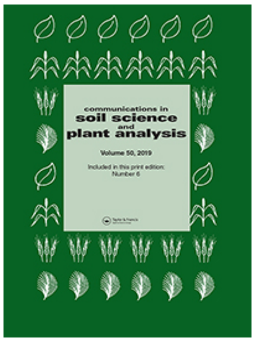

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A. K. Singh, M. S. Behera, S. P. Mazumdar, and D. K. Kundu

Crop Production Division, ICAR-Central Research Institute for jute and Allied Fibres (CRIJAF), Kolkata, West Bengal, India

ABSTRACT

Soil organic carbon (SOC) sequestration in response to long-term fertilizer management practices under jute-rice-wheat agro-ecosystem in alluvial soils was studied using a modeling approach. Fertilizer management practices included nitrogen (N), phosphorus (P) and potassium (K) fertilization, manure application, and root-stubble retention of all three crops. Soil carbon (C) model RothC was used to simulate the critical C input rates needed to maintain initial soil C level in long timescale (44 years). SOC change was significantly influenced by the long-term fertilizer management practices and the edaphic variable of initial SOC content. The effects of fertilizer combination "100%NPK+FYM" on SOC changes were most significant over "100%NPK" fertilization. If the 100% NPK fertilizer along with manure applied with stubble and roots retention of all crops, alluvial soils of such agro-ecosystem would act as a net C sink, and the average SOC density kept increasing from 18.18 Mg ha^{-1} during 1972 to the current average of □22 Mg ha^{-1} during 2065 s. On an average, the critical C input was estimated to be 5.30 Mg C ha^{-1} yr^{-1}, depending on local soil and climatic conditions. The critical C input could be effectively estimated using a summary model driven by current SOC level, mean annual temperature, precipitation, and soil clay content. Such information will provide a baseline for assessing soil C dynamics under potential changes in fertilizer and crop residues management practices, and thus enable development of management strategies for effectively mitigating climate change through soil C sequestration.

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Carbon sequestration; jute-rice-wheat system; long-term fertilization; RothC model

Introduction

The soil has been found to be both source and sink of carbon and the accumulation of soil organic carbon (SOC) is influenced by long-term land management practices (Bhattacharyya et al. 2008). Soil contains as much as 1550 Pg C as SOC and 950 Pg C as soil inorganic carbon (C) together constituting about 3.3 times the size of the atmospheric pool and 4.5 times the size of the biotic pool (Lal 2004; Smith, Martino, and Cai et al. 2007a). Any attempt to enrich this reservoir through sequestration of atmospheric C will help to manage global warming significantly including maintenance of soil health for sustainable crop production (Mandal 2005). The magnitude of decline or enhancement of SOC due to continuous cultivation depends on the balance between the loss of C by oxidative forces and crop residues and manures that are added to the soils. The loss of C is likely to be enormous in tropical and subtropical regions of the world where soils are inherently low in C, as well as in productivity because of high atmospheric temperature (Jenny and Raychaudhuri 1960). There is little information available on C sequestration in different Indian agro-ecosystem (Lal 2004;

CONTACT A. K. Singh singhak30@gmail.com Crop Production Division, ICAR-Central Research Institute for Jute and Allied Fibres (CRIJAF), Nilganj, Barrackpore, Kolkata, West Bengal 700120, India

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Pathak et al. 2011; Velayutham, Pal, and Bhattacharyya 2000), although there is possibly a greater potential for sequestrating SOC with crop rotations in this region. Carbon sequestration can be indirectly assessed through the modeling of SOC content. The SOC models are an alternative to explore the possibilities for modification of SOC through different management practices (Falloon and Smith 2009; Smith and Smith 2007). Among the many SOC models published, the Rothamsted Carbon Model (RothC) has a simpler and best performing structure (Coleman and Jenkinson 1996). Analysis of RothC model output data showed that this model could be used as a tool to arrive at different threshold values of rainfall to influence decomposition rate modifier and thus to find out rate of organic carbon sequestration in various bioclimatic systems in both humid and semi-arid region (Bhattacharyya et al. 2011, 2007).

