



INFLUENCE OF SOIL TEXTURE AND LAND USE PRACTICES ON AGGREGATE STABILITY AND SOIL ORGANIC CARBON STOCKS

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Abstract: This study was carried out in different agricultural plots situated in Dumuria, Botiaghata, Bagerhat, Pirojpur, Rajapur and Tala under South-Western part of Bangladesh during 2010. The Fallow-Fallow-T.aman cropping pattern shows the highest normalized stability index (0.92) and lowest value (0.25) was found in Shrimp-T.aman cropping pattern. The index varies according to soil texture these are in silty clay loam, silt loam and loam and clay soils. The index values were 0.92, 0.61 and 0.69, respectively. The lower NSI values in different textures (0.25, 0.43 and 0.47) were found under Shrimp-T.aman, Fallow-Fallow-T.aman and Fallow-Jute-T.aman cropping pattern respectively. Soils in Fallow-Fallow-T.aman cropping pattern had higher NSI value. This is presumably in reverse of cultivating intensity such as tillage, causing aggregate breakdown. Aggregate stability of fallow soils with few sample area, however, was lower than crop-cultivated soil. This indicated that the cultivation of soil could enhance soil aggregation. The higher organic carbon content was found in silty clay loam soils where the aggregate size ranges from 8-2, 2-0.25 and 0.25-0.05 mm. Lower organic carbon content was found in loam soils. Higher SOC content was found in aggregates of 2-0.25 mm size. It may be concluded that macro-aggregate formations have contribution the storage of organic carbon in soils. Soils in Fallow-Sweet gourd-T.aman cropping pattern had the highest SOC in different aggregates.

Keywords: Aggregate stability, soil texture, soil organic carbon content, land use practices

Introduction

It is well known that substantial soil organic carbon (SOC) losses occur from cultivated agricultural soils and that SOC levels are controlled by soil aggregation and texture. In general, levels of SOC increase as soil texture becomes finer. The rice (*Oryza sativa* L.) has emerged as a major production system in the South-Western region of Bangladesh. Under this system, wetland rice culture destroys soil aggregates and released organic matter mineralizes readily in the aerobic phase of the rotation leading to severely depleted soil carbon contents. In recent years, conservation and retention of terrestrial carbon has been highlighted by the necessity to mitigate an increase in atmospheric carbon, as well as by enhancing soil functions supporting ecosystem. Soil aggregation is the main process whereby organic matter is retained in soil, depending on organics supply such as plant residues from vegetation. Climate and soil type can strongly influence both the degree of soil aggregation and organic matter storage in soil. Especially, temperature and precipitation control plant productivity and the subsequent accumulation and decomposition of organic matter. Soil parent material and mineralogical differences can also influence the level of potential soil aggregation and consequently the degree of soil organic carbon. Land use and management, within a climatic or soil zone, can also impact on soil structure formation and storage of organic matter (Carter, 2002).

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Aggregation processes across different scales give us the understanding for the sequestration mechanism of organic carbon in soil aggregates. At the atomic or molecular level, charged colloid surface, organic molecule, cation, and water molecules bridge each other and flocculate. At the microscopic level, clay and organic matter act as bridges between the sand and silt particles, producing microaggregates of soil (McLaren and Cameron, 1996). The soil microaggregates are bound together into macroaggregates by fungal hyphae, plant roots and other stabilizing agents at macroscopic level (Oades, 1984). Tisdall and Oades (1982) proposed the boundary between microaggregate and macroaggregate be 0.25 mm of aggregate diameter. Carter and Gregorich (1996) reported that the turnover time of organic matter in aggregate could be much longer than that of litter remained without aggregation. Organic carbon in intra-microaggregate has longer turnover time than that in inter-microaggregate, which can be characterized by both relatively short-term storage in macroaggregates or long-term sequestration in microaggregates. In other words, organic matter or fractions thereof are basic to the aggregation process, and consequently organic matter sequestered within aggregates is protected against degradation (Carter and Gregorich, 1996).

