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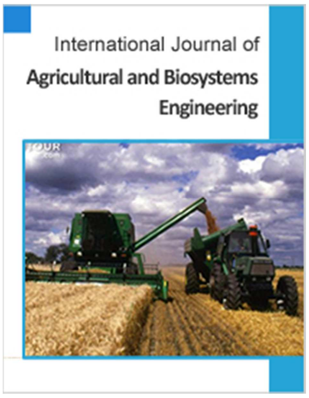

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Soil Carbon and Nitrogen Dynamics in Agricultural Soils of Mymensingh, Bangladesh

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Abstract
This study was conducted to evaluate the effect of land uses and soil management practices on the soil organic carbon (SOC) and soil total nitrogen (STN) in different agricultural soils of Mymensigh district located in northern Bangladesh 24°45′14″N 90°24′11″E. The land use types considered were cultivated (single, double and triple cropped), agroforestry, fallow land and grass land. 32 soil samples were collected covering above land use types. SOC and STN were significantly varied in different land use pattern and soil management practices. Among all land use pattern the highest SOC and STN were found under agroforestry and the lowest was found under fallow land. Cropping pattern also influenced the SOC accumulation in soil where rice-fallow-rice cropping pattern had highest SOC accumulation and lowest was found in rice-rice-rice cropping pattern. Organic carbon dynamics highly regulated by organic fertilizer application and tillage operation. The carbon to nitrogen (C: N) ratio was affected by land use systems and the ranges obtained 4.9 to 11.6. The C: N ratio was narrows in different agricultural land use pattern and higher in agroforestry system. The contents of total nitrogen was strongly associated (R^2 = 0.98) with total organic carbon and decreased consistently with increasing soil depth under all land use systems. The result of this study will help to develop future plan about land use and soil management regarding soil carbon and nitrogen dynamics for better economic returns with environmental protection.

1. Introduction

Soil plays an important role in global carbon (C) cycle as it contains around three times more C than in atmosphere and 3.8 times more C than in biotic pool [1]. It can be a source or a sink of atmospheric C depending upon land use and management [2]. Land use and vegetation cover type influence soil erosion and C dynamics in soil [3]. Land management with less soil disturbance increased higher SOC accumulation, while intensive disturbance decreased SOC accumulation. As a demand of food increased farmers practiced intensifying crop production. According to FAO [4] 89.8% of the total arable lands are used for rice cultivation throughout the year either single, double or triple cropping pattern in Bangladesh. Land intensification and land use change from native ecosystem to cultivated ecosystem causes loss of soil C. On the other hand, vegetation development on abandoned agricultural land enhances the C sequestration. Thus study of land use changes in field level is needed to determine the fate of C in the system.

SOC is greatly influence on soil properties and takes important role in agronomic production and environmental quality. C sequestrations help to mitigated global warming alleviated soil degradation and ensure sustainable agriculture production [3]. Land use change (LUC) has contributed to soil degradation and changes in both quantity and quality of SOC which enhanced C emissions to atmosphere [5-6]. Rotations and intercropping systems and improved cultural system like minimum tillage, improved crop residue management and organic farming contribute to conservation and elevation of SOC.

The store of nitrogen (N) found in the atmosphere, organic matter in soil and the oceans. Although atmosphere stored huge amount of N but it is considered the most important growth-limiting factor in crops for growth and development [7]. Prior to field application the soil available N level and crop requirement information is essential for improving fertilizer use efficiency and minimizing the adverse impacts on the environment. Over-application of nitrogenous fertilizer can result in N losses that affect surface and groundwater resources by leaching and runoff of nitrates [8] and also contribute to increasing threats of GHGs. Thus N management optimization is highly required for better agronomic performance as well as environmental protection.

SOC and soil total nitrogen (STN) dynamics varied with different agronomic practices like crop rotation, type and length of tillage operations and fertilizer application [9-10] and environmental factors, such as soil properties, topography, and climate [11]. The study of inter-relationship of land use and soil management with SOC and STN dynamics is quite important in recommending sound land management practices for better economic returns and to mitigate the impact of the climate change at the local to regional level. The interrelationship study can be utilized for prediction tools for SOC and STN management. Therefore, an understanding of possible differential effects of management practices on SOC and STN dynamics of different soil types and under different production areas is essential. Globally it was reported that the SOC content of arable land increased substantially resulting from proper irrigation, optimal fertilization, and an increase in crop productivity [12-13]. The land use change dynamics and its effect on C and N pool in ecosystem level are limited in this area. Therefore, a study was conducted in Mymensingh to evaluate soil organic carbon and soil total nitrogen in different agricultural field with various land uses and soil management practices.

