www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(3): 3967-3975

www.thepharmajournal.com
Received: 08-01-2023
Accepted: 14-02-2023

Chandini Pradhan
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Amlan Kumar Ghosh
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Shalini Sharma
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Dibya Jyoti Panda
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Corresponding Author:
Chandini Pradhan
Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Variation in soil organic carbon content and its dynamics under different cropping sequences and nutrient management practices in middle indo-gangetic plains

Chandini Pradhan, Amlan Kumar Ghosh, Shalini Sharma and Dibya Jyoti Panda

DOI: https://doi.org/10.22271/tpi.2023.v12.i3aq.19386

Abstract
In the era when the population is escalating at a rapid rate while on other hand the land for cultivation is declining, there is tremendous pressure in high fertile lands like the Indo-Gangetic plains to produce food grains with intensified cropping. This intensification of agriculture has lead to stagnation of yield in cropping systems due to decline in soil organic matter and nutrient cycling. Soil organic carbon along with the microbial biomass are important indicators of physical, chemical as well as biological properties. This two parameters can be determined by various methods like dehydrogenase activity, soil respiration rate and microbial biomass calculation by chloroform and irradiation method. The current paper comprises of the study of different cropping systems in the Indo Gangetic plains in order to analyze its different organic carbon pool, relationship between them and different land use system that influences them. It was noticed that the system receiving both organic and inorganic fertilizers had higher total organic carbon, higher respiration rate, labile carbon along with higher microbial population. Under the nutrient management consisting of FYM + NPK fertilizer treatment there was increasing microbial biomass carbon and total organic carbon over other treatments because of more or higher root biomass. Therefore for a healthy soil and sustainable production system in high fertile and demand area of Indo Gangetic plain it is necessary to assess the soil organic carbon pools and maintain them by using integrated nutrient management.

Keywords: Indo-gangetic plains, organic carbon, carbon pools

1. Introduction

The Indo Gangetic plains which can also be aptly be described as the green revolution region of India extends from 73 E and 32 N to 89 E and 21 N and consists of 5 states namely Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. The Indo Gangetic plains are formed from three major rivers systems-the Indus, the Ganga and the Brahmaputra. These plains are known as "Great plains" these plains comprise one of deep alluvium and world's greatest stretches of flat. This region is "food basket" that feeds the entire nation, considering the fact that it produces 50% of total food grain which feeds about 40% of the population of the country (Pal *et al*. 2009) [19]. Its high productivity can be attributed to the fact that it's rich in fertile alluvium soil, better adaptability, use of high yielding varieties and mechanization of both crops which is favorable for double and triple cropping. The soil of this region being rich in nutrients supports growth of many crops like maize (*Zea mays* L.), rice (*Oryzae sativa* L.), sorghum (*Sorghum bicolor* L.) and pearl millet (*Pennisetum glaucum* L.) in kharif season and in rabi season wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), chick pea (*Cicer arietinum* L.) and mustard (*Brassica* sp.) are grown. Cotton (*Gossypium* sp). Sugarcane (*Saccharum officinarum* L.) and potato (*Solanum tuberosum* L.) are the cash grops that are grown in the region (Duxburv *et al*. 2000) [9]. The rice (*Oryzae sativa* L.)- wheat (*Triticum aestivum* L.) cropping system in which rice is mostly grown in kharif season and wheat is grown in rabi season is the most predominant cropping system of the region which occupies about 72 % of the total cultivated area (Yadav *et al*. 2001 [27] Apart from this cropping system other widely adopted cropping systems of the region are maize-wheat, sugarcane -wheat, rice-potato, cotton-wheat, rice-mustard-jute, and rice-vegetable-jute. Historically though the IGP has been renowned as the most productive area of the Indian sub-continent, but as per current scenario Long-term soil fertility studies have shown reductions in soil organic carbon pool as well as other essential nutrients. The soil organic carbon pool both in terms of its quality an amount determine the physical, chemical, biological an ecological quality of the soil an also its fertility. Thus decline in this soil organic carbon due to the intensive cropping system with disregard to or injudicious residue management thus it has led to stagnation of yield of both rice and wheat. The losses due to low soil organic carbon is not just restricted to yield, the realms of its disadvantage expand to curtailing of essential rhizospheric processes, limiting the use efficiency of inputs, reducing agronomic productivity and degradation of environment. The already soil low organic carbon pool may decline even further due to the projected global warming and climate change. Considering the importance of soil organic carbon pool, it is necessary to assess the impact of soil management, land use conservation and farming systems on soil organic carbon pool to understand the magnitude of depletion of soil organic carbon pool, form the cause- effect relationship and thus suggest best management practices as suiting to the roping system an ecology.

Soil organic carbon pool consists of mainly two pools namely labile and non-labile or stable or recalcitrant carbon. Analysis of proportion of these two pools specially the labile pool and relationship between them could indicate the changes in soil quality due to management practices an cropping systems more rapidly as compare to total soil organic carbon. The labile pools which can be indicators of soil quality are microbial biomass carbon, mineralizable organic carbon, particulate organic carbon and potassium permanganate oxidizable labile organic carbon. Apart from these other parameters like proportion of micro and macro- aggregates, dehydrogenase activity also serve for the purpose. The available literature on soil organic and inorganic pools suggest that we need to put thrust on the systematic study of carbon pool for soils of India on basis of agro-eco region using standardize methodology. The current research focuses on determination of proportion an amount of labile carbon and stable carbon along with different parameters in different cropping system in the Indo Gangetic plains, which will help us determine the status of soil quality and soil fertility of the region and the forming the best management practices the region and the cropping system.

2. Material and Method

The present work entitled as “Variation in soil organic carbon content and its dynamics under different cropping sequences and nutrient management practices in middle Indo-Gangetic Plains” involved study of different cropping system grown in agricultural farms, followed by laboratory analysis of the soil samples in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. (India).