To optimize the efficiency of C sequestration in agriculture, cropping systems play a critical role by influencing optimal yield, total increased C sequestered with biomass, and that remained in the soil. Based on the Rothamsted model, series of Long-Term Fertilizer Experiments (LTFE) were established for different cropping system at different locations in India (Swarup and Wanjari 2000). LTFE on jute based cropping system (jute-rice-wheat) in alluvial soils were started in Barrackpore (India) during the year 1972 to understand the complex interactions involving soils, plants, climate, and management practices and their effects on crop productivity. Research reports (Abrol et al. 2000; Manna, Swarup, and Wajari 2005) on temporal trends of crop yields in the region are available, but there are no trends on C sequestration at regional or smaller levels available (Benbi and Brar 2009). Jute *(Corchorus capsularis, Corchorus olitorius)* is a second important fiber crop next to cotton and grown under wide variation of climatic conditions mainly in developing countries like India, Bangladesh, Myanmar, Nepal, Taiwan, Thailand, Vietnam, Cambodia, Brazil, and some other countries. Depending on demand, price and agro-climate, the annual production of jute and allied fibers in the world is around 3 million tonnes (FAOSTAT 2016). India is the single largest producer of jute in the world, contributing about 60% of the global production (Singh 2017). Natural jute fibers are eco-compatible by nature from cradle-to-grave. Life cycle assessment study by the National Jute Board of India (NJB) reveals that the most significant impact is carbon sequestration by green jute plants during the growth stage. It was estimated that, on an average, as much as 1.8–2.0 Mg ha^{-1} of the left over above- and below-ground biomass of jute (leaves, stubbles, and roots) is added annually to the soils under jute cultivation (Singh 2017). The carbon build-up rate is about 0.11 to 0.25 Mg C $ha^{-1}yr^{-1}$ under jute-rice-wheat cropping system (Mandal et al. 2007). Approximately 4.88 Mg of carbon dioxide gets sequestered per Mg of raw jute fiber production which is much higher than many tree species (Rajagopal and Sanyal 2012). In this study, simulation of the long-term SOC content changes over time as influenced by different combinations of fertilizer under jute–rice–wheat-based agro-ecosystem was carried out. There are three simulations in this study. In simulation-I, the importance of initial SOC content for SOC change over time, and which fertilizer combination has more capability to recover from depleted SOC condition was worked out. In simulation-II, SOC change with measured climate data from 1972 to 2016, for each fertilizer treatment was assessed. In simulation-III, SOC change under current and expected future climate change from 2017 to 2065 was compared. The information on resulting change in soil organic carbon (SOC) may be helpful in the modification of existing soil management practices to increase SOC levels, productivity and sustainability and also the estimation of CER (certified emission reduction) revenue per hectare of jute-based agro-ecosystem.

Research methodology

Study site

The study was conducted over a 44-year period (1972–2016) at Research Farm of Central Research Institute for Jute and Allied Fibre (ICAR-CRIJAF). The study area located in Barrackpore of West Bengal (India), at 88° 26′ E, 22° 45′ N and elevations of 9 m. According to the National Agricultural

Research Project classification (NARP 1979) of Agriculture Climatic Zone (India), the study area belongs to the New Alluvial Zone (WB-4). Climate is humid (rainfall>1600 mm) with a distinct wet monsoon, summer and a cool winter season. Average maximum and minimum temperatures during the experimental period were 36.9°C and 19.7°C, respectively.

During the study period, three crops were grown in rotation, i.e., jute, rice, and wheat (JRW) under upland situation. The trial involved eight different management strategies consisting of different combinations of chemical fertilizer and farmyard manure (FYM). Chemical fertilizer application rates were based on percentages of the recommended doses for rice, wheat, and jute. Three of these fertilizer management strategies (0%NPK, 100%NPK, and 100%NPK+FYM) were chosen for C sequestration on the basis that they are most representative of current practices found in farmer's field of India.