2. Materials and Methods

2.1. Study Area

The location experiences a tropical monsoon-type climate, with a hot and rainy summer, and dry winter. Annual mean air temperature was 25.4°C and the highest mean temperature is reached in the month of April. Annual rainfall was 2055 mm where 70% of the annual rainfall is received during monsoon season (May to August) [14]. The relative humidity varies from 60-98% with some diurnal fluctuations in the various seasons with annual average of 56.8. The area lies within latitude 24°45′14″N and longitude 90°24′11″E of Bangladesh. The soil is darkgray non-calcareous floodplain) with a sandy loam and loam texture [15].

2.2. Soil Sampling and Analysis

Thirty-six soil samples were collected from twelve different lands covering cropped land, agroforestry, fallow land and grassland. Cropping pattern means the proportion of area under various crops at a point of time in a unit area. We found eight different cropping patterns namely Rice-sunhemp-rice; Rice-fallow-fallow; Rice-Jute-rice; Rice-rice-rice; Rice-aroid-fallow; Rice-fallow-rice; Rice-mustard-rice and Rice-vegetables. In Bangladesh there is three crops growing seasons in a year namely Rabi, pre-kharif and Kharif. In a unit crop land the number of cropping season observed is known as unit cropped land as for example in triple cropped land crop grown all three seasons in a year.

The soil sample was taken from the center of each quadrate by driving a core sampler up to 30 cm depth. Soil cores were sectioned into 0-10, 10-20 and 20-30 cm increments for 30 cm samples, then the soil was categorized as top soil (up to 10 cm) and sub soil (up to 30 cm). The soils were collected by an augur and kept in polythene bags so that they remain in field moist condition. Before collecting sample from particular field relevant information regarding fertilizer application and tillage practices was collected from the concern farmer of that field. After completion of collecting soil samples, the unwanted materials like stones, granules, plant parts, leaves, roots etc. were discarded from sample. The samples were dried at room temperature, crushed, mixed thoroughly and sieved with a 2 mm sieve. Composite samples were prepared by mixing the sieved soils and preserved in polythene.

Walkley and Black method as modified by Allison [16] was used to determine SOC. The procedure involved the oxidation of the soil organic matter with potassium dichromate ($K_2Cr_2O_7$) using concentrated sulphuric acid (H_2SO_4) and the percentage OC found by titrating with IN ferrous ammonium sulphate solution. The Kjeldahl method of Bremner [17] using $CuSO_4$-Na, SO_4 catalyst mixture was used to determine TN. All data were analyzed using SPSS statistical software version 16.0. Analysis of variance (ANOVA) was carried out using two-factor randomized complete plot design. Significant F-values were obtained; differences between individual means were tested using the LSD (Least Significant Difference) test.

3. Results and Discussion

3.1. Soil Carbon Dynamics in Different Land Use Pattern

There was significant difference in SOC in different land use pattern. In our study the highest SOC was found under agroforestry system (1.438%) and the lowest SOC was found under fallowland (0.124% for 20-30 cm). Cropland and grassland organic carbon were found respectively 0.63% and 0.39% for top soil respectively [Fig. 1]. It is well known that tree species strongly influence the forest floor in terms of C stock and chemistry, it also regulates annual C turn over. It was reported that the highest SOC stock found under forestland and the lowest under grassland [18]. Greater OM inputs in agroforestry systems contribute to the long-term storage of C in the soil [19]. Land use were all strong explanatory variables for differences in SOC, soil carbon stock, and total nitrogen [20]. It was observed that OC decreased when depth increased. Highest SOC was found for 0-10 cm depth in all land use types. It was reported that SOC contents decreased usually with increasing soil depth, with significant differences in different horizon [21]. Differences of SOC also found under different agricultural land use pattern where crop intensification showed lower SOC accumulation and higher SOC depletion. In case of agricultural cropped land single and double cropped land found significant similar SOC in the top soil but lower in other depth. Higher SOC was found in double cropped land and lower in triple cropped land [Fig. 2]. When soil used frequently for cultivation then more nutrient of soil used by the crop; intensify crop cultivation from cropland accelerate higher C loss than other ecosystem [22].