2.1. Description of the experimental site

Located in the western bank of river Ganga, Varanasi is situated at an altitude of 80.71 meters above mean sea level and located between $25^0$19’ North latitude and 83^0 10’ East longitude. The area of experimental site lies in the Indo-Gangetic plain. The soil of this area belongs to order *Inceptisol* and consist mainly of alluvial soil. Texture of soil is classified as sandy, sandy loam to clay loam along with sodic / saline soil. Varanasi falls in a semi-arid to sub humid climate with moisture deficit index between 20-40. The normal period for onset of monsoon in this region is the 3^{rd} week of June which lasts up to end of September or sometimes extends up to the first week of October. The annual rainfall of this region is about 1100 mm. The mean relative humidity is about 68% which rises to 82% during wet season and goes down to 30% during dry season.

2.2. Experimental Design and treatment details

Soil samples were being collected from seven different cropping system which were grown in the agricultural farm in the year 2017-18. Each cropping system were given different fertilizer treatment. The details of each cropping system and their nutrient management are given in table 1. Out of all cropping system the cereal-mustard, pulse and submerged rice were given only recommended dose of inorganic fertilizers whereas the rice-rice and rice-wheat were given recommended dose of inorganic fertilizers along with FYM @ 12 tonnes per hectare and Dhaincha, vegetable i.e. Brinjal was given recommended dose of inorganic fertilizer and FYM @ 12 t ha^{-1} and the fodder crop was being grown in fallow.

2.3. Soil sampling

In order to determine the initial physio-chemical properties of the soil of the sample were collected from the field of each cropping system after the harvest of crops using zig-zag sampling method covering entire field from depth of 0-15 cm as per the prescribed standard sampling method followed by drying and processing.

2.4. Soil analysis

The soil sample after being collected, was then divided into two parts weighing 100g each. In order to analyze biological properties one part of the fresh soil sample (100 g) was sieved through a 2-mm screen and immediately kept in a refrigerator at 4 °C in plastic bags for a few days to stabilize the microbiological activity. The other part of the sample was air-dried in shade, ground to pass through a 2-mm sieve was used for the estimation of soil chemical properties. Chemical properties like soil pH and electrical conductivity were determined by the 1:2 soil-water suspension using pH meter and conductivity meter respectively. The organic carbon was determined by the wet oxidation method as described by Walkley and Black (1934) [25]. Which is based on oxidation of organic matter by $K_2Cr_2O_7$ with H_2SO_4 heat of dilution and organic carbon is determined by the amount of $K_2Cr_2O_7$ left unreacted by titrating it against Ferrous ammonium sulphate. For determining the physical properties of soil like the bulk density was determined by the core sampler method, the soil texture was also determined by using
Bouyoucos hydrometer (Bouyoucos, 1962) [2] and the textural categories of the soils were analyzed by USDA textural triangle (Brady and Weil, 2002).

For determining the biological properties, total SOC was then determined by subtracting soil inorganic C concentrations from total C concentrations. Soil microbial biomass carbon (MBC) was determined following chloroform fumigation extraction method (Jenkinson and Powlson, 1976) [16] using the following formula:

1. **Microbial biomass carbon = (OCF-OCUF)/KEC**
   Where, OCF and OCUF = organic carbon extracted from fumigated and unfumigated soil, respectively (expressed

on oven dry basis), and KEC = the efficiency of extraction. A KEC value of 0.45 was considered as a general value for microbial extraction efficiency and was used for the calculation.

2. **Oxidizable organic carbon (OOC) and its different pools** in the soil were estimated using Walkley and Black (1934) [25] method as modified by Chan *et al*. (2001) [5]. Total SOC was divided in four pools of decreasing oxidizability (Chan *et al*., 2001) [5].

Pool 1: (very labile OC; P1): Organic C oxidizable with 12.0 mol L^{-1} H_2SO_4

Pool 2: (labile OC; P2): Difference in OC oxidizable with 18.0 mol L^{-1} and that with 12.0 mol L^{-1} of H_2SO_4

Pool 3: (Less labile OC; P3): Difference in OC oxidizable with 24.0 mol L^{-1} and that With 18.0 mol L^{-1} of H_2SO_4 (24.0mol L^{-1} H_2SO_4 is equivalent to the standard Walkley and Black method)

Pool 4: (Non-labile OC; P4): Residual organic C after oxidation with 24.0 mol L^{-1} H_2SO_4 when compared with TOC.

Pools I and 2 together constituted the labile pool, while Pools 3 and 4 constituted together the recalcitrant pool (Chan *et al*., 2001) [5].

3. Dehydrogenase activities in bulk soils as well as in soil aggregates were measured as µg triphenylformazon formed per g of dry soil per 24 h (µg TPF g-1 24 hr-1) (Casida *et al*., 1964) [4] at two different temperatures (25 and 35 °C) for soils of two sampling depths.
4. The respiration rate of soils of each cropping system was determined by the alkali trap method at interval of 7 days on i.e. on day 1, day 7 and day 15.

2.5. Statistical analysis
The data generated were processed for analysis of variance as applicable to completely randomized design to test differences among the treatment means as described by Gomez and Gomez (1984) [12]. Duncan multiple range test was used as a post hoc mean separation test (p<0.05) using SAS 9.3 (SAS Institute, Cary, North Carolina, USA). All figures were drawn using the Microsoft Office Excel 2013 and the correlation coefficient was being determined by SPSS (Statistical Package for the Social Science, SPSS, Inc., Chicago, USA) window version 20.0.

3. Result and Discussion
3.1. Initial soil properties
The initial soil properties of soil in all the cropping system has been given in table 2. It can be observed that in case of pH all the cropping sequences have neutral to slightly alkaline reaction, highest being observed in case of rice wheat system (8.56). The electrical conductivity in all the cropping system are low indicating lack of any salinity stress. The initial organic carbon status of cropping sequence indicate the rice wheat system having the highest amount of organic carbon followed by rice-rice, pulse(leguminous crop), cereal-mustard (oilseed) and lowest observed in case of submerged rice.