Aggregates resulted from the above various processes and cementing agents, however, could be broken down during natural and artificial stresses such as erosion and tillage and subsequently organic matter sequestered in them can be decomposed. Actually, macroaggregates have their own life cycles (Denef *et al.*, 2001; Six *et al.*, 2004), repeating formation-breakdown, depending on biological activity and fresh residue inputs (Bidisha *et al.*, 2010). Nevertheless, artificial stress of various management practices including tillage and traffic with agricultural machines, as well as natural stress such as rainfall, could accelerate aggregate breakdown and inhibit aggregate formation (Bronick and Lal, 2005). Especially, aggregate stability against water is important in region under monsoon climate because aggregate break down processes including slaking is largely dependent on its water stability. Many researchers reported that water stable aggregate is one of the standard features of soil quality, sensitive to land management practices, as well as relating to erosion, carbon dynamics, and material transport (Kay, 1989).

Temporal and spatial heterogeneity and complexity in soil continuum make it difficult directly to measure the aggregation and carbon storage in soil (Bronick and Lal, 2005). Stability test of soil aggregate is an indirect and discrete method for estimating aggregation, which could give us a simple and fast answer for understanding the management effect on aggregation and carbon storage. The goal of this study was to assess the influence of soil texture on aggregate stability and carbon stocks of soils under different land management practices to provide a perspective on the potential for carbon sequestration in agricultural soils.

Materials and methods

Top soil (0-6 cm) samples were collected from different locations of agricultural fields under different cropping pattern and conventional tillage practices (Table 1) in the Ganges Meander and Ganges Tidal Floodplains. Soil samples were collected on the basis of composite sampling method as suggested by the Soil Survey Staff of the USDA (1951) and then processed for subsequent analyses.

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Table 1: Description of sampling sites

Sample	GPS	Soil Series	Physiography	Location	Land use	Land type
1	22°47'48.5" N 89°27'02.9" E	Bajoa	Ganges Tidal Floodplain	Dumuria, Khulna	Til-Fallow- T.aman	Medium High Land
2	22°48'36.9" N 89°20'04.7" E	Dumuria	Ganges Tidal Floodplain	Dumuria, Khulna	Fallow- Fallow- T.aman	Medium High Land
3	22°46'49.6 "N 89°20'03.6 "E	Dumuria	Ganges Tidal Floodplain	Dumuria, Khulna	Shrimp- T.aman	Medium High Land
4	22°46'55.8 "N 89°33'05.1 "E	Bajoa	Ganges Tidal Floodplain	Botiaghata, Khulna	Fallow-sweet gourd-T.aman	Medium High Land
5	22°46'56.4 "N 89°33'05.2 "E	Bajoa	Ganges Tidal Floodplain	Botiaghata, Khulna	Fallow- Fallow- T.aman	Medium High Land
6	22°41'56.1 "N 89°42'25.6 "E	Garuri	Ganges Meander Floodplain	Bagerhat Sadar, Bagerhat	Boro-Fallow- T.aman	Medium High Land
7	22°35'01.7 "N 90°01'14.5 "E	Bajoa	Ganges Tidal Floodplain	Pirojpur Sadar, Pirojpur	Fallow- Fallow- T.aman	Medium High Land
8	22°34'39.7 "N 90°06'15.2 "E	Jhalokathi	Ganges Tidal Floodplain	Rajapur, Jhalokati	Fallow- Fallow- T.aman	Medium High Land
9	22°48'37.5 N 89°22'07.9 E	Sara	Ganges Meander Floodplain	Dumuria, Khulna	Jute-Fallow- Veg	High Land
10	22°42'44.0 "N 89°41'04.6 "E	Gopalpur	Ganges Meander Floodplain	Bagerhat Sadar, Bagerhat	Fallow- Fallow- T.aman	Medium High Land
11	22°33'36.3 "N 89°57'37.4 "E	Ramgati	Ganges Tidal Floodplain	Morelgonj, Bagerhat	Fallow- Fallow- T.aman	Medium High Land
12	22°48'54.4 "N 89°15'25.6 "E	Darshana	Ganges Meander Floodplain	Dumuria, Khulna	Fallow-Jute- T.aman	High Land
13	22°45'51.5 "N 89°08'20.6 "E	Pirojpur	Ganges Tidal Floodplain	Tala, Satkhira	Boro-Shrimp	Low Land