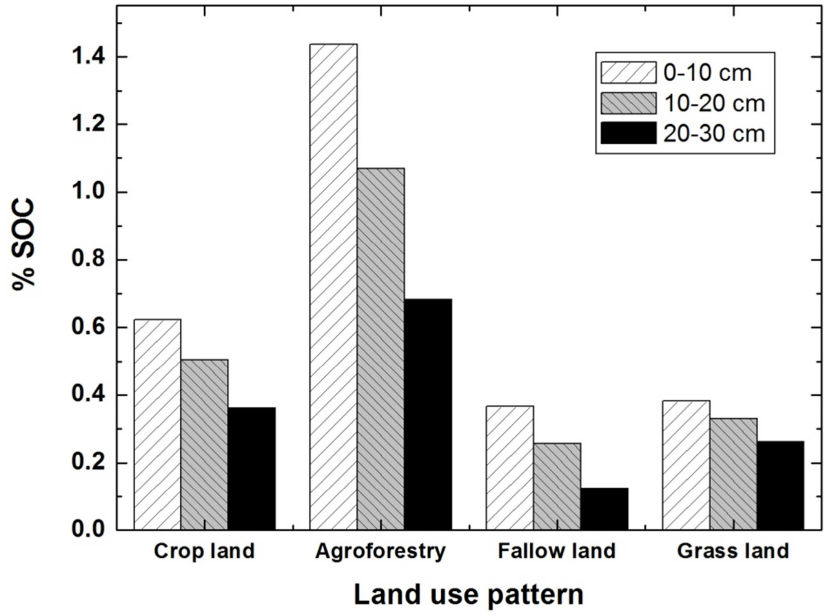

Fig. 1. *Amount of organic carbon in different land use pattern.*

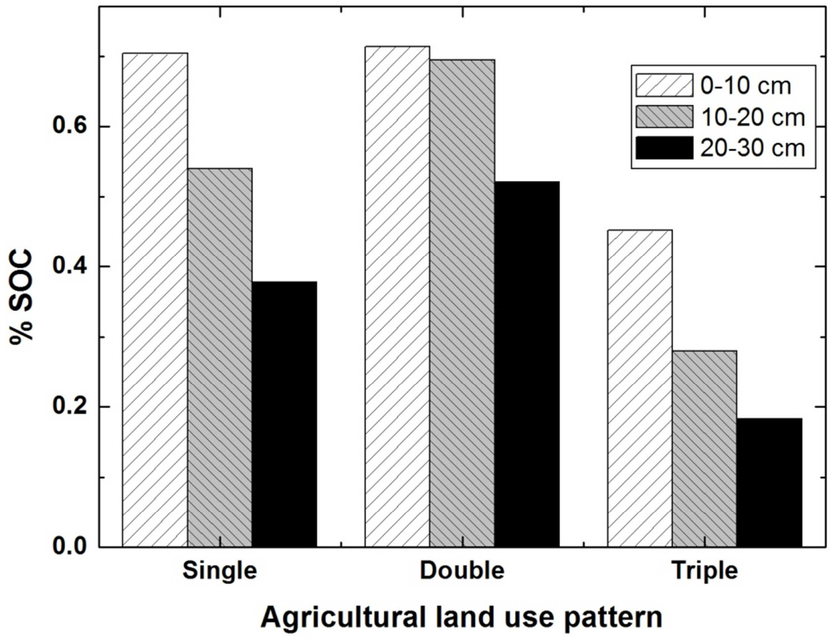

Fig. 2. *Amount of organic carbon in different agricultural land use pattern.*

3.2. Soil Carbon Dynamics in Different Cropping Pattern

The amount of OC stored in soil results from the net balance between the rate of SOC inputs and rate of mineralization in each of the OC pools. Cropping pattern has great impacts on SOC in soil. As soil management practices and crops morphology have differed in different cropping pattern it helps to develop or depleted SOC in various cropping pattern. In our study we found that rice-fallow-rice cropping pattern had highest SOC accumulation followed by rice –aroid-fallow and lowest was found in rice-rice-rice cropping pattern [Fig. 3]. Results revealed that crop intensify with same crop lead to SOC depletion where less intensify and different cropping scheme help to accumulated SOC in agricultural field. Although duration of cropping pattern is another factors, if farmers frequently change their cropping pattern then effect will be negligible.