3.2. Dehygrogenase activity of different cropping system
The dehydrogenase enzyme activity as analyzed by estimating amount of triphenyltetrazoliumformazon (Casida *et al*., 1964) [4] has been presented in table 3 and figure 1. It was observed that the dehydrogenase activity was found to be highest for the rice-rice system, whereas submerged rice and fodder system show quite low dehydrogenase activity. High activity of dehydrogenase enzyme in case of rice -rice system can be attributed to addition of FYM and Dhaincha along with normal dose of NPK, which may have enriched the soil with organic matter and thus higher microbial activity. The low dehydrogenase activity in case of submerged rice is addition of only inorganic fertilizer and prevalence of anaerobic condition. The fodder crop being grown in fallow may be the reason of its low dehydrogenase activity. Its low activity indicates low microbial oxidative activity in case of fodder and submerged rice. The role of dehydrogenase enzyme as an indicator of soil microbial activity has also been illustrated and conformed by Trevors 1984 [24]; Garcia and Hernandez *et al*., 1997 [11]. It has also been seen that in order to measure of any interference caused by pesticides, trace elements or effect of management practices on the soil, the dehydrogenase enzyme can be utilized (Reddy and Faza 1989; Wilke 1991; Frank and Malkomes 1993) [21, 26, 10].

3.3. Rate of Soil respiration at specific intervals in different cropping system
The rate of respiration of soil indicates the extent of activity of microorganisms present in soil. The respiration rate of different cropping system at day 1, day 7 and day 15 is being presented in table 3 and figure 2. It can be inferred from the table that in all cropping systems the rate of respiration increased with number of days since initiation of experiment indicating that with time the microbial population and hence the respiration rate increased. On day 1 the highest amount of carbon dioxide is being evolved in the sample from rice-rice system where as lowest in case of cereal-mustard system. As the number of days proceeded so did the respiration rate and accumulation of carbon dioxide. It was observed that he respiration rate increased to almost two to three times of the 1st day at day 7 but there was slight decrease in increase in rate of respiration from day 7 to day 15 as compared to day 1 to day 7 indicating exponential growth. At 15 days after inoculation or beginning of experiment highest respiration rate was found in rice- rice system and lowest in submerged rice system. It can be distinctly seen that the rice-rice system has the highest respiration rate throughout the period whereas the overall increase in rate of respiration is low in case of fodder and submerged rice. Soil respiration has been proposed as a indicator of soil quality as well as good estimator of overall biological activity (Doran & Parkin, 1994) [8]. Estimation of the soil respiration is being widely used to detect early changes in decomposition rate of soil organic matter in response to various soil or crop management practices thus contributing to studies of soil C cycling (Jensen *et al.*, 1996; Rochette & Angers, 1999) [17, 22]. From the pearson coefficient it was found that the respiration rates of the amount of carbon dioxide released is positively correlated to dehydrogenase activity as carbon dioxide released on day 1 (r=0.564), on day 7(r=0.685) and on day 15(r=0.777) show that with increase in number of days as amount of carbon dioxide released increased the correlation with dehydrogenase also increased.

3.4. Proportions and relationship between different carbon pools in soil of different cropping systems

The estimation of all four pools of carbon in all cropping system by using $H_2SO_4$and also the total organic carbon in each system has been shown in table 4 and figure 3. It can be observed from the table that in all the cropping system the labile pool is more or less equal to the recalcitrant pool except for the fodder and submerged cropping system in which the recalcitrant pool is nearly double or more than that of the labile pool. It can be inferred that in both fodder and submerged rice system have slow turnover rates and had relatively less active soil organic matter. In case of labile organic carbon, cropping systems like rice-wheat, rice-rice, pulse, cereal-mustard have higher value than other systems indicating existence of high population of microorganisms and higher turnover rate and thus more quality and fertility. If the non-labile or recalcitrant carbon pool is considered then fodder and submerged rice system has higher value which indicates soil in such systems have lower population of microorganism and less active soil organic carbon. When it comes to total organic carbon it can be noticed that cropping system like rice-rice, pulse, rice-wheat, cereal-mustard have higher total organic carbon as compared to other systems, thus ensuring better fertility and nutrient availability in soil.

3.5. Total organic carbon

The total organic carbon consists of the sum of both labile and non-labile carbon pool. It is evident from the table 3 and the graph that the total organic carbon is highest in those systems where both inorganic and organic sources of nutrients are being provided in form of FYM and dhaincha, like in the rice-rice system, rice-wheat system and vegetable system. The amount of total organic matter in systems with only inorganic fertilizers were substantially low, because of low amount of organic matter provided. Among all the systems the cereal rice system had lowest total organic carbon. Such results are being supported by many studies in past where effects of manure and inorganic fertilizer applications on soil organic C has been reported from Rothamsted classical experiments (Jenkinson, 1991) [15] and long-term experiments elsewhere (Kukreja *et al*., 1991; Campbell *et al*., 1996; Biswas and Benbi, 1997; Potter *et al*., 1998; Rudrappa *et al*., 2006) [18, 3, 1, 20, 23].

3.6. Relationship between labile and non-labile pool of carbon

The carbon pool 1 and 2 which comprise of labile pool and the carbon pool 3 and 4 which together known as non-labile carbon pool. The Pearson coefficient was found out to be r= -0.919. The graph of both the pool forms a straight line with negative slope of -0.506 (fig. 5). These facts clearly indicate that both the pool share an inverse or negative correlation and with increase in labile pool the non-labile pool decreases and vice- versa. This can be explained as, the non-labile pool consisting of the stable organic matter slowly decompose or get transformed into the labile pool through different processes and thus it decreases and the labile pool in return increases. The labile pool of soil organic C is more sensitive to impact of manuring and fertilization as a result higher proportion of labile carbon pool is observed in case of combined application of FYM + NPK fertilizer. This pool also has higher turn-over of root biomass as compared to other treatment being under integrated nutrient management (FYM + NPK). Such results are in line with the values reported by others (Conteh *et al*., 1997; Rudrappa *et al*., 2006) [6, 23].

