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Assessment of rice farming management practices based on soil organic carbon pool analysis

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Abstract: It has been suggested that different pools of soil organic carbon (SOC) in agricultural lands are more effective in indicating soil quality parameters than total soil organic carbon (TOC) content. Diverse physiographic conditions of Barak Valley part of North East India has evolved diverse rice farming management practices for e.g. rainfed lowland rice, upland or dry rice (mountains and plateaus), boro rice (summer rice grown in shallow areas of wetlands) and flood prone semi deep water rice. The objective of the study was to investigate how different pools of SOC are affected by rice farming practices based on landscape positions and also to identify the best rice management practices in terms of soil sustainability and productivity through SOC pools from short term on-farm fertilizer experiment in lowland rainfed condition. Study revealed rice farming systems influence the different pools of SOC and, therefore, can be an important tool for classification in terms of soil C sink management. Study further revealed the integrated use of organic with inorganic fertilizer enhances the productivity and appreciable increase in SOC over control treatment. Present study confirmed $C_{Very\ Labile}$, C_{Labile} or $C_{Active\ Pool}$ is the important determinant of rice yield over TOC.

Key words: $C_{Active\ Pool}$, $C_{Passive\ Pool}$, humic acid, on-farm fertilizer experiment.

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Soil is known as the largest terrestrial carbon pool on the Earth where soil organic matter (SOM) constitutes the important biologically active form (Bhattacharyya *et al.* 2013). The maintenance of SOM is desirable for long-term land use because of the multiple beneficial effects of organic matter on nutrient status, water holding capacity and physical structure (Alekhya *et al.* 2015; Lal 2004). Due to recent concern on increasing concentrations of greenhouse gases in the atmosphere the environmental scientists are focusing on the management of carbon sink in the agricultural soils because they are the major emitters of greenhouse gases. SOC fractions with different stabilities and turnover rates are important variables to detect the influence of agricultural management on soil quality (Chivhane & Bhattacharyya 2010; Mandal *et al.* 2008; Silveira *et al.* 2008). SOC stock is comprised of labile or actively cycling pool and stable, resistant/recalcitrant pools with varying residence time (Chan *et al.* 2001). The labile C pool has been the main source of nutrition which influences the quality and productivity of soil (Chan *et al.* 2001; Mandal *et al.* 2008). Highly recalcitrant or passive C pool is slowly altered by microbial activities (Weil *et al.* 2003) and due to this nature it may not be a good soil quality parameter but contributes towards overall TOC stock (Mandal *et al.* 2008). Few studies have shown rice farming has lot of potential to improve soil

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Table 1. Rice farming systems in Barak Valley, Assam showing SOC pools and management systems.

Rice farming systems	SOC (%)	Active Pool of C (%)	Passive Pool of C (%)	Management system practice
Upland	1.61[a*] (0.11)	43	57	Seed broadcasting, no fertilizer, no irrigation
Rainfed	1.15[b] (0.08)	37	63	Well managed cultivation with fertilizer and manure
Boro	2.24[c] (0.12)	32	68	Seed broadcasting/unsystematic planting of seedlings, no fertilizer application
Deepwater	2.01[d] (0.09)	26	74	Unsystematic planting of seedlings, no spacing, no fertilizer application

Values are mean and in parenthesis standard deviation; *significant differences were marked with different letter.

carbon sequestration and it may also mitigate global warming process (Bhattacharyya *et al.* 2013; Majumdar *et al.* 2008). It is a broad area of research; however the present study is an effort to address (i) to investigate rice farming management practices based on organic carbon pool analysis and (ii) to identify the best rice management practices in terms of soil sustainability and productivity from short term on-farm fertilizer experiment in the Barak Valley, Assam represented by the North Eastern Region of the country.

Barak Valley is predominantly a floodplain and located in the southern part of Assam (24° 80′ and 25° 80′ N latitude; 92° 15′ and 93° 15′ E longitude). The region is named as Barak Valley following the name of its main river Barak. Administratively, the region comprises three districts, namely Cachar, Karimganj and Hailakandi. The valley is characterized by undulating topography. The hills and hillocks, locally known as *tillas* predominate the land surface. The climate of Barak Valley is sub-tropical warm and humid with average rainfall of 2300 mm, most of which is received during the southwest monsoon season (May-September). Alluvial soils in the flood plains are fertile. The Barak plains have a great deal of low marshy lands. Organic soils are found in the swampy *beels*. The soils are acidic, sandy loam to sandy clay loam in texture (Bhowmick *et al.* 2005; Das *et al.* 2005).