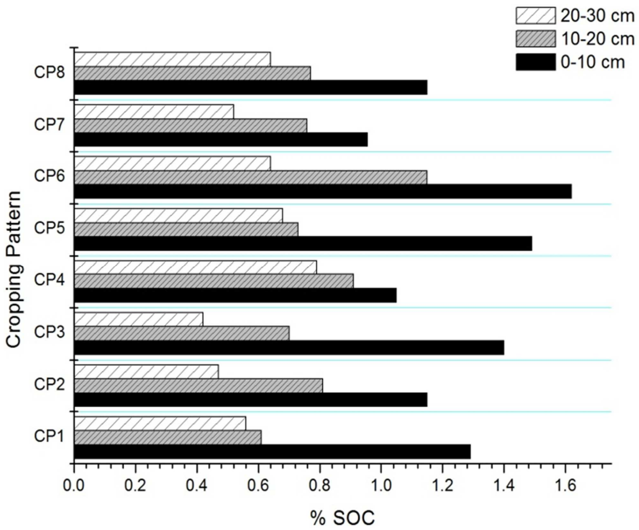

Fig. 3. *Soil organic carbon at different agricultural cropping pattern. (CP1: Rice-sunhemp-rice; CP2: Rice-fallow-fallow; CP3: Rice-Jute-rice; CP4: Rice-rice-rice; CP5: Rice-aroid-fallow; CP6: Rice-fallow-rice; CP7: Rice-mustard-rice and CP8: Rice-vegetables).*

3.3. Soil Carbon Dynamics with Soil Management Practices

The soil SOC accumulation was dependent on the use of various fertilizers. The highest SOC concentration was obtained where maximum organic fertilizer (mainly compost and cowdung) was used for crop production. From the figure 4 it was observed that accumulation of SOC was less when field provided less than 50% nutrient from inorganic fertilization and it was a linear increasing SOC up to 80% of organic fertilization. It was reported that sole application of inorganic fertilizer can cause decline in soil organic carbon [23]. The agricultural management practices had greater effects on SOC; a 30% increase in SOC with green manure cultivation [24]. Fertilizer application has the greatest role for determining soil organic carbon among the factors affecting soil carbon dynamics. Because any of other factors fertilizer application is the most direct factors which regulate carbon pool. Organic matter amendments have been proposed as a means to increase C storage in soils [25]; this can occur directly from the C inputs in the amendment and indirectly from increased plant production [26]. There was a distinct difference observed in SOC accumulation in different tillage system. When country plough used the amount of organic carbon for single cropping, double cropping and triple cropping were respectively 0.604%, 0.727%, and 0.340% on the other hand when power tiller used it was 0.477%, 0.560%, and 0.269% respectively. From the study it was observed that the highest amount of organic carbon was found when country plough used and the lowest amount of organic carbon was found when power tiller used (Table 1). Tillage, in addition to mixing and stirring of soil, breaks up aggregates and exposes organo-mineral surfaces otherwise inaccessible to decomposers. The greater C sequestration was observed for minimum tillage because of fewer disturbances of soil and slow decomposition of organic carbon. It was reported that a greater C sequestration was observed for minimum tillage because of fewer disturbances of soil and slow decomposition of organic carbon [27-29].

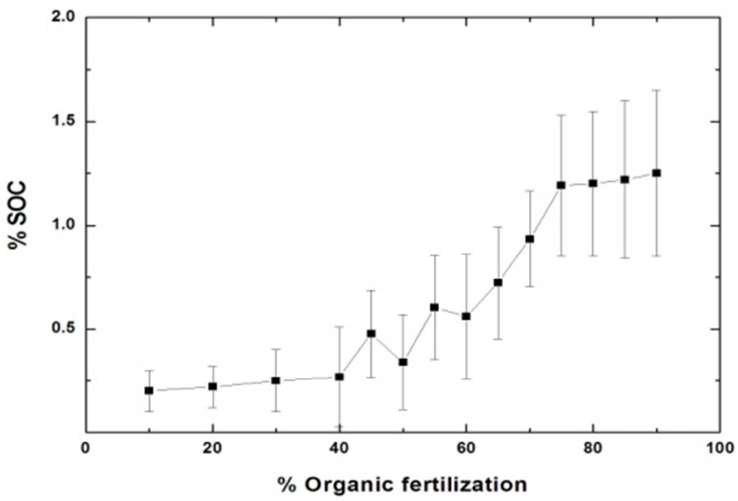

Fig. 4. *Soil organic carbon in relation to percent of organic fertilization. Bar represent standard errors.*