3.7. Comparison between two methods of Soil Microbial Biomass Carbon estimation

The soil microbial biomass can be determined by two methods which are chloroform fumigation and extraction method and Micro-wave irradiation method. Both the methods determine the soil microbial biomass in terms of µg g^{-1} dry soil. The results received from both the methods for all the cropping system is presented in table 5 and a graph for comparison of results of both the methods is depicted in the graph having the chloroform fumigation and extraction method results on x- axis and microwave irradiation method in the y- axis (fig. 6). The graph shows a linear relationship between both the results with slope of about 0.6588 and the Pearson coefficient is found to be 0.931, which indicates strong and positive correlation among the reading of both the methods.

The amount of soil microbial biomass was observed to be highest in cropping system with rice-rice cropping system where FYM and dhaincha were added along with the recommended dose of inorganic fertilizers followed by the vegetable system. Pulses cropping system has nearly similar microbial population as that of rice-wheat system. pulses which may be due the fact that pulse being leguminous crops harbor high numbers of microorganisms like Rhizobium in the rhizosphere. Submerged rice system had the lowest amount of soil microbial biomass, which may be due to prevalence of anaerobic condition in the submerged field. Under such condition only meager numbers of anaerobic bacteria sustain. This study shows that under integrated FYM + NPK treatment there is higher yield of root biomass which leads to highest value of microbial biomass as compared to no application of organic manure or only application of inorganic fertilizer. Application of fertilizer of major nutrients like N, P & K is required for synthesis of cellular components of microorganisms. This is in agreement with findings of Hopkins and Shiel, 1996 [14]; Grego *et al*., 1998 [13]; Dezhi *et al*., 2007 [7], who have demonstrated the same.

Table 1: Details of selected treatments

Sl. No.	Cropping System	Practices
1.	Cereal-Mustard	Maize is taken as kharif crop, sown on the end of June to mid July, adequate drainage is provided in very shallow surface drains at 40-50 m apart,. Two or three weedings by spraying Simazine or Atrazine @ 1-1.25 spraying, irrigation at flowering and grain filling stage, fertilizer@ NPK 120:60:60, harvested when the grains are nearly dry with max 20 per cent moisture. Mustard land prepared by one pre sowing irrigation given a deep ploughing soon after the Kharif crop is harvested, sown in well pulverized and fine soil, requires about 31-40 cms of water at about 30 and 60-65 DAS. First weeding done 30-35days after sowing. Hoeing and intercultural operation done a few days after irrigation since weeds would have sprouted. The crop should be harvested when 70 to 80 percent pods ripened and turned yellow.
2.	Fodder based	Shorgum: Sowing time: June-July, seed rate 12-15 kg/ha, spacing 40-50 cm, fertilizer: Fallow, harvest 70-75 days
3.	Pulse based	Urad: Land prepared to beds and channels with fine tilth, seed rate 20 kg/ha, seed treatment with thiram @ 2 g/kg followed by innocultion with Rhizobium culture @ 200 g/kg of seed, soeing at spcing 30x10 cm, irrigated 7-10 days interval mainly during flowering and pod formation, pre-emergence application of pendimithalin @ 2.5 litres /ha fertilizer NPK @30:60:30, harvesting by picking matured pods.
4.	Rice-Rice(wet seeded rice)	Rice: Field puddled with 2.5 cm standing water, FYM @ 12 t ha^{-1} +Dhaincha incorporated into soil, followed by sowing of germinated seeds by drum seeder at depth 2-3cm with seed rate 20 to 25kg ha^{-1}, thin film water maintained till week followed by increasing irrigation @ 2.5cm progressively with draining of excess water, Pre-germinated weed knocked by glyphosate or 1-2 shallow ploughing, fertilizer @NPK 120:60:60, harvested 90-120DAS.
5.	Rice - Wheat	Wheat land prepared by deep ploughing followed by two or three harrowing with disc or tines, seed rate 100 kg/hact. (for normal condition) Row to row spacing 22.5 to 23 cm, Sown up to 10th December, fertilizer @ NPK 120:60:40, irrigation 6 times mainly CRI stage, weeding by pre-emergence, only Stomp 30EC (Pendimethalin), post emergence after first irrigation at 30-35 DAS or 2-3 leaf stage of Phalaris; (Rice NPK 120:60:60+ FYM @12 t ha^{-1}+Dhaincha)
6.	Submerged Rice(transplanted)	Rice: Field ploughed once or twice followed by flooding to pudlle with standing water of 2.5 cm, 7-8 kg /ha for transplanting single seedling per hill, spacing 20 x 10-20 cm at 5-6 cm depth, 2 cm water maintained till 7 DAT followed by 5 cm cyclic submergence, weeding by pulling by hand, or hoe, spade or sickle. Fertilizer @ NPK 120:60:60. Harvest after 90-120 days.
7.	Vegetable (Brinjal)	Brinjal: Seeds sown on nursery beds (size 7.2 x 1.2 m and 10-15 cm in height) to raise seedlings for transplanting in the field. The field is ploughed to fine tilths, spacing 60-75 x 45cm, A light irrigation on first and third day after transplanting. Thereafter irrigation at interval of 8-10 days during winter and 5-6 days during summer. Frequent shallow cultivation with two-three hoeing and the earthing up. fertilizer DAP+MOP+FYM @ 12 t ha^{-1}

Table 2: Initial soil properties

Sl. No.	Cropping System	pH	E.C. (dS m^{-1})	Organic carbon (g kg^{-1})	Sand %	Silt %	Clay %
1.	Cereal-Mustard	7.27±0.08d	0.74±0.59c	5.37±0.02d	22.34	53.76	23.89
2.	Fodder	6.68±0.03e	0.44±0.93e	4.38±0.02f	47.83	26.09	26.09
3.	Pulse (urad)	7.75±0.06c	0.52±0.91d	5.70±0.02b	69.88	20.08	10.04
4.	Rice-Rice	7.92±0.04b	0.73±0.69c	5.56±0.02c	34.21	41.12	24.67
5.	Rice - Wheat	8.56±0.04a	0.87±0.49a	5.92±0.02a	54.79	27.12	18.08
6.	Submerged Rice	7.93±0.07b	0.81±0.81b	3.82±0.02g	41.78	36.39	21.83
7.	Vegetable (Brinjal)	8.04±0.04b	0.86±0.43a	5.18±0.02e	35.90	44.87	19.23
	S.E.(m±)	0.05	0.72	0.02	0.33	0.14	0.79
	C.D. (<0.05)	0.17	2.19	0.06			