Management practices, soil and weather data

Field plots of 200 m^2 (20 x 10 m) with three replications were established for each fertilizer treatments. Jute plant (*Corchorus olitorius)* as fiber crop was grown in summer season (April–July) followed by rice (*Oryza sativa*) during the rainy season (July–November), while wheat (*Triticum aestivum*) in the post-rainy season (December–March). Seeds of jute and wheat were sown while rice was transplanted as seedlings following standard methods. Three treatments of fertilizer applied for growing JRW crops is given in Table 1. FYM was incorporated once a year before sowing of jute crop. Phosphorous (P) and potash (K) were applied as single super phosphate (16% total P) and muriate of potash (60% of total K) respectively, before sowing of jute and wheat and transplantation of rice seedlings. Nitrogen (N) was applied as urea (46% of total N) in three splits before and after 25th and 50th days of sowing/transplantation. During the first tillage operation for each crop, the shredded leaves, stubbles, and roots of previous crop were mixed in soil in all the treatments of the study. Need-based irrigation, weeding, and plant protection measures were taken. The experiment was laid out in a randomized block design (RBD).

Three representative soil samples (0–22.5 cm) were collected from each of the plots every year during 1973 to 2016 and analyzed following standard procedures (Jackson 1967) for their physical and chemical analyses. The pH of the soil samples was measured in 1:2 soil-water suspension using a glass electrode. The soil textural fractions were determined following the hydrometer method (USDA, 1972). Soil bulk density was determined after the soil was oven dried at 105°C for 24 h (Hillel 2004). Cation exchange capacity (CEC) of the soil samples was determined by extracting the soil samples with ammonium acetate (1N NH_4OAC) at pH 7. Soil organic carbon was determined as per the Walkley and Black method (Schnitzer 1982). Monthly mean air temperature, monthly precipitation, and open-pan evaporation data were obtained from the Meteorological Data of Research Farm provided by the ICAR-CRIJAF for the period of 1972–2016.

Simulation procedure

The Rothamsted Carbon-26.3 Model, i.e., RothC (Coleman and Jenkinson 1996) was used to simulate the SOC trend over 44 years. In modeling, the initial SOC content was set to the 1971 value and then simulated the changes in SOC with time (1972 to 2016) for three fertilizer and crop

Table 1. Fertilizer doses for growing jute-rice-wheat crop system in new alluvial soils.

	Fertiliser applied [FYM:N:P:K (kg^{-1} ha^{-1})]			
Crop	0%NPK	100%NPK	100%NPK+FYM	Growing period (month)
Jute	00:00:00	60:13:50	60:13:50:5000	Apr–Jul
Rice	00:00:00	120:26:50	120:26:50:00	Jul–Nov
Wheat	00:00:00	120:26:50	120:26:50:00	Dec–Mar

residues management scenarios. The year 1972 was set as the baseline, and the RothC was run to reach equilibrium with that baseline SOC. As described by Jenkinson et al. (1990), assuming that the SOC content has reached equilibrium, the RothC model can be run inversely to calculate how much C needs to enter the soil annually to maintain a specified level of SOC. In the RothC model, soil organic matter (SOM) is partitioned into five conceptual pools, i.e., decomposable plant material (DPM), resistant plant material (RPM), microbial biomass (BIO), humified organic matter (HUM), and inert organic matter (IOM). In this calculation process, the allocation of SOC into each of the five compartments (DPM, RPM, BIO, HUM, and IOM) was determined. Therefore, the model was run inversely to calculate the C input required to maintain the SOC content at 1972 levels, and then SOC allocation was set in each of the five compartments to this equilibrium value. The DPM:RPM ratio was set at 1.44, a typical value for most agricultural crops and grasses (Coleman and Jenkinson 1996). The values of IOM were set by Eq. 1 (Falloon et al. 1998):

$$IOM = 0.049\ x\ SOC^{1.139} \tag{1}$$

Calibration of the Roth C turnover model was done using measurable soil organic carbon pools. Soil samples were fractionated by means of physical and chemical procedures as described by Zimmermann et al. (2007). The model performance was evaluated using simple measures of agreement between measured and calculated values such as (i) Bias: average difference between measured and simulated values; (ii) RMSE: root-mean-square error measuring total simulation error; (iii) Modelling efficiency (EF); and (iv) Agreement index (Ai); trends of simulated values with respect to the observed ones (Guo et al. 2006; Smith et al. 1997). To compare the changes that occur in total and labile carbon as a result of fertilizer management practice, the carbon management index (CMI) was also calculated by Eq. 2 (Blair, Lefroy, and Lisle 1995):

$$CMI = Carbon\ pool\ index\ (CPI)\ x\ Lability\ index\ (LI)\ x\ 100 \tag{2}$$

where CPI = Total C stock in the fertilizer treatment/Total C stock in control;
LI = C lability in the fertilizer treatment/C lability in control;
Lability = Labile C/Non-labile C