3.4. Soil Nitrogen Dynamics in Different Land Use Pattern

Similar to organic carbon, there were significant variations in total nitrogen among different land use. Total nitrogen increased in order of fallow land < grassland < cropped land < forestland at Mymensingh district. In our study the highest total nitrogen was found under forestland (0.17%) and the lowest organic carbon was found under fallowland (0.03% for 20-30 cm). Cropland and grassland Total-N were found 0.12% and 0.06% for top soil respectively [Fig. 5]. Cotching et al. [20] also found the variation of soil N with different land use pattern. It was observed that total nitrogen decreased when depth increased. Highest total nitrogen found for 0-10 cm depth in all land use types. Generally, cultivated soils had significantly lower total N at all depths when compared to forestlands, indicating that continuous cultivation ultimately reduces the total nitrogen contents in the soil. Differences of total nitrogen were also found under different agricultural land use pattern where crop intensification showed lower total nitrogen accumulation and higher total nitrogen depletion. In case of agricultural cropped land higher total nitrogen was found in double cropped land and lower in triple cropped land [Fig. 6]. Here also highest total nitrogen content found for top soil in all land use types. The decrease in total nitrogen with increasing depth was due to declining humus with depth. As per fertility ranking, nitrogen status in the top soils were low, while the average status in 0-30 cm soil depths were very low [30]. However, all the soil associations showed an increasing trend in both SOC and TN contents with no-tillage compared with chisel plowing at the 0–15 cm soil depth. [31].

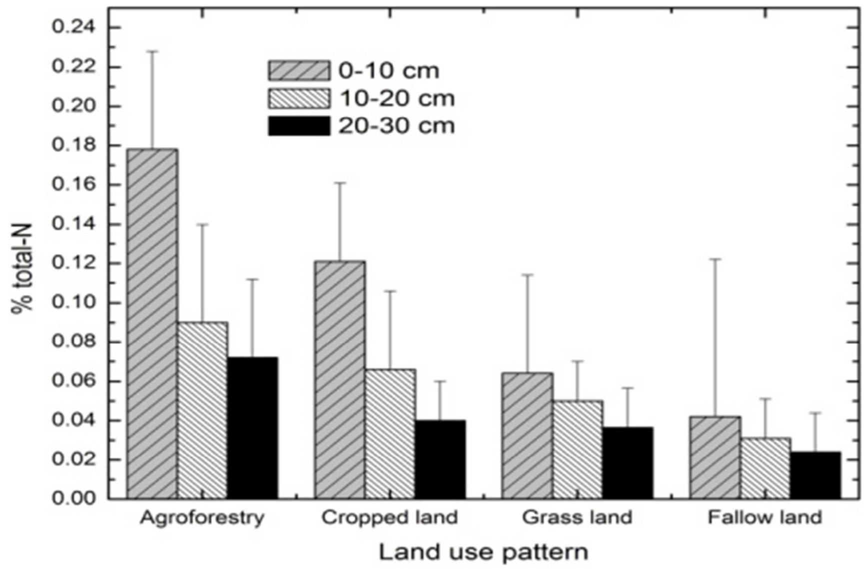

Fig. 5. Amount of total nitrogen in different land use pattern.

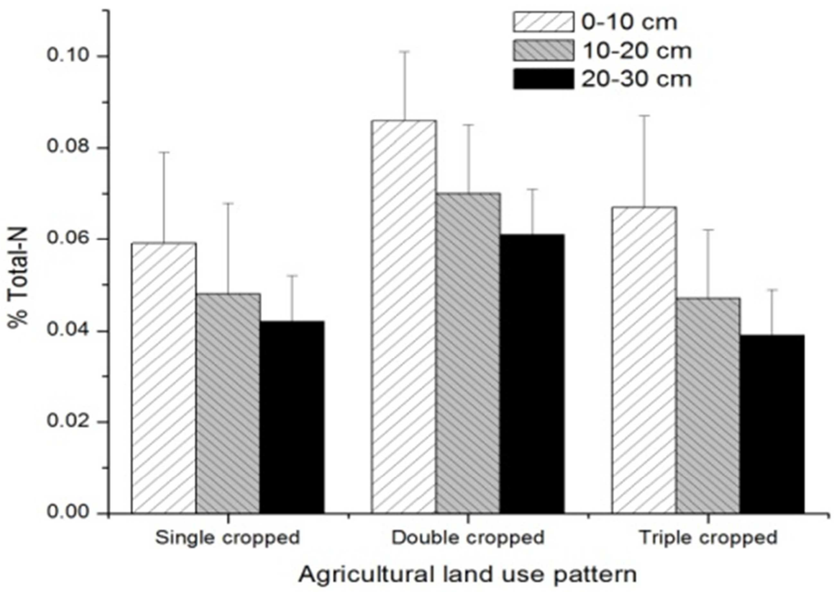

Fig. 6. Amount of total nitrogen in different agricultural land use pattern.

Table 1. *Difference of organic carbon for using country plough and power tiller.*

land use pattern	Amount of organic C (%) for using country plough		Amount of organic C (%) for using power tiller	
	Depth (cm)	Organic C (%)	Depth (cm)	Organic C (%)
Single cropping	0-10	0.733b	0-10	0.675a
	10-20	0.617c	10-20	0.463c
	20-30	0.463d	20-30	0.293d
Double cropping	0-10	0.849a	0-10	0.579b
	10-20	0.830a	10-20	0.560b
	20-30	0.501d	20-30	0.540b
Triple cropping	0-10	0.405e	0-10	0.498c
	10-20	0.366f	10-20	0.193e
	20-30	0.250g	20-30	0.115e

Letters indicate statistically significant differences in SOC affected by the different tillage in different crop intensities (p=0.05).