To estimate soil organic carbon pool of different rice farming managements of Barak Valley, Assam, studies in field were conducted. Field studies were made at block level (smaller subdivisions of a district) so as to cover all the different parts of the three districts of Barak Valley. Classification of the rice farming system was based on UNCTAD (2010) viz., (i) rainfed lowland rice: rice cultivation depends on monsoon rain and inundation period ranges from 45 - 60 days (ii) upland or dry rice (mountains and plateaus): rain water drains out due to physiographic condition of landscape. There is no inundation period as such. (iii) boro rice: summer rice grown in shallow areas of wetlands and inundation period is 150 - 200 days and (iv) flood prone semi deep water rice where waterlogged condition persist for 250 - 300 days. Fifty six (56) soil sampling points selected to represent all four farming systems of the Valley. Soil samples (0 - 10 cm) were analyzed for different SOC pools viz. very labile (C_{VL}), labile (C_L), less labile (C_{LL}) and non-labile (C_{NL}). The oxidizable total soil organic carbon was determined by wet oxidation (Walkley & Black 1934). This was approximated into different pools by the modified Walkley & Black method as described by Chan *et al.* (2001) using 5, 10 and 20 ml of concentrated (36 N) H_2SO_4 that resulted in three acid-aqueous solution ratios of 0.5:1, 1:1 and 2:1 (corresponding to 12, 18 and 24N of H_2SO_4 respectively). The amount of C thus determined allowed the sub-fractionation of TOC into the following four different pools according to their decreasing order of oxidizability.

Pool I (C_{VL} very labile soil carbon): OC oxidizable by 12 N H_2SO_4.

Pool II (C_L labile soil carbon): The difference between C oxidizable by 18N and that by 12 N H_2SO_4.

Pool III (C_{LL} less labile soil carbon): the difference between C oxidizable by 24 N and that by 18 N H_2SO_4.

Pool IV (C_{NL} non labile soil carbon): the difference between TOC and oxidizable C by 24 N H_2SO_4.

Pool I and II together represent the active pool [Active pool = ∑ (Pool I + Pool II)] while pool III and pool IV together constitute the passive pool [Passive pool = ∑ (Pool III + Pool IV)] of TOC in soils (Chan *et al.* 2001). The humic acid from the extracted organic matter was separated using Schnitzer (1977). To identify the best rice management practices in terms of soil sustainability and productivity in rainfed paddy farming, on-farm fertilizer experimental data were utilized which include triplicate treatments from (a) control: (without any organic and inorganic fertilizer), (b) village management: (VM) (partially decomposed/ humified cow dung @ 70 - 80 Mg ha^{-1}), (c) inorganic: (NPK) fertilizer (130 - 100 - 60 as recommended by Assam Agricultural University, Jorhat, Assam) was used in the form of urea, single super phosphate and muriate of potash, (d) organic: (phosphate solubilizing biofertilizer and *Azotobacter* biofertilizer were applied in two steps: seedling dip and soil application as recommended by Assam Agricultural University, Jorhat, Assam) and (e) organic + inorganic in combination. Fertilizer experimental plot was developed in 2010 in a randomized block design. Random soil samples (0 - 10 cm) were collected during January, 2013 from each treatment. Later these data were compared with the SOC data quantified at NBSS & LUP, Nagpur. Tukey's test was performed to determine the statistical significance of treatment effects on experimental traits and SOC values. The 5 % probability level was considered as statistically significant.

SOC stock was highest in boro rice (2.24 %) followed by semi deepwater (2.01 %), upland (1.61 %) and rainfed (1.15 %) respectively. Proportion of active pool (C_{VL} + C_L) of SOC in different systems follows the order: upland (43 %) > rainfed (37 %) > boro (32 %) > semi deepwater (26 %). This suggests duration of water logged condition in rice field and active C pool are negatively related. The higher the duration of waterlogged condition (e.g., 250 - 300 days in semi deepwater), the lower the proportion of active C pool. Submergence condition as observed in boro and deepwater prevented oxidative losses of carbon that resulted into built up of higher proportion of passive C pool (Table 1). Wetland rice culture favours better fertility management and build-up of organic matter in soil due to an ideal environment for aerobic and anaerobic microbial activity, and is the back bone of long term sustainability (Neue *et al.* 1997) and C sink management (Mitsch *et al.* 1998; Sahrawat 2004). Table 2 indicates that except deepwater farming, humic acid content is more than 50 % of SOC in soil. Because approximately between 60 – 70 % of the total soil C occurs in humic material (Paul *et al.* 2001) the role of humic substances in the C cycle either as CO_2 source or as a C reservoir needs to be worked out (Lal 2006). It seems upland and rainfed farming system has a blend of better organic matter decomposition (as evidenced by 64 and 56 % recovery) signifying its role in contribution to active C pool of SOC (Table 1). Higher level of humic acid (HA) in SOM indicates more decomposition of organic matter as is inferred by more recovery of HA from organic matter. After chemical analyses of these samples we observed 64 and 56 % HA are recovered in upland and rainfed farming systems respectively. More HA indicates relative ease (in terms of lability) of being extracted using Chan's method. Therefore, better recovery of HA indicates more active C pool of SOC. India's climate featuring high temperatures does not allow very labile forms of organic carbon to persist in soils (Chivhane & Bhattacharyya 2010). This will not improve as climate change will likely increase temperatures (IPCC 2007). This suggests under current scenario of atmospheric temperature rise in absence of appropriate management practices C content in active C pool are prone to degradation via oxidative losses.