Results

The study area focussed on the jute-rice growing regions that never been cultivated before the year 1971 and was previously covered with natural perennial weeds and grasses. Rice was the first crop grown followed by wheat and jute from the year 1972. The total SOC of mineral soils in the top 30 cm was 18.18 Mg C ha^{-1} during the year 1971 (before the start of crop cultivation). The long-term fertilizer experiment has been running in this study area for 44 years, and climate (rainfall and temperature) variability was observed in jute, rice, and wheat crop cycles during this period. The climatic variations and impacts were captured using a standardized precipitation index (SPI), diurnal temperature range (DTR) and crop productivity index (CPI). Overall, the SPI indicated the prevalence of frequent dry and wet periods and DTR recorded a decreasing trend (Table 2). Winter wheat yield was affected most due to the changing pattern of rainfall and night temperature. Impact

Table 2. Regression correlations between CPI, seasonal SPI, and DTR.

Crop	CPI	SPI	DTR
Jute	y = 0.0436x − 87.23 (R^2 = 0.36)	y = −0.0278x + 55.862 (R^2 = 0.16)	y = −0.0633x − 126.35 (R^2 = 0.67)
Rice	y = −0.118x + 235.21 (R^2 = 0.62)	y = 0.0802x − 160.45 (R^2 = 0.84)	y = −0.0508x + 102.01 (R^2 = 0.54)
Wheat	y = 0.0209x − 41.65 (R^2 = 0.07)	y = −0.0728x + 145.62 (R^2 = 0.69)	y = 0.0346x − 69.62 (R^2 = 0.15)

CPI: Crop productivity index, SPI: Standardized precipitation index, DTR: Diurnal temperature range

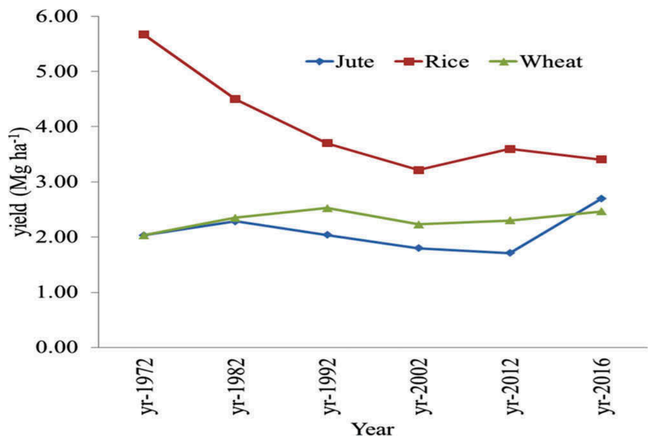

Figure 1. Trend in yield of jute, rice, and wheat during the year 1972–2016.

of rainfall variability did not affect rice yield significantly but benefited jute productivity during summer season (Figure 1). SPI and DTR are important indicators in determining the impact of climate variability on crop yield and biomass production (Fan et al. 2011).

Soil organic carbon accumulation

The total crop residue from the yield of all crops was calculated under three fertilizer treatments. As per RothC calculation, about 5.30 Mg C $ha^{-1}yr^{-1}$ is required to maintain the 1971 level of SOC. The C-input addition through leaves, stubbles, and roots was maximum (5.63 Mg C ha^{-1}) in “100%NPK+FYM”, which included 2.78 Mg C ha^{-1} in root-stubble and 2.85 Mg C ha^{-1} in leaves (Table 3). Conversely, the total amount of residue produced under control (without NPK fertilizer) was estimated to be 2.74 Mg C ha^{-1} which was much lower than the required C inputs. Jute plant contributed maximum C inputs through retention of root-stubbles and its shredded leaves. These large amounts of required C-input to maintain present SOC might result from the large C-input (net primary production) from original biomass production under long-term fertilization and crop residues addition every year.

