total glomalin associated with aggregates (TG-BRSP), microbial biomass carbon (MBC), particulate organic matter carbon (POMC), water soluble carbon (WSC), potassium permanganate oxidizable carbon (POXC), dehydrogenase (DHA) and  $\beta$ -Glucosidase activity.

Soil aggregation is the key indicator of soil quality. Aggregate formation stabilizes organic material within soil microsites, physically protecting soil organic matter from microbial decomposition and increasing the mean residence time relative to interaggregate (unprotected) organic matter. Aggregate stability conserves soil moisture, maintain constant soil temperatures and improve water infiltration rates (Bhattacharyya et al., 2012). Impact of seasonal tillage alters biological activity, major nutrient transformation potential and crop yield. Variations in aggregate size distribution due to treatments reflected the importance of organic matter in stabilizing soil aggregates. Continuous, intensive conventional tillage and removal of aboveground residues depleted aggregates in N, NP and unfertilized control plots compared to fallow. Stabilization is favoured through the binding actions of humic substances, polysaccharides and fungal hyphae (Haynes and Beare, 1996; Graham et al., 2002). The unbalanced treatments (N and NP) tended to produce less stable aggregate than the balanced fertilized plots.

The results on soil aggregation irrespective of soil orders was found similar with the study of Schutter and Dick (2002). They show that fallow treatment exhibits greater amount of soil aggregate than cultivated soil. Due to the use of heavy

machinery equipments used for tillage, for applications of fertilizer, herbicides, and pesticides, and for crop harvest results in rupturing of macroaggregates and microaggregates into smaller proportion (Whalen and Chang, 2002; Sainju, 2006). Such reductions in these aggregates might be due to lower content of water soluble carbon (WSC) as these act as binding agents in rhizosphere soil. The reduction in aggregates and the loss of organic matter with intensive cultivation has been used to explain the aggregate hierarchy theory by many authors (Six et al., 2000; Graham et al., 2002b). The water-soluble carbon is considered the most active component of SOM. Though it is a small fraction of SOM, it acts as buffering agent in replenishment mechanisms like desorption from soil colloids, dissolution from litter, and exudation from plant roots (McGill et al., 1986; Groot and Houba, 1995; Campbell et al., 1999; Curtin and Wen, 1999; Six et al., 2000). It also appears to be the immediate substrate for the soil microorganisms. Thus, water soluble fractions are considered the most active and highly labile components of total SOC; they catalyse nutrient supply (N, P, S and other nutrients) in response to management practices (Dalal and Mayer 1987; Parton *et al.* 1987; Janzen *et al.* 1992; Dalal 1998).

Greater SOC concentrations in macroaggregates suggested that the presence of decomposing roots and fungal hyphae within macroaggregates not only increased carbon concentrations but also contributed to their stabilization. Puget et al. (1998) suggested the greater SOC concentration in macroaggregates could be due to lower decomposable soil organic matter associated with these aggregates, and also the direct contribution of SOM to the these aggregates. Further, the bioproducts released by decomposition and by root exudation processes enhance aggregation of clay and silt particles and the temporary binding agents (i.e., fungal hyphae) increase macroaggregation. Further, many studies reported that materials with a higher lignin content (FYM) result in a greater accumulation per unit of C input than that of low-lignin residue amendments (Paustian et al., 1992; Stevenson, 1982).

Soil management practices strongly affect the size of the microbial biomass pool. In the present study, different long-term fertilizer treatments greatly affected soil MBC (Fig. 4). The MBC was low in the control and unbalanced fertilizer treatments and

increased significantly with manure and optimum NPK application. Similar results have also been reported by several other workers (Goyal et al., 1992; Chakrabarti et al., 2000; Kaur et al., 2005). The readily metabolizable carbon and N in organic manure in addition to increasing root biomass and root exudates due to greater crop growth are the most influential factors contributing to the biomass increase. This view is consistent with the observation of Hopkins and Shiel (1996) who reported that the microbial biomass was greater in soils following annual additions for nearly 100 years of FYM in the presence of inorganic NPK than additions of inorganic fertilizer or FYM alone. Similarly, Kaur et al. (2005) have also observed that in general, MBC tends to be smaller in unfertilized soils or those fertilized with chemical fertilizers compared to soil amended with organic manures. The trends in MBC among different fertilizer treatments are dependable with the SOC; however, the magnitude of treatment effect was much higher for MBC.

Particulate organic C is the precursor for the formation of soil MBC, soluble fraction of C and the humic and non-humic fractions of carbon in the soil, and hence, is a key attribute of soil quality. POMC fraction is affected by tillage and residue input, whereas other fractions are affected by aggregation and aggregate mineralization (Chan, 2001). The large pool of POMC maintains soil structure and macro aggregation (Campbell et al., 1999). These pools enhance labile and stabilized SOM fractions in the soil. In addition, the labile fraction has disproportionately large effect on the nutrient-supplying capacity and structural stability of the soil. POMC is a transient pool of the SOC that is intermediate in the decay continuum between fresh litter and humified organic matter and exert greater influence on soil aggregate stability (Nciizah and Wakindiki, 2012). In a long-term field trial, Li et al. (2012) reported that the SOC and light fraction of particulate organic carbon concentrations were considerably greater in soils receiving FYM along with NPK fertilizer. Many researchers have also reported redistribution of SOM from labile to more humified fractions with cropping (Ladd et al., 1977; Anderson et al., 1981; Elliott, 1986). Thus, long-term N or NP fertilizer application with simultaneous and continuous removal of crop residues reduced the quantity of POMC that could be physically occluded within aggregates. Sainju et al. (2003) also

reported that POMC varied due to tillage practices, amount, type and placement of crop residue, soil type, and environmental conditions. Balanced plant nutrition (NPK + FYM) was necessary to increase total amount of POC in the soils.