Table 3: Comparison between Dehydrogenase and SMBC

Sl. No.	Cropping System	Dehydrogenase (µg TPF g^{-1} dry soil)	Soil Respiration by Alkali trap method (mg CO2 per day)		
			1 day	7 days	15 days
1.	Cereal-Mustard	75.5±1.74bc	6.26±0.24e	18.94±1.72cd	32.26±1.06b
2.	Fodder	71.8±1.88c	7.86±0.48bc	16.66±0.33de	27.81±0.59c
3.	Pulse (urad)	80.7±1.61ab	7.67±0.06cd	20.31±1.19bc	33.65±0.75b
4.	Rice-Rice	85.2±1.65a	9.92±0.29a	25.06±0.93a	37.32±1.02a
5.	Rice - Wheat	78.1±2.43b	8.63±0.26b	23.87±0.80ab	35.04±1.17ab
6.	Submerged Rice	65.1±2.19d	6.95±0.24de	14.66±1.16e	26.94±0.79c
7.	Vegetable (Brinjal)	80.2±1.47ab	8.72±0.25b	21.94±1.08abc	33.72±1.37b
	S.E.(m±)	1.88	0.28	1.10	0.99
	C.D. (<0.05)	5.76	0.87	3.37	3.05

Table 4: Carbon pools (g kg-1)

Sl. No.	Cropping System	Very Labile pool	Labile pool	Less labile pool	Non-labile pool	TOC
1.	Cereal-Mustard	2.33±0.03e	2.25±0.03a	0.79±0.01f	3.80±0.03c	7.55±0.02g
2.	Fodder	1.18±0.03f	1.17±0.03c	2.03±0.02a	3.91±0.02b	7.84±0.02f
3.	Pulse (urad)	2.68±0.02c	2.01±0.02b	1.01±0.03de	3.61±0.02e	9.31±0.01a
4.	Rice-Rice	3.49±0.02a	1.15±0.04c	0.92±0.04e	3.69±0.03d	9.25±0.01b
5.	Rice - Wheat	2.90±0.03b	1.98±0.02b	1.05±0.03d	3.15±0.02f	9.10±0.02d
6.	Submerged Rice	1.11±0.04f	0.99±0.04d	1.71±0.04b	4.02±0.04a	8.29±0.02e
7.	Vegetable (Brinjal)	2.57±0.03d	1.03±0.01d	1.58±0.02c	2.38±0.01g	9.17±0.01c
	S.E.(m±)	0.03	0.03	0.03	0.03	0.02
	C.D. (<0.05)	0.086	0.087	0.088	0.082	0.05

Table 5: Comparison between two methods of Soil Microbial Biomass Carbon estimation

		SMBC (µg g^{-1} dry soil)	
Sl. No.	**Cropping system**	**Chloroform fumigation and extraction method**	**Micro-wave irradiation method**
1.	Cereal-Mustard	195.55c	224.32b
2.	Fodder	142.0d	156.45c
3.	Pulse (urad)	204.3c	214.83b
4.	Rice-Rice	242.04a	298.97a
5.	Rice - Wheat	204.09c	212.61b
6.	Submerged Rice	121.69e	102.98d
7.	Vegetable (Brinjal)	223.33b	226.89b
	S.E.(m±)		
	C.D. (<0.05)		