Particle size analysis was carried out by combination of sieving and hydrometer method (Gee and Bauder, 1986). Textural class was determined by Marshall's Triangular co-ordinate system. Soil structure was evaluated by microaggregate analysis of the soils following the method of Kachinskii (1965). The state of aggregation, degree of aggregation and dispersion factor was determined by using the following equations (Baver and Rhoades, 1932).

State of aggregation = $a - b$

Degree of aggregation = $\frac{a - b}{100 - b} \times 100$; Dispersion factor = $\frac{x}{y} \times 100$

Where, a = percentage of aggregates larger than a specified size in microaggregate analysis, b = percentage of particles larger than a specified size in particle size analysis, x = percentage of clay in microaggregate analysis and y = percentage of clay in particle size analysis.

For determination of soil organic carbon (SOC) associated with soil aggregates of 8-2 mm, 2-0.25 mm and 0.25-0.05 mm size ranges were kept submerged with distilled water for 5 minutes and then separated manually by moving the sieve 3 cm up and down under water with 50 repetitions during a period of 2 minutes. Soil samples of these three fractions were then oven dried at 70°C for 24 hours. The carbon content of each size fractions were determined by the method as described by Tyrin (1936).

For determination of aggregate stability, soils were divided into 8-2 mm, 2-0.25 mm and 0.25-0.05 mm size fractions by using mechanical shaker. For wet sieving with slaking pretreatment 10 g air dry soil samples from each aggregate size fraction were submerged for 5 minutes and then separated manually by moving the sieve 3 cm up and down under water with 50 repetitions during a period of 2 minutes. For wet sieving with wetted pretreatment the air dried samples were adjusted to field capacity by soaking with water for overnight before submerging in water. The soils were then sieved for 2 minutes by the method as stated before. Soil samples of these three fractions were then oven dried at 105°C for 24 hours. Primary particles retained on the sieves were determined by sieving and then oven dried at 105°C for 24 hours. The normalized stability index (NSI) of aggregates was calculated by the formula as described by Six *et al.* 2000.

$$NSI = 1 - [DL/DL \text{ (max)}]$$

The whole soil disruption level (DL) was calculated as:

$$DL = 1/n \sum_i^n [(n+1) - i] \times DLS_i$$

Where n = number of aggregate size classes. $i = 1$ for the smallest size class.

The disruption level of a size class upon slaking (DLS_i) was calculated by the following formula:

$$DLS_i = \frac{\left[\frac{\{(P_{io} - S_{io}) - (P_i - S_i)\} + |(P_{io} - S_{io}) - (P_i - S_i)|}{2} \right]}{[P_{io} - S_{io}]}$$

where DLS_i = disruption level for each size class i ; P_{io} = proportion of total sample weight in size class i before disruption (i.e., rewetted); P_i = proportion of total sample weight in size class i after disruption (i.e., slaked); S_{io} = proportion of sand with size i in aggregates of size i (= aggregate-sized sand) before disruption; S_i = proportion of sand with size i in aggregates of size i after disruption.