The study on enzyme activity suggests that dehydrogenase activity is sensitive to the inhibitory effects associated with large amount of nitrogenous fertilizer additions (Goyal et al., 1992). Hence, the application of a balanced amount of fertilizer nutrients and manure improved the organic matter status of soils, which in turn enhanced the enzyme activity. In LTFE-Parbhani, similar response is evident for the 100% N compared to the control for dehydrogenase activity. The low dehydrogenase activity response to N may be due to the interference of nitrates, which serve as an alternate electron acceptor resulting in low activities at higher rates of nitrogenous fertilizer application (Casida et al., 1964). These observations indicate that dehydrogenase activity may not be a reliable index of microbial activity for soils where rates of N fertilizer are at super optimal doses.

## CHAPTER- VI

### SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

#### 5.1 SUMMARY

Laboratory studies were conducted to evaluate the effect of manure and fertilizer application on nitrogen transformation in 3 different soil orders of India. The soil samples were collected from the experimental sites (LTFE Barrackpore and Parbhani) and analysis were conducted in the Division of Soil Biology, ICAR-Indian Institute of Soil Science (IISS) Bhopal. The six treatments each from LTFE Barrackpore and Parbhani were selected for the study. Various chemical and biological parameters of soil were studied during this study to explore the effect of long term application of manure and fertilizer on different steps of nitrogen transformation. Salient findings of the study are compiled objective wise as follows:

#### **5.1 Determination of effect of long term manure and fertilizer application on soil aggregates**

1. The effect of long-term use of farmyard manure (FYM) and inorganic fertilizers in Inceptisol (Rice–Wheat-Jute rotation) and Vertisol (Soybean-Safflower) has been investigated for aggregate size distribution, aggregate-carbon, particulate organic matter carbon, water soluble organic carbon, KMnO<sub>4</sub> extractable carbon and aggregate-glomalin content in the soil samples of LTFE Barrackpore and LTFE Parbhani. The targeted treatments are fallow, control, 100% N, 100% NP, 100% NPK, 100% NPK + FYM.
2. Significant variations in aggregate size distribution were noticed among different treatments in LTFE Barrackpore. Both the 250-2000 $\mu$ m macroaggregates and 53-250 $\mu$ m microaggregates contributed almost equally in aggregate size distribution and accounted for 28.7 to 47.01% and 35.2 to 47.9% of the dry weight of soil, respectively. Among all the treatments fallow had the highest % contribution to each aggregate size class and it was followed by the 100% NPK+FYM treatment. In contrast, in LTFE Parbhani the highest contributing aggregate class was 250-2000

$\mu$ m macroaggregates which accounted for 48.05 to 58.04% of dry weight of soil, whereas, 53-250 $\mu$ m microaggregates accounted for 28.5 to 39.75% of dry weight of soil. The relative weight of soil increased with decrease in aggregate size classes, and significant differences due to fertilizer treatments were observed in all aggregate size classes except for the silt–clay fractions (<53  $\mu$ m) in LTFE-Barrackpore and microaggregates in LTFE-Parbhani. Amongst treatments, fallow showed better aggregate stability than cultivated soil in both the Inceptisols and Vertisols. Continuous application of 100% N, 100% NP, and 100% NPK significantly reduced larger macroaggregates (>2000  $\mu$ m).

## **5.2 Estimation of associated soil carbon under long term manure and fertilizer application**

1. In both LTFE soils of Barrackpore and Parbhani, overall associated carbon concentrations were greater in macroaggregates (>2000  $\mu$ m) followed by small macroaggregates (250–2000  $\mu$ m) > microaggregates (53-250  $\mu$ m) > silt–clay fractions (<53  $\mu$ m). Irrespective of aggregate size classes, the concentration of carbon was significantly higher in the 100% NPK+FYM treatment followed by 100% NPK and fallow soils. Significant variation in aggregate size classes was also observed between 100% N and 100% NP treatment and control. The least carbon was present in the <53  $\mu$ m size class for all the treatments in both the soil orders.

2. Glomalin, a fungal glycoprotein, play a significant role in soil aggregation (Wright and Upadhyaya, 1996). Total glomalin related soil protein (TG-BRSP) concentrations ( $\mu$ g  $g^{-1}$ ) across all treatments. Significant amounts of bovine serum albumin (BSA) persisted after the extraction process were detected by the Bradford method. Regardless of soil type, fallow treatment showed significantly higher TG-BRSP over other treatments. In Barrackpore LTFE soil, significant difference in TG-BRSP content was observed amongst soil aggregates. Highest TG-BRSP was recorded in fallow treatment and in soil aggregates size >2000  $\mu$ m followed by 250-2000  $\mu$ m, 53-250  $\mu$ m and < 53  $\mu$ m in both Barrackpore and Parbhani LTFE soils. However, there is no significant difference between control, 100% N and 100% NP treatments in Parbhani LTFE soil. It was also observed that amongst aggregates,

significant and consistent decrease was seen from macroaggregates to microaggregates in Inceptisols. But, in Vertisols the decrease was not very much significant.

3. The soil microbial biomass is an essential component of nutrient cycling in the agro-ecosystems. The long-term effect of fertilizer and manure on soil microbial biomass carbon (MBC) was significant. Application of FYM along with NPK significantly increased the MBC over other treatments. The mean MBC (in  $\mu\text{g/g}$  soil) observed in individual treatments in decreasing order were: 100% NPK+FYM (612) > 100% NPK (574) > 100% NP (505) > fallow (497) > 100% N (411) > control (125) in Inceptisols (Barrackpore LTFE soils) and 100% NPK+FYM (278) > fallow (254) > 100% NP (210) > 100% NPK (209) > 100% N (199) > control (121) in Vertisols (Parbhani LTFE soils). It was also observed that soil microbial biomass carbon was recorded almost twice or more in Inceptisols than in Vertisols, in all treatments except for control. Means followed by different letter are significantly different as per DMRT