The SOC decreased during the first 10-year simulation period in all three fertilizer management scenarios because the C-inputs were lower than the C-inputs required to maintain the SOC level (Table 4). The rates of decrease were, however, different among the scenarios. As expected, “0%NPK” resulted in the greatest depletion in SOC. The fertilizer treatments had lower levels of depletion, reflecting the effects of organic matter application. The amount of SOC accumulated in “100%NPK+FYM” was greater than that in “100%NPK” fertilizer application. These accumulations increased slowly in every decade of the simulation and then reached towards required input of 5.30 Mg C ha^{-1}, although “100%NPK” fertilizer treatment had reached equilibrium at the 40th year of simulation. Again, there was a decrease in C-input accumulations after 40th year and reduction was about 0.43, 1.41, and 2.69 Mg ha^{-1} in 0% NPK, 100% NPK, and 100%NPK+FYM fertilizer treatment, respectively, in the 44th year of simulation.

Table 3. Carbon derived from crop residues and C inputs required to maintain the initial SOC level.

	C-input addition (Mg ha^{-1})[a]			
Crop	Root + stubbles	Other residue (leaves)	All residues	Annual C input requirement[b]
Jute	0.97	2.85	3.80	-
Rice	0.94	-	0.94	-
Wheat	0.89	-	0.89	-
Total	2.80	2.85	5.65	5.30

[a]Actual yield data of crop residue under field condition, [b]Calculated from Roth C model.

Table 4. Carbon input addition through plant residues.

	C-input addition (Mg ha^{-1})					
Year	0%NPK	Changes in C-input	100% NPK	Changes in C-input	100% NPK + FYM	Changes in C-input
1972	5.43	–	5.43	–	5.43	–
1982	4.26	−1.17	4.63	−0.80	5.31	−0.12
1992	4.10	−0.16	4.26	−0.37	5.43	+0.12
2002	4.04	−0.06	4.66	+0.40	5.99	+0.56
2012	5.53	+1.49	7.09	+2.43	8.73	+2.74
2016	5.10	−0.43	5.68	−1.41	6.34	−2.39

Carbon sequestration potential

The soil carbon sequestration data in Table 5 clearly indicate that total organic carbon (TOC) marginally increased when fertilizer is externally added through inorganic mode (100%NPK) when compared with control (0%NPK). Better increase in TOC was observed due to the addition of FYM in combination with inorganic fertilizer (100%NPK+FYM). Under 100% NPK fertilizer application, SOC content decreases till the year 30th year and then it increases gradually afterwards. Whereas in case of "100%NPK+FYM" treatment, SOC contents were maintained to its initial value till the 30th year and thereafter increased up to 22.36 Mg C ha^{-1} by the year 2016. An insignificant decrease in TOC was observed under current and expected future climate change between the year 2016 to 2030 under "100%NPK+FYM" fertilizer application. This is an indication of reaching the stagnation point of carbon sequestration. To arrive equilibrium point of SOC (18.18 Mg C ha^{-1}), 100%NPK fertilizer treatment took almost 40 years. Regular application of NPK increased TOC, but its addition alone did not bring an appreciable increase in TOC content over years (Figure 2). On an average, the CO_2 loss from soil to atmosphere was in the range of 4.2 to 4.9 Mg ha^{-1}yr^{-1} (Table 5).

Measured and modeled SOC

The total simulation error in terms of root-mean-square error (RMSE) ranged from 2.28% to 4.17% (Table 6). The simulation bias expressed by M was not significant as the model tended to overestimate by approximately 0.72% to 2.27% only as compared to the measured value for both fertilizer application treatments. The simulation agreement index (AI) supports this observation indicating a non-significant difference between modeled and measured values. Overall, the RothC model appears to predict soil C stocks and treatment effects (for fertilizer and manure additions) relatively well.

Table 5. Change in total soil organic carbon (TOC) and accumulated CO_2 lost in the environment under different fertilizer treatments under jute-rice-wheat cropping system over 44 years (1972–2016).