3.5. The Relationship Between SOC and STN

In this study the carbon to nitrogen (C: N) ratio was affected by land use systems (Table 2). Moreover, the ratio was narrower in soils of cultivated lands as compared to agroforestry indicating that mineralization and oxidation of organic matter is higher in cultivated soils. C: N ratio was narrows in different agricultural land use pattern as the loss of N is high than the loss of C due to cultivation, the Such differences in C: N ratios among land use systems may also reflect variations in qualities of organic residues entering the soil organic matter pool and could be attributed to contrasting vegetation covers. Brady and Weil [32] showed that C: N ratios varied between 8:1 and 15:1, with an average of 12:1. Farming techniques and agricultural management affected C: N ratios [33].

Table 2. *C: N ratio at different land use and cropping intensity.*

Land use type	C-N ratio
Single cropped	9.1
Double cropped	9.0
Triple cropped	6.14
Agroforestry	11.6
Grassland	6.80
Fallow land	4.88

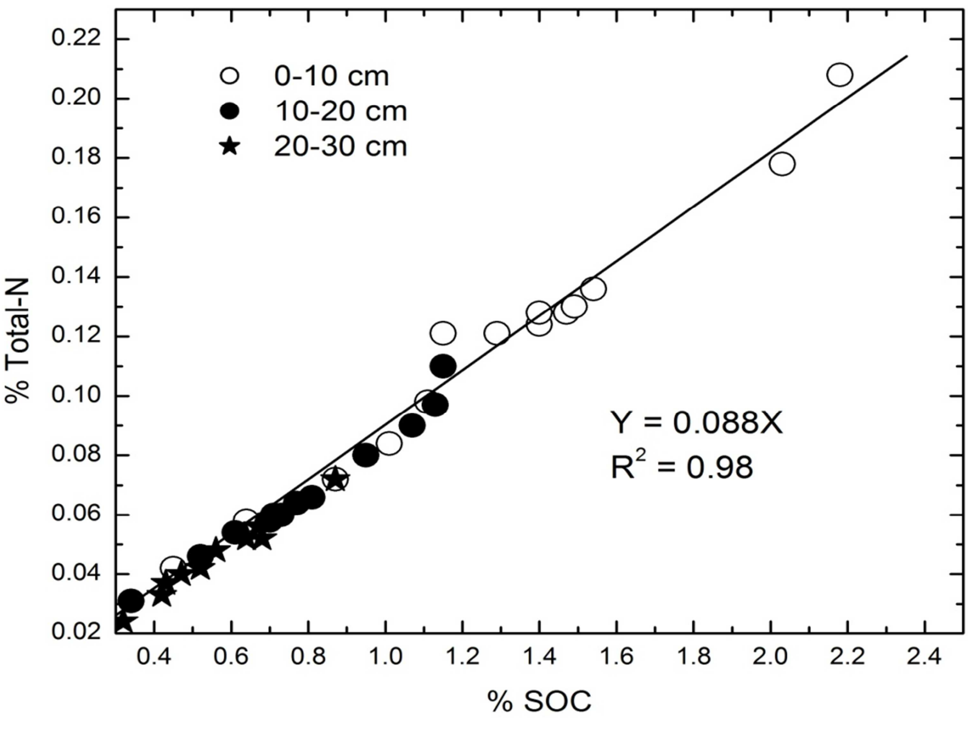

Fig. 7. *Relationship between SOC and STN at different soil depth.*

The contents of total nitrogen was strongly associated (R^2 = 0.98) with total organic carbon and decreased consistently with increasing soil depth under all land use systems [Fig. 7].

Pools of SOC and total nitrogen were strongly correlated with each other at 0-10, 10-20 and 20-30 cm depths. The equations for the regression at the three depths were STN= 0.089 * (SOC) -0.002, R^2 = 0.97, P = 0.0001; STN = 0.091 * (SOC) -0.001, R^2 = 0.974, P = 0.0001 and STN = 0.083 * (SOC) -0.000, R^2 = 0.985, P = 0.0001 for at 0-10, 10-20 and 20-30 cm depths respectively. STN pools were positively correlated with SOC pools. It was concluded that losses of STN and SOC were concomitant and losses were in proportional.