4. The particulate organic matter carbon (POMC) is an indicator of soil quality for any land use management and tillage practice and its disruption rate is primarily affected by soil aggregates (Cambardella and Elliott, 1992; Kuo et al., 1997). In LTFE-Barrackpore, as cultivation continued with unbalanced fertilization, there was an extensive depletion of particulate organic matter carbon (POMC). POMC was recorded highest in fallow treatment followed by 100% NPK + FYM. Whereas in LTFE-Parbhani, POMC was significantly highest in the treatment with 100% NPK + FYM. But, in other treatments no significant difference has been observed. Means followed by different letter are significantly different as per DMRT

5. Water soluble carbon represents the labile fraction of carbon from the soil, which is also important source for microorganisms. Water soluble carbons (WSC) of both the soils. Perusal of the data shows that the WSC was recorded significantly highest in fallow treatment irrespective of the soil order. In LTFE-Barrackpore, WSC in 100% NP, 100% NPK and 100% NPK+ FYM was non-significant followed by 100% N and lowest in control. In LTFE-Parbhani, WSC in 100% NPK+ FYM treatment is at

par with fallow treatment, whereas, 100% N, 100% NP and 100% NPK were non-significant. Lowest WSC was observed in control. Means followed by different letter are significantly different as per DMRT

6. The potassium permanganate oxidizable carbon (POXC) significantly increased due to fertilization in both the soil orders and recorded significantly highest in 100% NPK + FYM treatment. In LTFE-Barrackpore, other treatments showed non-significant difference. Whereas, in LTFE-Parbhani, 100%NP and 100% NPK values are at par with 100% NPK + FYM. These again signified the superiority of balanced fertilization over other nutrient management treatments (Sandeep et al. 2016). Means followed by different letter are significantly different as per DMRT

### **5.3 Assessment of effect of long term manure and fertilizer application on activities of main hydrolytic enzymes involved in soil carbon cycling**

1. In LTFE-Barrackpore, optimum and balanced application of nutrients (100% NPK + FYM) led to significant increase in DHA. However, in the most heavily fertilized treatment (100% NPK), significant reduction in dehydrogenase activity was observed followed by 100% NP > 100% N > fallow > control. In contrast to Inceptisols, in LTFE-Parbhani (Vertisols), dehydrogenase activity was recorded significantly more in fallow treatment followed by 100% NPK + FYM > 100% NP > 100% N > control. Means followed by different letter are significantly different as per DMRT.

2. In LTFE-Barrackpore,  $\beta$ -Glucosidase activity was observed significantly highest in fallow followed by 100% NPK + FYM. The treatments 100% NPK, 100% NP and control showed non-significant difference. Lowest enzyme activity was observed at 100% N treatment. Whereas, in LTFE-Parbhani (Vertisols),  $\beta$ -Glucosidase activity was recorded significantly more in 100% NPK + FYM, 100% NPK and 100% NP treatment followed by fallow, control and 100% N. Means followed by different letter are significantly different as per DMRT.

### **5.2 CONCLUSION**

From the findings summarized above, it could be concluded that over all integrated nutrient management, had recorded significantly higher carbon cycling enzymes activity, The effect of long-term use of farmyard manure (FYM) and inorganic

fertilizers in Inceptisol (Rice–Wheat-Jute rotation) and Vertisol (Soybean-Safflower) has been investigated for aggregate size distribution, aggregate-carbon. Significant variations in aggregate size distribution were noticed among different treatments in LTFE Barrackpore. Both the 250-2000 $\mu\text{m}$  macroaggregates and 53-250 $\mu\text{m}$  microaggregates contributed almost equally in aggregate size distribution and accounted for 28.7 to 47.01% and 35.2 to 47.9% of the dry weight of soil, respectively, in LTFE Parbhani the highest contributing aggregate class was 250-2000  $\mu\text{m}$  macroaggregates which accounted for 48.05 to 58.04% of dry weight of soil, whereas, 53-250 $\mu\text{m}$  microaggregates accounted for 28.5 to 39.75% of dry weight of soil. In both LTFE soils of Barrackpore and Parbhani, overall associated carbon concentrations, Irrespective of aggregate size classes, the concentration of carbon was significantly higher in the 100% NPK+FYM treatment followed by 100% NPK and fallow soils. Glomalin, a fungal glycoprotein, play a significant role in soil aggregation (Wright and Upadhyaya, 1996). Total glomalin related soil protein (TG-BRSP) concentrations ( $\mu\text{g g}^{-1}$ ) across all treatments are fallow treatment showed significantly higher TG-BRSP over other treatments. In LTFE- Barrackpore, POMC was recorded highest in fallow treatment followed by 100% NPK + FYM. Whereas in LTFE-Parbhani, POMC was significantly highest in the treatment with 100% NPK + FYM. the WSC was recorded significantly highest in fallow treatment irrespective of the soil order. In LTFE- Barrackpore. The potassium permanganate oxidizable carbon (POXC) significantly increased due to fertilization in both the soil orders and recorded significantly highest in 100% NPK + FYM treatment. In contrast to Inceptisols, in LTFE-Parbhani (Vertisols), dehydrogenase activity was recorded significantly more in fallow treatment. Whereas, in LTFE-Parbhani (Vertisols),  $\beta$ -Glucosidase activity was recorded significantly more in 100% NPK + FYM

### **5.3 SUGGESTIONS FOR FUTURE WORK**

The present study has made a platform for the future in-depth research regarding the ecological role of soil microbes regulating the carbon cycle cycling in crop production and sustainable environment.