	TOC (Mg C ha^{-1})			Total accumulated CO_2 lost (Mg ha^{-1})		
Year	0% NPK	100% NPK	100% NPK + FYM	Control	100% NPK	100% NPK + FYM
1972	18.17^{b}	18.17^{b}	18.17^{b}	5.42	5.42	5.42
1982	17.76^{b}	17.91^{c}	18.22^{b}	58.93	59.16	59.53
1992	16.51^{c}	17.01^{c}	18.33^{b}	102.62	105.96	112.63
2002	15.76^{c}	16.42^{c}	18.80^{b}	144.35	149.54	166.99
2012	15.86^{c}	17.48^{c}	20.75^{a}	186.16	197.55	227.67
2016	16.54^{c}	18.77^{b}	22.36^{a}	202.07	217.54	252.26
2030	17.26^{c}	19.10^{b}	21.78^{a}	272.74	296.72	341.60
2065	18.03^{b}	19.92^{b}	22.20^{a}	455.58	500.39	569.43
SE±		1.03			9.40	
CD (P = 0.05)		2.27			20.69	

Mean values followed by the same lower case letter (a, b, c) in a column do not differ significantly to the level of 5% probability.

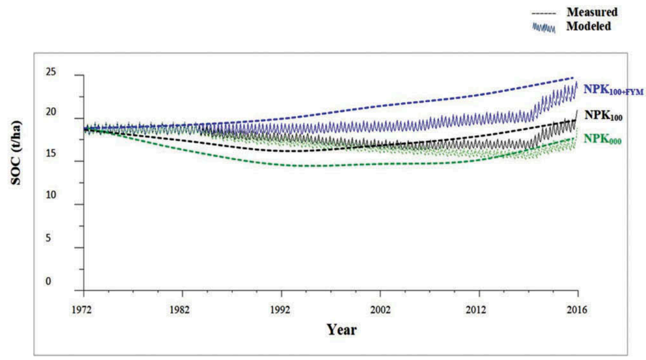

Figure 2. Carbon sequestration under jute-rice-wheat cropping system (1972–2016).

Table 6. Quantitative statistical analysis of modeled vs measured soil organic carbon data.

Statistics	Control	100% NPK	100% NPK+FYM
Bias (M)	−0.27	+0.72	+2.27
Root mean squared error (RMSE)	2.28	3.15	4.17
Model efficiency (EF)	0.51	0.37	0.26
Agreement index (AI)	0.49	0.63	0.74

Carbon management

The loss of C from a soil with a large carbon pool is of less consequence than the loss of the same amount of C from a soil with a smaller total C pool. The more a soil has been depleted of carbon the more difficult it is to rehabilitate. The loss of labile C is of greater consequence than the loss of non-labile C. To account for this a Carbon Pool Index (CPI), Liability Index (LI) and Carbon Management Index (CMI) was calculated and presented in Table 7. Total and labile C was greater in FYM–amended soil as compared to soils receiving inorganic fertilizers only. Application of FYM and addition of an enhanced amount of roots, stubbles, and leaves increased the mean CMI (129.33) as compared to 100%NPK application (87.62).

Discussion

The results of the study estimated the soil carbon sequestration rate and critical C input to maintain current C level in jute-rice-wheat agro-ecosystems and showed that the average critical C-input was 5.30 Mg C ha^{-1} yr^{-1} in order to maintain current SOC levels depending on soil and climatic conditions. The critical C-input to maintain current soil C stocks was significantly and positively related to the amount of current soil C stock (Wang et al. 2016). The FYM-amended soil accumulated more SOC than soils receiving inorganic fertilizers only. In unfertilized plots, it was assumed that only root-stubble and shredded leaves entered the soil. Obviously, this amount of C-input was smaller and this treatment was used as a basis of comparison with the other two fertilizer application scenarios to assess the effects on carbon sequestration.

Table 7. Carbon rehabilitation of jute-rice-wheat eco-system.