Table 2. Relative proportion of humic acid and its characteristics in soils.

Rice farming system	Humic acid (%)	% Humic acid in SOC
Upland	1.03[a*] (0.04)	64
Rainfed	0.64[b] (0.06)	56
Boro	1.20[c] (0.07)	54
Deepwater	0.90[d] (0.05)	45

Values are mean and in parenthesis standard deviation; *significant differences were marked with different letter.

Mean comparison through Tukey's test of experimental traits after three years of experimental plot development showed higher plant height in inorganic treatment. True grain production and grain yield was highest in organic + inorganic (Table 3). Grain yield was 45 and 66 % higher in inorganic and organic + inorganic plot

Table 3. On-farm experimental datasets for plants and soils in Barak Valley, Assam.

Treatment	Plant height (cm)	Panicle no/rice hill	No of true grains/panicle	Grain yield (t ha^{-1})	TOC (%)	Active pool of C (%)	Passive pool of C (%)
Control[1]	78.90[a*]	7[a]	137[a]	0.86[a]	1.30[a]	25	75
	(4.31)	(2.0)	(23)	(0.09)	(0.03)		
VM[2]	80.94[a]	7[a]	165[b]	0.93[b]	1.36[b]	31	69
	(3.86)	(2.0)	(22)	(0.08)	(0.04)		
Inorganic[3]	89.62[b]	8[a]	192[c]	1.25[c]	1.33[a]	30	70
	(3.64)	(1.0)	(35)	(0.11)	(0.06)		
Organic[4]	80.96[a]	6[a]	178[d]	1.13[d]	1.46[c]	34	66
	(3.26)	(2.0)	(28)	(0.08)	(0.08)		
Organic + Inorganic[5]	86.76[b]	8[a]	198[e]	1.43[e]	1.43[c]	36	64
	(3.77)	(1.0)	(37)	(0.11)	(0.05)		

Values are mean and in parenthesis standard deviation; *significant differences were marked with different letter

[[1]Control: without any organic and inorganic fertilizer; [2]VM: village management (partially decomposed cow dung applied @ 70 - 80 Mg ha^{-1}); [3]Inorganic (NPK) fertilizer (130 - 100 - 60 was used in the form of urea, single superphosphate and muriate of potash); [4]Organic (phosphate solubilizing biofertilizer and *Azotobacter* bio-fertilizer applied in two steps: seedlings dip and soil application; [5]Organic + Inorganic: both organic and inorganic fertilizer applied in combination].

respectively over control plot. Organic treatment recognized an increase of 31 % over control plot signifying organic treatment alone cannot enhance productivity or replace application of inorganic fertilizer. The integrated use of organic manure with inorganic fertilizer enhances the availability of the nutrients for a longer period (Rani & Srivastava 1997), increases nutrients use efficiency of the crops and enhances the activities of N fixers (Ladha *et al.* 1989). While simulating changes in SOC in long term fertilizer experiment in Akola, Maharashtra, it was reported that application of inorganic and organic in combination brings overall increase in SOC and crop yield; however, manure application alone increases SOC without appreciable increase in crop yield (Bhattacharyya *et al.* 2013). Our data show a trend that seems to indicate a broad relationship between crop yield and the active carbon pool. This may mean that C_{VL} and C_L of SOC is important for better crop performance. Chivhane & Bhattacharyya (2010) reported C_{VL} and C_L should be considered as more logical soil quality parameter as these vary with climate and land use. Present study confirmed C_{VL}, C_L or C_{AP} are the important determinant of yield over TOC.

Boro and deep water rice farming systems are important in the sense that they store more SOC in soil and the larger proportion is stocked in passive pool. Higher proportion of passive pool for a given system suggests its role in soil C sink management through protecting SOC from oxidative losses. Promotion of combined application of organic and inorganic fertilizer for enhancing SOC stock and crop productivity in rainfed paddy soils in the valley is recommended.

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References

Alekhya, V. V. L., G. S. Pujar, C. S. Jha & V. K. Dadhwal. 2015. Simulation of vegetation dynamics in Himalaya using dynamic global vegetation model. *Tropical Ecology* **56**: 219-231.