## BIBLIOGRAPHY

- Acton, D. F., and Padbury, G. A. (1993). A conceptual framework for soil quality assessment and monitoring. *A Program to Assess and Monitor Soil Quality in Canada: Soil Quality Evaluation Program Summary. Research Branch, Agriculture and Agri-Food Canada: Ottawa, Ontario.*
- An S, Mentler A, Mayer H, Blum WEH. (2010). Soil aggregation, aggregate stability, organic carbon and nitrogen in different soil aggregate fractions under forest and shrub vegetation on the Loess Plateau, China. *Catena*. **81**:226-33.
- Anderson, T. W. and Hsiao, C. (1981). Estimation of dynamic models with error components. *Journal of the American statistical Association*, **76**(375), 598-606.
- Angers, D.A., Recous, S. and Aita, C. (2005). Fate of carbon and nitrogen in water-stable aggregates during decomposition of <sup>13</sup>C<sup>15</sup>N-labelled wheat straw *in situ*. *V. 48*(2): 295-300.
- Aoyama, M., Angers, D. A., Dayegamiye, A. and Bissonnette, N. (1999). Protected organic matter in water-stable aggregates as affected by mineral fertilizer and manure applications. *Can. J. Soil Sci.* **79**: 419-425.
- Arnab, B. (2012). Soil erodibility and organic carbon dynamics in relation to land use and soil type in sub montane Punjab. M.Sc. thesis, Punjab Agricultural University, Ludhiana, India.
- Bado, B.V., Aw, A. and Ndiaye, M. 2010. Long-term effect of continuous cropping of irrigated rice on soil and yield trends in the Sahel of West Africa. *Proceeding of Second Africa Rice Congress, Bamako, Africa Rice Centre, Sahel regional station, B.P. 96 Saint-Louis, Senegal, : 2.10.1-2.10.5.*
- Behera, S.K., Singh, D. And Dwivedi, B.S.(2009). Changes in Fractions of Iron, Manganese, Copper, and Zinc in Soil under Continuous Cropping for more than three decades. *Communications in Soil Science and Plant Analysis*, **40**: 1380–1407.
- Bellaki, M. A. and Badanur, V. P. (1997). Long term effect of integrated nutrient management on properties of Vertisol under dryland agriculture. *J. Indian Soc. Soil Sci.*, **45**(3):438-442.
- Benbi, D. K., Brar, K., Toor, A. S. and Pritpal, S. (2015). Total and labile pools of soil organic carbon in cultivated and undisturbed soils in northern India. *Geoderma*, **237**: 149-58.
- Bezdicsek, D. F., Papendick, R. I. and Lal, R. (1996). Introduction: Importance of soil quality to health and sustainable land management. *Methods for assessing soil quality, (methods for assesses)*, 1-8.

- Bhattacharyya, R., Tuti, M. D., Kundu, S., Bisht, J. K. and Bhatt, J. C. (2012). Conservation tillage impacts on soil aggregation and carbon pools in a sandy clay loam soil of the Indian Himalayas. *Soil Science Society of America Journal*, **76**(2):617-627.
- Black, J. W., Duncan, W. A. M., and Shanks, R. G. (1965). Comparison of some properties of pronethalol and propranolol. *British journal of pharmacology and chemotherapy*, **25**(3), 577-591.
- Brookes, P.C. (1995). The use of microbial parameters in monitoring soil pollution by heavy metals. *Biology and Fertility of soils*, **19**(4): 269-279.
- Cambardella, C.A. and Elliott, E.T. (1992). Particulate soil organic matter changes across a grassland cultivation sequence. *Soil Scien. Society Ame J*, **56**: 777-783.
- Campbell, J. Y. and Cochrane, J. H. (1999). By force of habit: A consumption-based explanation of aggregate stock market behavior. *Journal of political Economy*, **107**(2):205-251.
- Casida, J.L.E., Klein, D. A. and Santoro, T. (1964). Soil dehydrogenase activity. *Soil science*, **98**(6), 371-376.
- Chakraborti, A. and Chakrabarti, B. K. (2000). Statistical mechanics of money: how saving propensity affects its distribution. *The European Physical Journal B-Condensed Matter and Complex Systems*, **17**(1):167-170.
- Chan, C. Y., Gherzi, R., Ong, S. E., Chan, E. L., Raijmakers, R., Pruijn, G. J. and Karin, M. (2001). AU binding proteins recruit the exosome to degrade ARE-containing mRNAs. *Cell*, **107**(4):451-464.
- Chang, E. H., Wang, C. H., Chen, C. L. and Chung, R. S. (2014). Effects of long-term treatments of different organic fertilizers complemented with chemical N fertilizer on the chemical and biological properties of soils. *J.S.Sci.and Pl. Nu.Vo.* **60** (4):499-511.
- Chatterjee, D., Hokayem, P., and Lygeros, J. (2011). Stochastic receding horizon control with bounded control inputs: A vector space approach. *IEEE Transactions on Automatic Control*, **56**(11), 2704-2710.
- Colazo, J. C. and Buschiazzo, D. E. (2010). Soil dry aggregate stability and wind erodible fraction in a semiarid environment of Argentina. *Geoderma*, **159**: 228-36.
- Curtin, D., and Wen, G. (1999). Organic matter fractions contributing to soil nitrogen mineralization potential. *Soil Science Society of America Journal*, **63**(2), 410-415.