Fertilizer	LI	CPI	CMI
100% NPK	0.90	0.97	87.62
100% NPK+ FYM	1.21	1.07	129.33
Mean	1.06	1.02	108.47

SOC levels increased before decreasing and then increasing again for unfertilized and 100% NPK fertilizer treatments (Figure 2). The trend of SOC levels for fertilizer treatments suggests that analytical differences between years could be influencing the dataset. Saha et al. (2000) reported an overall decline in SOC when describing similar data set during the first 25 years of fertilizer application. It was observed that SOC change under current and expected future climate change from 2017 to 2065 has reached to the stagnation point with the highest value of 22.36 Mg C ha^{-1} under "100%NPK+FYM" fertilizer application. The effect of current soil C level may be further strengthened by higher temperature and rainfall, suggesting that more C-input may be required in order to maintain C balance in wetter and warmer year given a typical current C stock (Bond-Lamberty and Thomson 2010; Goidts, Wesemael, and Van Oost 2009; Saby et al. 2008). The C-input addition through root-stubble and leaves, under "100%NPK+FYM" exceeded the required input of 5.30 Mg C ha^{-1}, implying that SOC in jute-rice-wheat crop cycle could be maintained if such crop residues are incorporated into the soils every year. The mixing of shredded jute leaves in the soil helped in doubling the C-input (2.85 Mg ha^{-1}) as compared to root-stubble of all crops (2.80 Mg ha^{-1}). In jute crop, daily potential biomass production of 49.7 $gm^{-2}day^{-1}$ has been reported (Palit 1993). Usually, the harvesting of annual crops is done almost from the ground level and root-stubble left on the ground is mixed in the soil before sowing the next crop. The inclusion of jute crop in the cropping system gives a very good scope of returning the biomass back to soil as well as for total potential primary productivity and increased carbon fixation (Singh 2017).

Simulated SOC storages were comparatively closer to the measured values. The addition of FYM in C-input improved association between modeled and measured values, and reduced simulation errors significantly. Low values of RMSE indicate the reliability of simulations and modeled data and can be used as a general indication of predictions of the effect of fertilizer management on soil C (Farina et al. 2013). Little overestimation of carbon sequestration by RothC model might be due to the fact that this study involved a triple cropping rather than a double cropping system (Bhattacharyya et al. 2007) and this model does not include the processes or mechanisms involved with anaerobic respiration during rice growing season (Wang et al. 2016). The simulation value indicates a minor modification in TOC content (0.7% to 2.6%) after the year 2017. The higher value of C management index (CMI) provided an integrated measure for quantity and quality of SOC over time including carbon rehabilitation in the soil (Blair, Lefroy, and Lisle 1995). Labile C plays an important role in the maintenance of physical fertility of soils and thus sustainability of the cropping system (Sodhi, Beri, and Benb 2009). Fertilizer management under "100%NPK+FYM" was found more appropriate to improve the SOC status than soils receiving inorganic fertilizers only.

Conclusions

The model RothC adequately simulated the change/loss in SOC storage in jute-rice based cropping systems on long-term basis fertilizer application in alluvial soils of humid region. The model successfully initialized and parameterized using our fertilizer management approach to predict SOC changes under different fertilizer management in jute-rice-wheat cropping systems. The result shows that fertilizer management systems, which include FYM along with roots, stubbles, and shredded jute leaves, have more capacity to recover the soil carbon. The initial SOC content had a large effect on the SOC recovery capacity. If the 100% NPK fertilizer along with manure applied with root-stubble retention of all crops, alluvial soils of such agro-ecosystem would act as a net C sink. As per this study, 1 ha of jute plants sequesters about 3.8 MT CO_2 in only 120 days. Through cultivation on about approximately 0.75 million hectare area, India may reduce about approximately 2.85 million tonnes of CO_2 from atmosphere every year. The CER revenue per hectare from jute cultivation can further benefit the jute growers. Inclusion of jute production system during the fallow period of summer can be a double win in the form of enhanced adaptation, increased mitigation and stability in the soil carbon sequestration. It can be concluded that the use of research-based recommendations for maintaining and/or increasing SOC stocks through judicious crop practices are crucial for all land use types. The use of standardized sampling and modeling techniques for different cropping system and adoption of SOC sequestration practices are necessary to mitigate climate change.

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Notes on contributors

A. K. Singh, Principal Scientist (Soil Science). Research interest in soil and water quality, soil fertility & plant nutrition, organic farming, environmental soil science and integrated farming system.

M. S. Behera, Principal Scientist (Agronomy). Research interest in fibre and medicinal plants and integrated farming system.

S. P. Mazumdar, Scientist (Soil Science). Research interest in soil chemistry, soil fertility and soil quality.

D. K. Kundu, Principal Scientist (Soil Science). Research interest in soil and water management, long term fertiliser trials.

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