Bhattacharyya, T., D. K. Pal, S. K. Ray, P. Chandan, C. Mandal, B. Telpande, A. S. Deshmukh & P. Tiwary. 2013. Simulating change in soil organic carbon in two long fertilizer experiments in India: with the Roth C model. *Climate Change and Environmental Sustainability* **2**: 107-117.

Bhowmick, B. C., B. C. Barah, S. Pandey & N. Barthakur. 2005. *Changing Pattern of Rice Production Systems and Technology in Assam: a Spatio-Temporal Analysis of Performance and Prospects*, Policy Paper 22, National Centre for Agricultural Economics and Policy Research (NCAP) Indian Council of Agricultural Research, New Delhi, India.

Chan, K. Y., A. Bowman & A. Oates. 2001. Oxidizable organic carbon fractions and soil quality changes in an oxicpaleustaff under different pasture leys. *Soil Science* **166**: 61-67.

Chivhane, S. P. & T. Bhattacharyya. 2010. Effect of land use and bio-climatic system on organic carbon pool of shrink-swell soils in Vidarbha region, Maharashtra. *Agropedology* **20**: 145-156.

Das, T. & A. K. Das. 2005. Local soil knowledge of smallholder rice farmers: A case study in Barak Valley, Assam. *Indian Journal of Traditional Knowledge* **4**: 94-99.

Intergovernmental Panel on Climate Change (IPCC). 2007. IPCC Fourth Assessment Report 2007.

Ladha, J. K., A. T. Padre, G. C. Punzalan, M. Garcia & I. Watanabe. 1989. Effect of inorganic N and organic fertilizers on nitrogen-fixing (acetylene-reducing) activity associated with wetland rice plants. pp. 263-272. *In*: F. A. Skinner (ed.) *N_2 Fixation with Non-legumes.* Kluwer Academic Publishers, Dordrecht.

Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. *Science* **304:** 1623-1627.

Lal, R. 2006. Soil carbon sequestration in Latin America. pp. 49-64. *In*: R. Lal, C. C. Cerri, M. Bernoux, J. Etcheves, E. Cerri (eds.) *Carbon Sequestration in Soils of Latin America.* Food Products Press, New York.

Majumdar, B., B. Mandal, P. K. Bandhyopadhyay, A. Gangopadhyay, P. K. Mani, A. L. Kundu & D. Majumder. 2008. Organic amendments influence soil organic carbon pools and crop productivity in nineteen year old rice-wheat agro-ecosystem. *Soil Science Society of America Journal* **72**: 1-11.

Mandal, B., B. Majumder, T. K. Adhya, P. K. Bandopadhyay, A. Gangopadhyay, D. Sarkar, M. C. Kundu, S. Gupta, G. C. Choudhury, G. C. Hazra, S. Kundu, R. N. Samantaray & A. K. Misra. 2008. Potential of double-cropped rice ecology to conserve organic carbon under subtropical climate. *Global Change Biology* **14**: 1-13.

Mitsch, J. W., X. Wu., R. W. Nairn., P. E. Weihe., N. Wang., R. Deal & C. E. Boucher. 1998. Creating and restoring wetlands: a whole-ecosystem experiment in self-design. *Bioscience* **48**: 1019-1030.

Neue, H. U., J. L. Gaunt, Z. P. Wang, P. Becker-Heidmann & C. Quijano. 1997. Carbon in tropical wetlands. *Geoderma* **79**: 163-185.

Paul, E. A., H. P. Collins & S. W. Leavitt. 2001. Dynamics of resistant soil carbon of Midwestern agricultural soils measured by naturally occurring ^{14}C abundance. *Geoderma* **104**: 239-256.

Rani, R. & O. P. Srivastava. 1997. Vermicompost: a potential supplement to nitrogenous fertilizer in rice nutrition. *International Rice Research Notes* **22**: 30-31.

Sahrawat, K. L. 2004. Fertility and organic matter in submerged rice soil. *Current Science* **88**: 735-739.

Schnitzer, M. 1977. *Soil Organic Matter.* 3rd Edn. Braunchweig. International Atomic Energy Agency, Vienna.

Silveira, M. L., N. B. Comerford, K. R. Reddy, W. T. Cooper & H. El-Rifai. 2008. Characterization of soil organic carbon pools by acid hydrolysis. *Geoderma* **144:** 405-414.

Walkley, A. & I. A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

Weil, R. R., K. R. Islam, M. A. Stine, J. B. Gruver, & S. E. Samson-Liebig. 2003. Estimating active carbon for soil quality assessment: a simplified method for laboratory and field use. *American Journal of Alternative Agriculture* **18**: 3-17.

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