Liu [34] stated that the soil carbon and nitrogen circulation and the atmospheric greenhouse gas concentrations in terrestrial ecosystems are closely related to carbon, and nitrogen fixation, and their accumulation in terrestrial ecosystems reduces the concentration of greenhouse gases. In forest ecosystems, soil nitrogen availability influences SOC storage through plant growth and litter quantity by the process of soil carbon decomposition [35].

4. Conclusions

Changes in SOC stocks are directly related to atmospheric C concentration. Agricultural management practices that increase SOC stocks thus may have profound effects on climate mitigation. Most agricultural soils in the study area contain below their potential level of SOC where triple cropped area contained extremely lower level. The highest organic carbon was found under agroforestry and the lowest organic carbon was found under fallow land. Organic carbon dynamics highly regulated by organic fertilizer application. Soil organic matter contents in farmlands have influenced by changes in land use intensity and soil management effects. Conventional tillage leads to significant increase of the soil organic matter content. Soil total nitrogen followed the similar results of soil organic carbon found higher in agroforestry system and lower in fallow land. Soil organic carbon contents decreased usually with increasing soil depth. Highest organic carbon found for 0-10 cm depth and lowest organic carbon found for 20-30 cm depth. C: N ratio found ranged from 4.9 to 11.6 and total nitrogen was strongly associated (R^2 = 0.98) with total organic carbon. This study showed clearly that land use change and land management have direct influence SOC and STN accumulation in soil. Therefore understanding and implementation of carbon and nitrogen balance in agriculture will help to maintain climate change mitigation and environmental protection from agriculture.

Authors' Contributions

This research was carried out in collaboration between authors. The idea was designated by author MSH. Author MNI conducted the field and lab work. Author MAB performed the statistical analysis. All authors contributed to manuscript writing and formatting. All authors read and approved the final manuscript.

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References

[1] Zomer R, Ustin S, and Ives J. Using satellite remote sensing for DEM extraction in complex mountainous terrain: landscape analysis of the Makalu Barun National Park of Eastern Nepal. Int. J. Remote Sensing, 2002; 23 (1): 125-143.

[2] R. Lal. Offsetting global CO_2 emissions by restoration of degraded soils and intensification of world agriculture and forestry. Land Degrad. & Develop., 2003; 14 (3): 309-322.

[3] Swift RS. Sequestration of carbon by soil. Soil Sci., 2001; 166 (11): 858-871.

[4] FAO. Water Profile of Bangladesh. Irrigation in Southern and Eastern Asia in figures – AQUASTAT Survey – 2011.

[5] Watson RT, Noble IR, Bolin B, Ravindranath NH, Verardo DJ, and Dokken DJ.. *Land use, land-use change, and forestry*. A special report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 2000.

[6] Ogle SM, Breidt FJ, and Paustian K. Agricultural management impacts on soil organic carbon storage under moist and dry climatic conditions of temperate and tropical regions. Biogeochem., 2005; 72: 87-121.

[7] Zebarth BJ, Dury CF, Tremlay N, and AN Cambouris. Opportunities for improved fertilizer nitrogen management in production of arable crops in eastern Canada: A review. Can. J. Soil Sci., 2009; 89 (2): 113–132.

[8] Fageria NK, and VC Baligar. Enhancing nitrogen use efficiency in crop plants. Adv. Agron., 2005; 88: 97–185.

[9] Cambardella CA, and ET Elliot.. Particulate Soil Organic matter changes across a grassland cultivation sequence. Soil Sci. Soc. Am. J., 1992; 56: 777-783.

[10] Christensen BT. Effects of animal manure and mineral fertilizer on the total carbon and nitrogen contents of soil size fractions. Biol. Fertil. Soils, 1988; 5: 304-307.

[11] Campbell CA, Biederbeck VO, McConkey BG, Curtin D, Zenter RP. Soil quality-effect of tillage and follow frequency. Soil organic matter quality as influenced by tillage and fallow frequency in a silt loam in southwestern Saskatchewan. Soil Biol. Biochem., 1999; 31 (1): 1–7.

[12] Benbi DK, and Brar JS. A 25-year record of carbon sequestration and soil properties in intensive agriculture, Agr. Sustain. Develop., 2009, 29: 257–265.

[13] Reijneveld A., van Wensem J, and Oenema O. Soil organic carbon contents of agricultural land in the Netherlands between 1984 and 2004, Geoderma, 2009, 152: 231–238.

[14] Hossen MS, Mano M, Miyata A, Baten A, and Hiyama T. Surface energy partitioning and evapotranspiration over a double-cropping paddy field in Bangladesh. Hydrol. Proces, 2012, 26: 1311–1320.