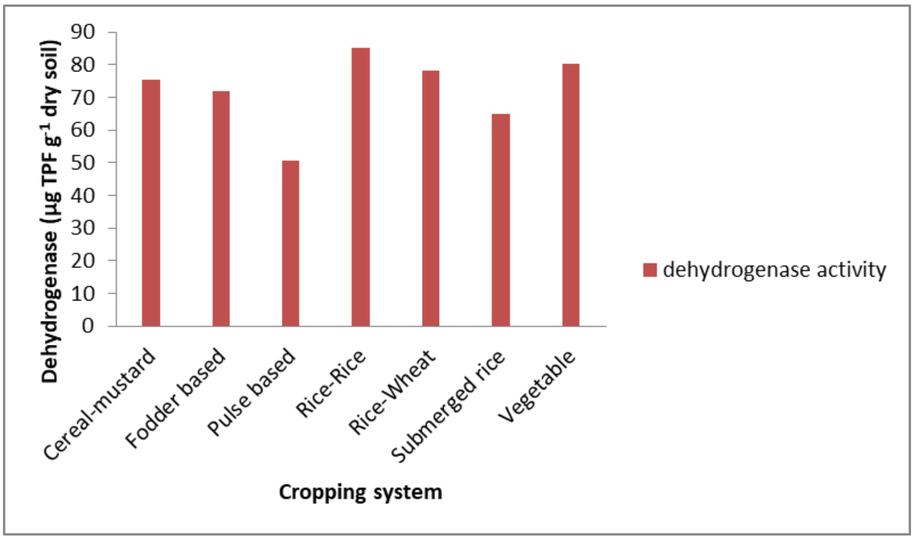

Fig 1: Dehydrogenase activity in different cropping systems

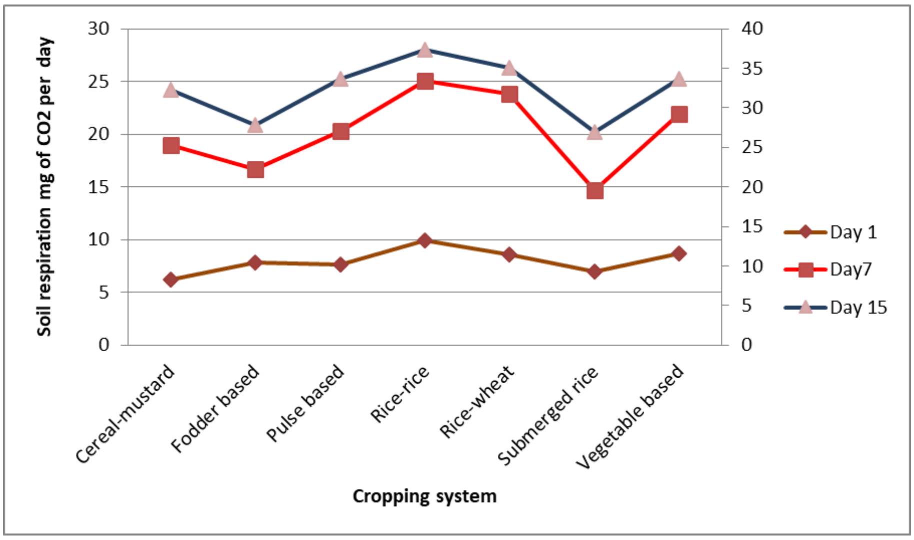

Fig 2: Variation in rate of respiration with increase in number of days

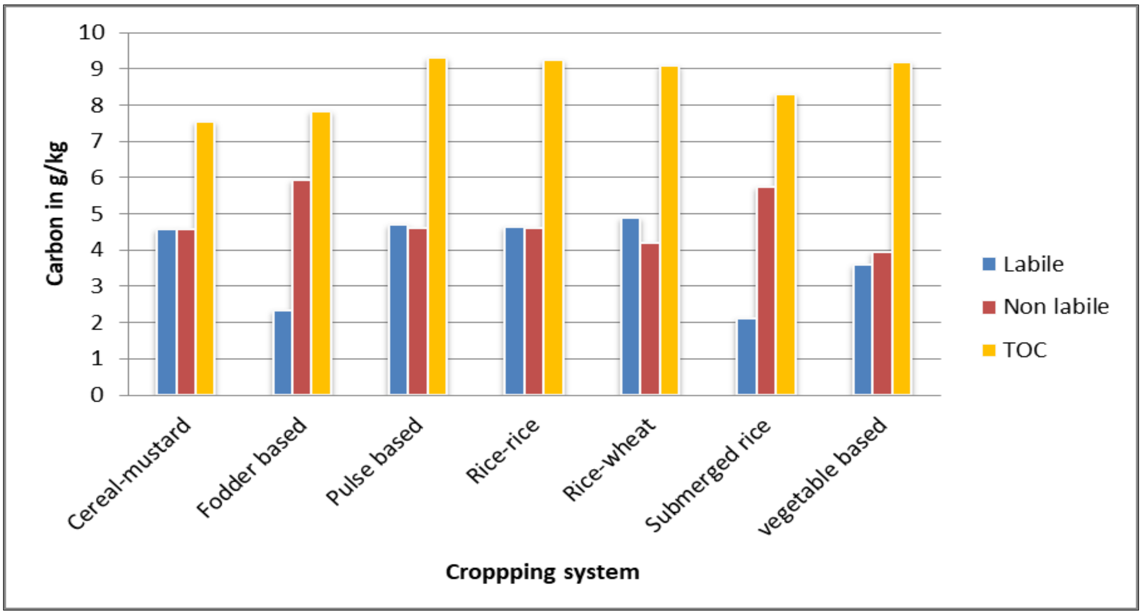

Fig 3: Proportion of carbon pools in different cropping system

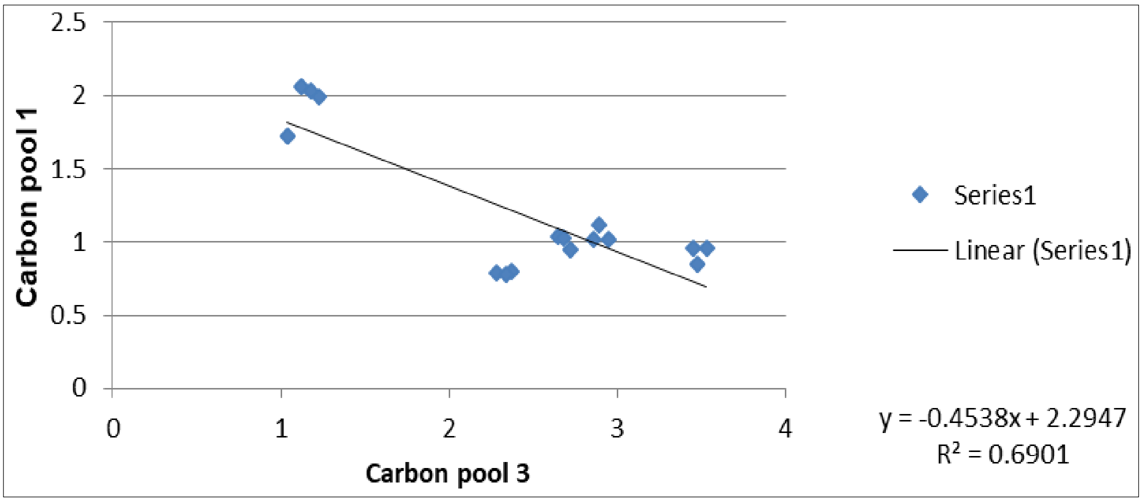

Fig 4: Relationship between carbon pool 1 and 3