- Dalal, R. C. (1998). Soil microbial biomass—what do the numbers really mean?. *Australian Journal of Experimental Agriculture*, **38**(7):649-665.
- Dalal, R. C. and Mayer, R. J. (1987). Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. VII. Dynamics of nitrogen mineralization potentials and microbial biomass. *Soil Research*, **25**(4):461-472.
- Das, B., Chakraborty, D., Singh, V.K., Ahmed, M. and Singh, A. (2016). Evaluating fertilization effects on soil physical properties using a soil quality index in an intensive Rice-Wheat cropping system. *Pedosphere* **26**(6): 887–894.
- Davoud, S. G., Ahmad, L. and Angel, F. C. (2016). Total and labile forms of soil organic carbon as affected by land use change in southwestern Iran. *Geoderma Regional*, **7**: 29-37.
- Dawe, D., Dobermann, A., Moya, P., Abdulracman, S., Singh, B., Lal, P., Li, SY., Lin, B., Panaullah, G., Sariam, O., Singh, Y., Swarup, A., Tan, P.S. and Zhen, QX. 2000. How widespread are yield declines in long term rice experimental in Aisa ?. *Field Crop Research*, **66**: 175-193
- Denef K, Six J, Bossuyt H, Frey SD, Elliott ET, Merckx R, Paustian K. (2001) Influence of dry-wet cycles on the interrelationship between aggregate, particulate organic matter, and microbial community dynamics. *Soil Biol Biochem.* **33**:1599-611.
- Dhakshinamoorthy, M., santhy, M., selvi, P and savitthi, P and thyagarajan, T.M. (2013). Lessons from long term fertilizer experiments.
- Dong, W., Zhang, X., Wang, H., Dai, X. and Sun, X. (2012). Effect of Different Fertilizer Application on the Soil Fertility of Paddy Soils in Red Soil Region of Southern China. *PLoS ONE* **7**(9): 44504.
- Doran, J.W. and Parkin, T.B. (1996). Quantitative indicators of soil quality: a minimum data set. In: *Methods for assessing soil quality*. J.W. Doran and A.J. Jones (eds.), Special Publication Number 49. SSSA, Madison. pp. 25-37.
- Eivazi and Tabatabai (1988). Glucosidases and galactosidase in soils. *Soil biology and biochemistry* **V.20**(5):601-606.
- Elliott E.T. (1986) Aggregate structure and carbon, nitrogen, and phosphorus in native and cultivated soils. *Soil Sci Soc Am* **J50**:627–633.
- Elliott, E.T., Paustian, K. and Frey, S.D. (1996). Modeling the measurable or measuring the modelable: a hierarchical approach to isolating meaningful soil organic matter fractionations.

In: Powlson, D.S., Smith, P., Smith, J.U. (Eds.), Evaluation of Soil Organic Matter Models. NATO ASI Series. Springer Verlag, pp. 161–179.

- Fan, T., Xu, M., Zhou, G. and Ding, L. (2007). Trends in grain yields and soil organic carbon in a long-term fertilization experiment in the China Loess Plateau. *American-Eurasian J. Agric. and Environ. Sci.*, **2**(5): 600- 610
- Ferro, N. D., Berti, A., Matthews, P., Giardini, L. and Morari, F. (2010). Study of the effects of structure on soil aggregate stability using a 3D network model. World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia. Published on DVD.
- Franzluebbers A.J. (2002) Soil organic matter stratification ratio as an indicator of soil quality. *Soil Till Res.* **66**:95-106.
- Franzluebbers, J., Wright, S. F. and Stuedemann, J. A. (2000). Soil Aggregation and Glomalin under Pastures in the Southern Piedmont USA A. *Published in Soil Sci. Soc. Am. J.* **64**:1018–1026.
- Gajic, B. and Zivkovic, M. (2006). Aggregate composition and stability of structural aggregates of non-calcareous rendzinas in Eastern Serbia. *J. Agric. Sci.* **51**: 141-50.
- Galazka, A., Gawryjolek, K., Perzyński, A., Gałazka, R. and Księżak, J. (2017). Changes in enzymatic activities and microbial communities in soil under long-term Maize monoculture and crop rotation. *Pol. J. Environ. Stud. Vol.* **26**(1):39-46.
- Gale, W.J., Cambardella, C.A., Bailey, T.B., (2000). Root-derived carbon and the formation and stabilization of aggregates. *Soil Sci. Soc. Am. J.* **64**:201–207.
- Geisseler, D., and Scow, K. M. (2014). Does long-term use of mineral fertilizers affect the soil microbial biomass. *Better Crops Plant Food*, **98**(4): 13-15.
- Goyal, S., Mishra, M. M., Hooda, I. S. and Singh, R. (1992). Organic matter-microbial biomass relationships in field experiments under tropical conditions: effects of inorganic fertilization and organic amendments. *Soil Biology and Biochemistry*, **24**(11):1081-1084.
- Graham S, Marvin S. Splintering urbanism: networked infrastructures, technological mobilities and the urban condition. Routledge; 2002 .
- Graham, M. H., Haynes, R. J. and Meyer, J. H. (2002). Soil organic matter content and quality: effects of fertilizer applications, burning and trash retention on a long-term sugarcane experiment in South Africa. *Soil biology and biochemistry*, **34**(1):93-102.

- Groot, J. J. R., and Houba, V. J. G. (1995). A comparison of different indices for nitrogen mineralization. *Biology and Fertility of Soils*, **19**(1):1-9.
- Hanway, J. J., and Heidel, H. (1952). Soil analysis methods as used in Iowa state college soil testing laboratory. *Iowa Agriculture*, **57**:1-31.
- Hati, K.M., Anand, S., Dwivedi, A.K., Mishra, A.K., Bandyopadhyay, K.K.(2007). Changes in soil physical property and organic carbon status at the topsoil horizon of Vertisols of central India after 28 years of continuous cropping fertilization and manuring. *Agricultural, ecosystem and Environmental* **119**: 127-134.
- Haynes, R. J. and Beare, M. H. (1996). Aggregation and organic matter storage in meso-thermal, humid soils. *Structure and organic matter storage in agricultural soils*, 213-262.
- Hevia G.G., Buschiazzo D., Hepper E. and Uriste A.M.(2003). Organic matter in size fractions of soils of the semiarid Argentina. Effects of climate, soil texture and management. *Geoderma* **116**(3):265-277
- Hopkins, D. W. and Shiel, R. S. (1996). Size and activity of soil microbial communities in long-term experimental grassland plots treated with manure and inorganic fertilizers. *Biology and Fertility of Soils*, **22**(1-2):66-70.
- Hu, S., Coleman, D. C., Carroll, C. R., Hendrix, P. F. and Beare, M. H. (1997). Labile soil carbon pools in subtropical forest and agricultural ecosystems as influenced by management practices and vegetation types. *Agric Eco syst Envir* **65**: 69-78.
- Huggins, D. R., Allen, D. L., Gardner, J. C., Karlen, D. L., Bezdicsek, D. F., Rosek, M. J., Alms, M. J., Flock, M., Miller, B. S. and Staben, M. L. (1997). Enhancing carbon sequestration in CRP managed land. Pp 323-34.
- IPCC(2007). Climate change Synthesis Report summary & Policy Maker. IPCC XXVII , Valencia, Spain, 12-17 .
- Jackson, M.L. (1973). Soil chemical analysis. Prentice Hall of India Private Limited., New Delhi.
- Janzen, H. H., Campbell, C. A., Brandt, S. A., Lafond, G. P. and Townley-Smith, L. (1992). Light-fraction organic matter in soils from long-term crop rotations. *Soil Science Society of America Journal*, **56**(6):1799-1806.
- Järvan, M., Edesi, L., Adamson, A. and Võsa, T. (2014). Soil microbial communities and dehydrogenase activity depending on farming systems. *Plant Soil Environ*. Vol. **60**(10): 459–463.