[15] UNDP and FAO. Land Resources Appraisal of Bangladesh of Agricultural Development. Report No. 2. Agro-ecological regions of Bangladesh. United Nations Development Programme and Food andAgriculture Organization. 1988 Pp. 212–221.

[16] Allison LE. Organic carbon. In: C. A. Black *et al*; (Eds). Method of Soil Analysis Part 1. m. Soc. Agron., 1965; 9: 1367-1378.

[17] Bremner JM. Total Nitrogen. In: C. A. Black *et al*; (Eds). Methods of Soil Analysis Part 1. Am. Soc. Agron., 1965; 9: 1149-1178.

[18] Manojlovic M, Cabilovski R, and Sitaula B. Soil organic carbon in Serbian mountain soils: effects of land use and altitude. Polish J. of Environ. Stud., 2011; 20 (4): 977-986.

[19] Oelbermann M, and Voroney RP. An evaluation of the century model to predict soil organic carbon: examples from Costa Rica and Canada. Agroforestry Systems., 2011; 82 (1): 37-50.

[20] Cotching WE, Oliver G, Downie M, Corkrey R, and Doyle RB. Land use and management influences on surface soil organic carbon in Tasmania. Soil Research, 2013, 51: 615–630.

[21] Wang ZP, Han XG, and Li LH. Effects of grassland conversion to croplands on soil organic carbon in the temperate Inner Mongolia. J. Environ. Man., 2008, 86 (3): 529–534.

[22] Roose E, and Barthes B. Organic matter management for soilconservation and productivity restoration in Africa: a contribution from francophone research. Nutr. Cycl. agroecosys, 2001; 61: 159–170.

[23] Pichot J, Sedogo MP, Poulain JF, and Arrivets J. Evolution de lafertilite´ d'un sol ferrugineux tropical sous l'influence de fumuresminérales et organiques. Agronomie Tropicale, 1981; 36 (2): 122–133.

[24] Genxing P, and Futian Q. Effect of household land management in constraining soil organic carbon storage at plot scale in a red earth soil area of South China. Institute of Resource, Ecosystem and Environment of Agriculture, Nanjing Agricultural University, 1 Weigang, Nanjing 210095, China. 2001.

[25] Powlson DS, Bhogal A, Chambers BJ, Coleman K, Macdonald AJ, Goulding KWT and Whitmore AP. The potential to increase soil carbon stocks through reduced tillage or organic material additions in England and Wales: a case study. Agric. Ecosyst. Environ., 2012, 146: 23-33.

[26] Ryals R and Silver WL. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands. Ecol. Appl., 2013, 23: 46-69.

[27] Phillips RE, Blevins RL, Thomas GW, Frye WW and Phillips SH. No-tillage agriculture. Science, 1980; 208: 1108–1113.

[28] Lal R, Follet RF, Stewart BA, and Kimble JM. Soil carbon sequestration to mitigate climate change and advance food security. Soil Sci., 2007; 172 (12): 943–956.

[29] Morell, F. J., Cantero-Martínez, C., Lampurlanés, J., Plaza-Bonilla, D., Álvaro- Fuentes, J. Soil Carbon Dioxide Flux and Organic Carbon Content: Effects of Tillage and Nitrogen Fertilization. Soil Sci. Soc. Am. J. 2011, 75: 1874–1884.

[30] BARC (Bangladesh Agricultural Research Council). Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council (BARC). Soil Publication No. 45. Farm Gate, Dhaka 1215, Bangladesh, 2005. 260 p.

[31] Mahdi MA, Yin X, Licht MA. Soil carbon and nitrogen changes as influenced by tillage and cropping systems in some Iowa soils. Agric, Ecosyst. Environ., 2005; 105 (4): 635–647.

[32] Brady C, and Weil RR. The nature and properties of soils. 14th ed. Pearson Prentice hall. Upper Saddle River, New Jersey Columbus, Ohio, USA, 2008.965 pp.

[33] Yimer F, Ledin S and Abdelkadir A. Changes in soil organic carbon and total nitrogen contents in three adjacent land use types in the Bale Mountains, southeastern highlands of Ethiopia. Fores. Ecol. Manage., 2007; 242: 337–342.

[34] Liu M, Yu WT, Jiang ZS, Ma Q. Soil labile organic carbon. Chinese J of Ecol., 2006; 25 (11): 1412–1417.

[35] Nave LE, Vance ED, Swanston CW, Curtis PS. Impacts of elevated N inputs on north temperate forest soil C storage, C/N, and net N-mineralization. Geoderma, 2009; 153: 231–240.