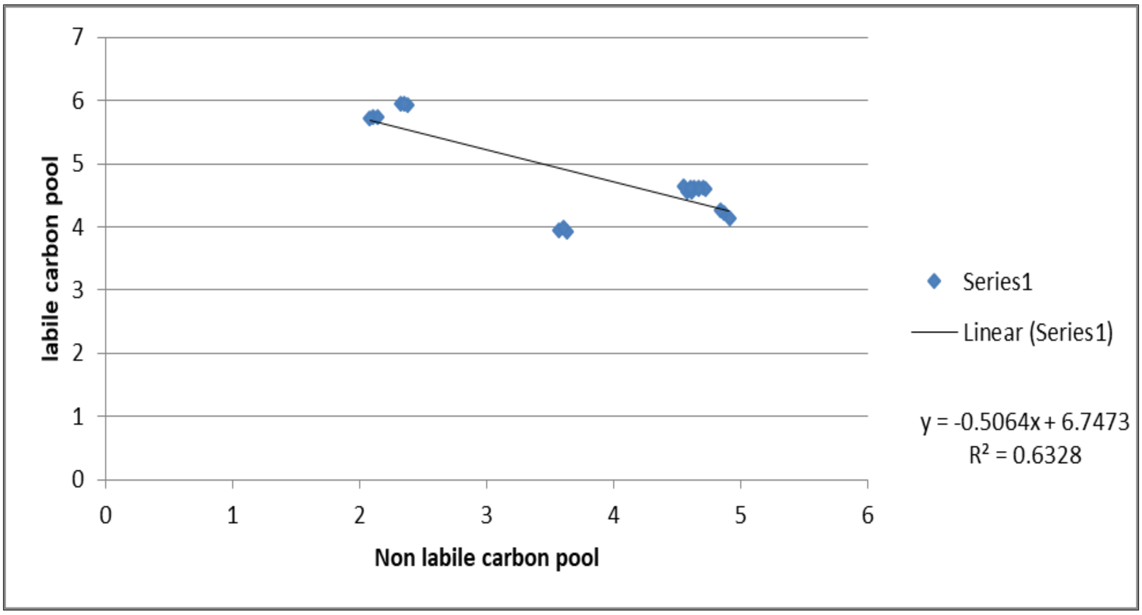

Fig 5: Relationship between labile and non-labile pool

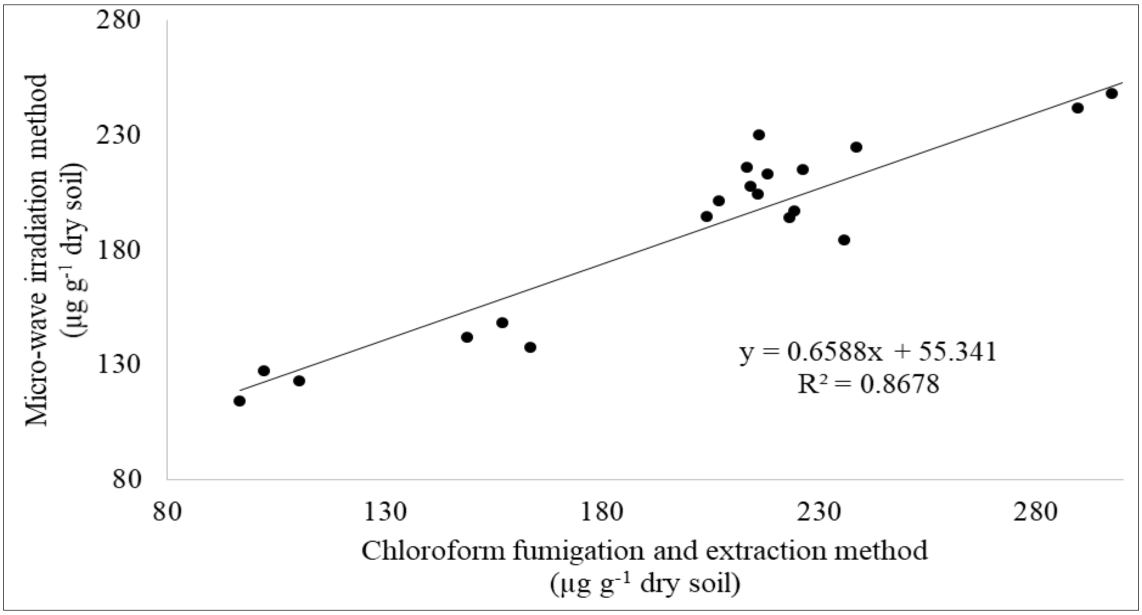

Fig 6: Comparison between two methods of Soil Microbial Biomass Carbon estimation

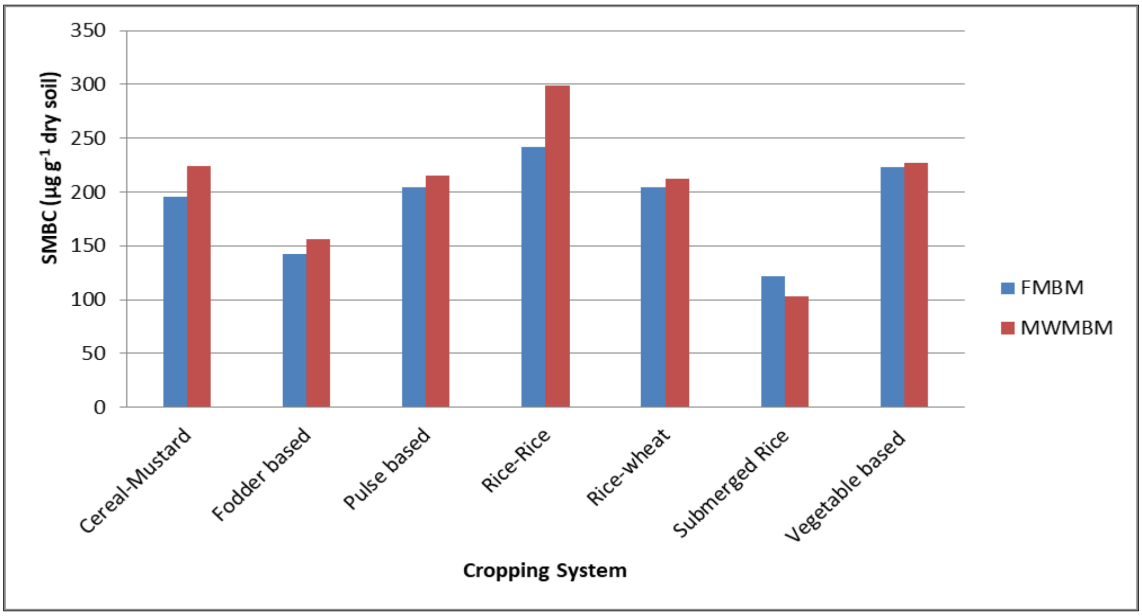

Fig 7: Comparision of soil microbial biomass carbon by Chloroform fumigation method and Micro-wave irradiation method