- Jedidi, N., Hassen, A., Cleemput, O. V. and Mhiri, A. (2004). Microbial biomass in a soil amended with different types of organic wastes. *Waste Mang Res.* **22**: 93-99.
- John, B., Yamashita, T., Ludwig, B. and Flessa, H. (2005). Storage of organic carbon in aggregate and density fractions of silty soils under different types of land use. *Geoderma* **128**:63-79.
- Kaur, B., Gupta, S. R. and Singh, G. (2000). Soil carbon, microbial activity and nitrogen availability in agroforestry systems on moderately alkaline soils in northern India. *Appl Soil Ecol.* **15**(3): 83-294.
- Kaur, K., Kapoor, K. K. and Gupta, A. P. (2005). Impact of organic manures with and without mineral fertilizers on soil chemical and biological properties under tropical conditions. *Journal of Plant Nutrition and Soil Science*, **168**(1):117-122.
- Kaur, K., Kapoor, K. K. and Gupta, A. P. (2005). Impact of organic manures with and without mineral fertilizers on soil chemical and biological properties under tropical conditions. *Journal of Plant Nutrition and Soil Science*, **168**(1):117-122.
- Kerlen. D.L., Mauschbach, M.I., Doron, J.W., Cline, R.G., Harris, R. F. and Sehuman, G.E. (1997). Soil quality; A concept ,Defination and a frame work evalution. *Soil.Sci.Soc.Amrrican.J.* Vol. **61**.PP. 4-10.
- Kuo, C. T., Morrisey, E. E., Anandappa, R., Sigrist, K., Lu, M. M., Parmacek, M. S. and Leiden, J. M. (1997). GATA4 transcription factor is required for ventral morphogenesis and heart tube formation. *Genes and development*, **11**(8):1048-1060.
- Ladd, J. N., Amato, M., Zhou, L. K. and Schultz, J. E. (1994). Differential effects of rotation, plant residue and nitrogen fertilizer on microbial biomass and organic matter in an Australian Alfisol. *Soil BiolBiochem.* **26**: 821-31.
- Ladd, J. N., Parsons, J. W. and Amato, M. (1977). Studies of nitrogen immobilization and mineralization in calcareous soils—I: Distribution of immobilized nitrogen amongst soil fractions of different particle size and density. *Soil Biology and Biochemistry*, **9**(5):309-318.
- Ladha, J.K., Dawe, D., Pathak, H., Padre, A.T., Yadav, R.L., Singh, B., Li, G., Zhu, R. and Yang, Y. (2012). Polymer solar cells. *Nature photonics*, **6**(3):153.
- Liang, B. C., Mackenzie, A. F. and Gregorich, E. G. (1999). Changes in <sup>15</sup>N abundance and amounts of biologically active soil nitrogen. *BioFert Soil*, **30**: 69-74.

- Liang, Q., Chen, H., Gong, Y., Fan, M., Yang, H., Lal, R. and Kuzyakov, Y. (2012). Effect of 15 years of manure and inorganic fertilizers on soil organic carbon fractions in a wheat-maize system in the north China plain. *Nutr. Cycl. Agroecosyst.*, **92**: 21-33.
- Liu, E.K., Yan, C.R., Mei, X.R., He, W.Q., Bing, S.H., Ding, L.P., Liu, Q., Liu, S. and Fan, T.L. (2010). Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma*. **158**:173-180.
- Long, P., Sui, P., Goa, W.S., Wang, B. B., Huongp, J. X., Yan, E., Zou, J.X., Yan, L. L. and Chen, Y. Q. (2015). Aggregate stability and associated C and N in a silty loam soil as affected by organic material inputs. *Journal of Integrative Agriculture* Vo. **14**(4):774-787.
- López, M. V., Dios, H. J. M., Hevia, G. G., Gracia, R. and Buschiazzi, D. E. (2007). Determination of the wind-erodible fraction of soils using different methodologies. *Geoderma* **139**: 407-11.
- Madari B.E., Machado, PLOA, Torres, E., Andrade, A.G. and Valencia, L.I.O. (2005) No tillage and crop rotation effects on soil aggregation and organic carbon in a Rhodic Ferralsol from southern Brazil. *Soil Till Res.* **80**:185-200.
- Mahmood, T., Azam, F., Hussain, F. and Malik, K. A. (1997). Carbon availability and microbial biomass in soil under an irrigated wheat-maize cropping system receiving different fertilizer treatments. *Biol Fer Soils* **25**: 63-68.
- Mangalassery, S., Mooney, S. J., Sparkey, D. L., Fraser, W. T. and Sjogersten, S. (2015). Impacts of zero tillage on soil enzyme activities, microbial characteristics and organic matter functional chemistry in temperate soils. *Eur J Soil Biol* **68**: 9-17.
- Manna, M.C., Swarup, A., Wanjari, R.H., Mishra, B. and Shahi, D.K. (2007) A long term fertilization, manure and liming effects on soil organic matter and crop yields. *Soil and Tillage Research*, **94**: 397-409.
- Manna, M.C., Swarup, A., Wanjari, R.H., Singh, Y.V., Ghosh, P.K., Singh, K.N., Tripathi, A.K. and Saha, M.N. (2006). Soil organic matter in a west Bengal Inceptisol after 30 years of multiple cropping and fertilization. *Soil Sci. Soc. Am. J.*, **70**: 121-129
- Mathan, K. K. and Mahendran, P. P. (1994). Infiltration characteristics of soils as related to soil physical properties. *Journal of the Indian Society of Soil Science* **42**(3): 441-444
- Mazumdar, S. P., Kundu, D. K., Saha, A. R., Majumdar, B., Saha, R., Singh, A. K. and Mitra, S. (2018). Carbon and nutrient dynamics under long-term nutrient management in tropical rice-wheat-jute system. *Archives of Agronomy and Soil Science*, 1-13.