4. Conclusion

In the present study it was seen that the cropping system receiving integrated nutrients where inorganic nutrient source are being combined with organic sources like FYM +Dhaincha +NPK out performed those receiving only NPK or not receiving any fertilizer at all as in case of fodder in terms of biological properties of soil like total organic carbon, microbial biomass etc. It was seen that all the parameters indicating the soil organic carbon or microbial biomass were significantly correlated among themselves and all of them followed similar pattern of indicating that those system receiving benefit of organic plus inorganic sources are more sustainable in terms of soil quality and heath. Another interesting fact that was being seen was that the microbial irradiation method used to determine the microbial biomass was significantly correlated to the conventional chloroform method which give a hint for adoption or replacement of the lethal chloroform method by the safe and rapid method of microbial irradiation. irradiation Today when the population is skyrocketing and the land for cultivation is shrinking, the pressure for production of more grain from less land is increasing in traditionally fertile lands like Indo-Gangetic plains, thus conserving its quality through maintaining the soil organic matter is need of hour. Therefore adoption of more and more integrated use of inorganic nutrients with organic nutrients in cropping system can lead to a sustainable production system.

5. References

1. Biswas CR, Benbi DK. Sustainable yield trends of irrigated maize and wheat in LTFE on loamy sand in semi-arid India. Nutr. Cycl. Agroecosyst. 1997;46:225-234.
2. Bouyoucos GJ. Hydrometer method improved for making particle size analysisof soils. Agron. J. 1962;54:464.
3. Campbell CA, McConkey BG, Zentner RP, Selles F,

Curtin D. Tillage and crop rotation effects on soil organic C and N in a coarse-textured Typic Haploboroll in South western Saskatchewan. Soil Till. Res. 1996;37:3-14.
4. Casida Jr LE, Klein DA, Santoro T. Soil dehydrogenase activity. Soil science. 1964;98(6):371-376.
5. Chan KY. Soil particulate organic carbon under different land use and management. Soil use and management. 2001;17(4):217-221.
6. Conteh A, Lefroy RDB, Blair GJ. Dynamics of organic matter in soil as determined by variations in 13C/12C isotopic ratios and fractionation by ease of oxidation. Aust. J Soil Res. 1997;35:881-890.
7. Dezhi Y, Dejian W, Linzhang Y. Long-term effect of chemical fertilizer, straw, and manure on labile organic matter fractions in a paddy soil. Biol. Fertil. Soils. 2007;44:93-101.
8. Doran JW, Parkin TB. Defining and assessing soil quality. p. 3-22. In J.W. Doran *et al*. (ed.) Defining soil quality for a sustainable environment. SSSA Spec. Publ. 35. SSSA, Madison, WI; c1994.
9. Duxburv C, *et al*. Legumes in rice and wheat cropping systems of the Indo-Gangetic Plain - Constraints and opportunities Patancheru, Andhra Pradesh, India: ICRISAT and Ithaca, New York, USA; c2000.
10. Frank T, Malkomes HP. Influence of temperature on microbial activities and their reaction to the herbicide Goltix in different soils under laboratory conditions. Zentralblatt f€ur Mikrobiol. 1993;148:403-412.
11. Garcia C, Hernandez T. Biological and biochemical indicators in derelict soils subject to erosion. Soil Biol Biochem. 1997;29:171-177.
12. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Wiley & Sons; c1984.
13. Grego S, Marinari S, Moscatelli MC, Badalucco L. Effect of ammonium nitrate and stabilized farmyard manure on microbial biomass and metabolicquotient of soil under *Zea mays*. Agric. Meditern. 1998;128:132-137.
14. Hopkins DW, Shiel RS. Size and activity of soil microbial communities in long term experimental grassland plots treated with manure and inorganic fertilizers. Biol. Fertil. Soils. 1996;22:66-70.
15. Jenkinson DS. The Rothamsted long-term experiments: are they still in use? Agron. J. 1991;83:2-10.
16. Jenkinson DS, Powlson DS. The effects of biocidal treatment on metabolism in soil. I. Fumigation with chloroform. Soil Biol. Biochem. 1976;8:167-177.
17. Jensen LS, Mueller T, Tate KR, Ross DJ, Magid J, Nielsen NE. Soil-surface CO2 flux as an index of soil respiration in situ: A comparison of two chamber methods. Soil Biol. Biochem. 1996;28:1297-1306.
18. Kukreja K, Mishra MM, Dhankar SS, Kapoor KK, Gupta AP. Effect of long term manurial application on microbial biomass. J Indian Soc. Soil Sci. 1991;39:685-688.
19. Pal DK, *et al*. Soils of the Indo-Gangetic Plains: their historical perspective and management. Current Science 2009;96(9):1193-1202.
20. Potter KN, Tolbert HA, Jones OR, Matocha JE, Morrison JE, Unger PW. Distribution and amount of soil organic C in the long-term management systems in Texas. Soil Till. Res. 1998;47:309-321.
21. Reddy GB, Faza A. Dehydrogenase activity in sludge amended soil. Soil Biol Biochem. 1989;21:327.
22. Rochette P, Angers DA. Soil-surface CO2 fluxes induced by spring, summer and fall moldboard plowing in a sandy loam. Soil Sci. Soc. Am. J. 1999;63:621-628.
23. Rudrappa L, Purakayestha TJ, Singh D, Bhadraray S. Long-term manuring and fertilization effects on soil organic carbon pools in a Typic Haplustept of semi-arid sub-tropical India. Soil Till. Res. 2006;88:180-192.
24. Trevors JT. Dehydrogenase activity in soil: a comparison between the INT and TTC assay. Soil Biol Biochem. 1984;16:673-674.
25. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 1934;37:29-38.
26. Wilke BM. Effect of single and successive additions of cadmium, nickel and zinc on carbon dioxide evolution and dehydrogenase activity in a sandy Luvisol. Biol Fertile Soils. 1991;11:34-37.
27. Yadav RL, *et al*. Atlas of cropping systems in India" PDCSR Bulletin; c2001. p. 96.