- McGill, W. B., Cannon, K. R., Robertson, J. A., and Cook, F. D. (1986). Dynamics of soil microbial biomass and water-soluble organic C in Breton L after 50 years of cropping to two rotations. *Canadian journal of soil science*, **66**(1): 1-19.
- Moore, J. M., Klose, S. and Tabatabai M. A. (2000). Soil microbial biomass carbon and nitrogen as affected by cropping systems. *BioFert Soil* **31**: 20-210.
- Nambiar, K.K.M and Abrol, I.P.(1989). Long term fertilizer experiments in India. *Fertilizers News*.**34**(4): 11-20.
- Nayak, A.K., Gangwar, B., Shukla, Arvind K., Majumdar, Sonali P., Kumar, Anjani, Raja, R., Kumar, Anil, Kumar, Vinod, Rai, P.K. and Mohan Udit. (2012). Long term effect of different integrated nutrient management on soil organic carbon and its fractions and sustainability of rice – wheat system in Indo-Gangetic plains of India. *Field Crop Research*, **127**: 129-139.
- Nciizah, A. D. and Wakindiki, I. I. C. (2012). Particulate organic matter, soil texture and mineralogy relations in some Eastern Cape ecotopes in South Africa. *South African Journal of Plant and Soil*, **29**(1):39-46.
- Nimmo, J. R. and Perkins, K. S. (2002). Aggregate stability and size distribution in Dane, J. H. and Topp G. C. eds. *Methods of soil analysis, part-4 Physical method: Madison Wisconsin, Soil Science Society of America* P. 317-328.
- Nunan, N., Lerch, T. Z., Pouteau, V., Mora, P., Changey, F., Katterer, T., Miller, S. G. and Herrmann, A.M. (2015). Metabolising old soil carbon: Simply a matter of simple organic matter. *Soil Biol. Bioch.*, **88**:128-136
- Olsen, Sterling R. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department Of Agriculture; Washington, 1954.
- Pal, S.S. and Shurpali, N. J. (2006). Variation in soil organic carbon as influenced by climate under different cropping system in India. *Journal of the Indian Society of Soil Science*. **54** (3): 294-299.
- Parton, W. J., Schimel, D. S., Cole, C. V. and Ojima, D. S. (1987). Analysis of factors controlling soil organic matter levels in Great Plains Grasslands. *Soil Science Society of America Journal*, **51**(5):1173-1179.
- Paustian, K., Parton, W. J. and Persson, J. (1992). Modeling soil organic matter in organic-amended and nitrogen-fertilized long-term plots. *Soil science society of America journal*, **56**(2):476-488.

- Puget, P., Angers, D. A. and Chenu, C. (1998). Nature of carbohydrates associated with water-stable aggregates of two cultivated soils. *Soil Biology and Biochemistry*, **31**(1):55-63.
- Pullemean, M. M., Six, J., Van, B. N. and Jongmans, A.G. (2005). Soil organic matter distribution and microaggregate characteristics as affected by agricultural management and earthworm activity. *European Journal of Soil Science*, in press.
- Rao, P. J., Prasad, P.R.K., Kumari, A. L., Rani, P. and Rao C.H. (2017) Long-Term Effect of Manures and Fertilizers on Nutrient Status under Cotton Mono-Cropping in Vertisol. *Int.J.Curr.Microbiol.App.Sci***6**(7): 2084-2094
- Rhoton, F. E. and Lindbo, D.L. (1997). A Soil depth approach to soil quality assessment. *J. Soil Water Cons.* **52**(1): 66-72.
- Saha, D., Kukal, S. S., & Sharma, S. (2011). Landuse impacts on SOC fractions and aggregate stability in typicustochrepts of Northwest India. *Plant and Soil*, **339**(1-2), 457-470.
- Saha, S., Gopinath, K.A., Mina, B.L., Kundu, S., Bhattacharyya, R. and Gupta, H. S. (2010). Expression of soil chemical and biological behavior on nutritional quality of aromatic rice as influenced by organic and mineral fertilization. *Commn. Soil Sci. Plant Analysis*,**41**(15): 1816-1831.
- Sainju, U. M. (2006). Carbon and nitrogen pools in soil aggregates separated by dry and wet sieving methods. *Soil science*, **171**(12);937-949.
- Sainju, U. M., Whitehead, W. F. and Singh, B. P. (2003). Cover crops and nitrogen fertilization effects on soil aggregation and carbon and nitrogen pools. *Canadian Journal of Soil Science*, **83**(2):155-165.
- Schutter, M. E., and Dick, R. P. (2002). Microbial community profiles and activities among aggregates of winter fallow and cover-cropped soil. *Soil Science Society of America Journal*, **66**(1), 142-153.
- Sekhon, K.S., Singh, J.P. and Mehla, D.S. (2011). Long-term effect of manure and mineral fertilizer application on the distribution of organic nitrogen fractions in soil under a rice-wheat cropping system. *Archives of agronomy & Soil Science*, **57**(7): 705-714.
- Shrestha, R. K., Ladha, J. K. and Gami, S. K. (2006). Total and organic soil carbon in cropping systems of Nepal. *Nut Cycl Agro eco syst.* **75**(1-3): 257-69.
- Singh, Y., Singh, P., Kundu, A.L., Sakal, R., Ram, N., Regmi, A.P., Gami, S.K., Bhandari, A.L., Amin, R., Yadav, C.R., Bhattarai, E.M., Das, S., Agarwal, H.P., Gupta, R.K. and Hobbs, P.R.

- (2003). How extensive are yield declines in long-term rice-wheat experiments in Asia ?. *Field Crop Research*, **81**: 159-280.
- Singh, R., Kundu, D. K., & Bandyopadhyay, K. K. (2010). Enhancing agricultural productivity through enhanced water use efficiency. *Journal of Agricultural Physics*, *10*(2), 1-15.
- Six, J., Bossuyt, H., De, G. S. and Denef, K. (2004). A history of research on the link between (micro) aggregates, soil biota, and soil organic matter dynamics. *Soil Till Res.* **79**:7-31.
- Six J, Elliott E.R., Paustian, K. and Doran, J.W. (1998) Aggregation and soil organic matter accumulation in cultivated and native grassland soils. *Soil Sci Soc Am* **J62**:1367–1377.
- Six, J. A. E. T., Elliott, E. T. and Paustian, K. (2000). Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. *Soil Biology and Biochemistry*, **32**(14):2099-2103.
- Skopp, J., Jawson, M. D., & Doran, J. W. (1990). Steady-state aerobic microbial activity as a function of soil water content. *Soil Science Society of America Journal*, **54**(6):1619-1625.
- Sleutel, S., De Neve, S., Németh, T., Tóth, T. and Hofman, G. (2006). Effect of manure and fertilizer application on the distribution of organic carbon in different soil fractions in long-term field experiments. *European Journal of Agronomy*, **25**(3), 280-288.
- Souza, E.D., Costa, SEVGA, Anghinoni, I., Carvalho, PCF, Andrigheti, M.H. and Cao, E.G. (2009). Soil organic carbon and nitrogen stocks in an untilled crop-livestock system under different grazing intensities. *R Bras Ci Solo*. **33**:1829-36.
- Stevenson, F. J. (1982). Organic forms of soil nitrogen. *Nitrogen in agricultural soils*, (nitrogen in agrics), 67-122.
- Subbiah, B. V., and Asija, G. L. (1956). A rapid method for the estimation of nitrogen in soil. *Current Science*, **26**:259-260.
- Tian, K., Zhao, Y., Xu, X., Hai, N., Huang, B. and Deng, W. (2015). Effects of long-term fertilization and residue management on soil organic carbon changes in paddy soils of China: A meta-analysis. *Agric. Ecosyst. Environ.* **204**:40–50.
- Tisdall, J.M. and Oades, J.M. (1982). Organic matter and water stable aggregate in soils. *J Soil Sci* **33**:141–163.
- Turchenek, L. W. and Oades, J. M. (1979). Fractionation of organomineral complexes by sedimentation and density techniques. *Geoderma*, **21**: 311-43.

- Urkurkar, J. S., Alok, T., Shrikant, C., & Bajpai, R. K. (2010). Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols. *Indian Journal of Agricultural Sciences*, **80**(3), 208-212.
- vance E. D., Brooks P. C. and Jenkinson D. S. (1987). An extraction method for measuring soil microbial biomass carbon. *Soil biology and biochemistry*, **19**(6):703-707.
- Verma, G., Mathur, A. K., Bhandari, S. C. and Kanthaliya, P. C. (2010). Long-term effect of integrated nutrient management on properties of Typic Haplustep under maize-wheat cropping system. *Journal Indian society soil science*. **58** (3) : 299-302.
- Virmani, J., Schneiderman, L. J., and Kaplan, R. M. (1994). Relationship of advance directives to physician-patient communication. *Archives of Internal Medicine*, **154**(8), 909-913.
- Virmani, S.M., Pathak, P. and Singh, R. (1991). Soil related constraints in dryland crop production in Vertisols, Alfisols and Entisols of India. In Soil related Constraints in crop production, *J. Indian Soc. Soil Sci.* New Delhi, India. PP. 80-95.
- Vladimir, C., Milivoj B., Ljiljana, N., Srdan, S., Borivoj, P., Atila, B. and Maja, M. (2016). The sensitivity of water extractable soil organic carbon fractions to land use in three soil types. *Arch Agron Soil Sci*. **62**: 1654-64.
- Walkley, A., and Black, I. A. (1934). An examination of the method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, **37**(1): 29-38.
- Wandile, R. M.; Raut, M. M.; Washimkar, S. V. and Bhisare, B. S. (2005). Residual effect of long-term application of N, P, Zn and FYM on soil properties of vertisols, yield, protein and oil content of soybean. *J. of Soils and Crops*. **15**(1):155-159.
- Whalen, J. K. and Chang, C. (2002). Macroaggregate characteristics in cultivated soils after 25 annual manure applications. *Soil Science Society of America Journal*, **66**(5), 1637-1647.
- Wright, A. L. and Hons, F. M. (2004). Soil aggregation and carbon and nitrogen storage under soybean cropping sequences. *Soil science society of America journal*, **68**(2):507-513.
- Yoder, R. E. (1936). A Direct Method of Aggregate Analysis of Soils and a Study of the Physical Nature of Erosion Losses 1. *Agronomy Journal*, **28**(5):337-351.
- Yuan, Y., Li, L., Li, N., Yang, C. and Hang, X. (2013). Long-term fertilization effects on organic carbon stabilization in aggregates of Mollisols. *J. food, Agric. Environ*. **11**(2): 1164-1168.

Zhu, L., Dwyer, J.P., Chang, V.S., Granda, C.B. and Holtzaple, M.T. (2008). Structural affecting biomass enzymatic digestibility. *Bioresour Technol.* **99**(9):3817-28.

Zou, C., Li, Y., Huang, W., Zhao, G., Pu, G., Su, J., Coyne, M, S., Chen, Y., Wang, L., Hu, X. and Jin, Y.(2018). Rotation and manure amendment increase soil macro-aggregates and associated carbon and nitrogen stocks in flue-cured tobacco production. *Geoderma*, **325**: 49–58.

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