The whole soil DL (max) was calculated by the following formula:

$$DL \text{ (max)} = 1/n \sum_i^n [(n+1) - i] \times DLS_{i \text{ (max)}}$$

The maximum disruption [DLS_i (max)] was calculated with the following formula:

$$DLS_{i \text{ (max)}} = \frac{\left[\frac{(P_{io} - P_p) + |(P_{io} - P_p)|}{2} \right]}{[P_{io} - S_{io}]}$$

P_p = primary sand particle content with the same size as the aggregates size class after complete disruption of the whole soil.

Results

Soil organic carbon (SOC) associated with aggregates: For the study thirteen locations were selected which were different each other in both of texture and land use practices, which could determine the amount of organic carbon in soil aggregates. Table 2 shows the average values of soil organic carbon content in different aggregates for each land use types. Soil organic carbon content was highest in Fallow-Sweet gourd-T.aman cropping pattern (sampling site 4), and decreased in Jute-Fallow-Vegetables, Fallow-Jute-T.aman and Boro-Shrimp cropping pattern. Soil organic carbon associated with aggregates had higher value in silty clay loam soils than others (Table 2).

Table 2: Normalized Stability Index (NSI) and soil organic carbon (%SOC) associated with the aggregates of different size range in different texture under different land use practices.

Soil series	Sampling sites	Cropping pattern	NSI	% SOC associated with the aggregates of different size range (mm)		
				8-2	2-0.25	0.25-0.05
Bajoa	1	Till-Fallow-T.aman	0.43	1.98	2.77	2.66
Dumuria	2	Fallow-Fallow-T.aman	0.67	2.22	2.39	2.30
Dumuria	3	Shrimp-T.aman	0.25	1.28	2.20	1.40
Bajoa	4	Fallow-Sweet gourd-T.aman	0.87	2.37	2.70	3.16
Bajoa	5	Fallow-Fallow-T.aman	0.65	1.68	2.56	2.20
Garuri	6	Boro-Fallow-T.aman	0.43	2.17	2.49	1.93
Bajoa	7	Fallow-Fallow-T.aman	0.67	1.41	1.73	1.71
Jhalokathi	8	Fallow-Fallow-T.aman	0.92	1.98	2.46	1.89
Sara	9	Jute-Fallow-Veg.	0.45	1.19	1.65	1.05
Gopalpur	10	Fallow-Fallow-T.aman	0.43	0.95	2.51	1.97
Ramgati	11	Fallow-Fallow-T.aman	0.61	1.35	1.74	1.83
Darshana	12	Fallow-Jute-T.aman	0.47	1.14	1.98	0.59
Pirojpur	13	Boro-Shrimp	0.69	1.26	1.45	1.90

Soils under Jute-Fallow-Vegetables, Fallow-Jute-T.aman and Boro-Shrimp cropping pattern had lower organic carbon content than soils under Fallow-Fallow-T.aman cropping pattern. This is probably due to grazing by animals or periodic removal of residues for feeding livestock.

Soil organic carbon content of Fallow-Fallow-T.aman cropping pattern with few sample area, however, was lower than others cropping pattern (Table 2). This indicated that the cultivation of soil could enhance soil aggregation.

Normalized stability index (NSI): It has been reported that stable macro-aggregate of tilled soils is lower than that of no-tilled soils (Pagliai *et al.*, 2004) due to aggregate breakdown in tillage process. The NSI value varied between 0.25 and 0.92 in study area (Table 2). The highest NSI was found 0.92 under Fallow-Fallow-T.aman cropping pattern in Silty clay loam soils and the lowest was 0.25 under Shrimp-T.aman cropping pattern in Silty clay loam soils. **Particle size distribution:** The percentage of silt was the highest under Fallow-Fallow-T.aman cropping pattern

and was the lowest under Boro-Shrimp cropping pattern whereas clay was the highest under Boro-Shrimp and was the lowest under Jute-Fallow-Vegetable cropping pattern. The percentage of silt and clay ranged from 36.37-59.54% and 14.12-49.84%, respectively (Table 3). The percentage of sand was the highest under Fallow-Jute-T.aman cropping patterns and the lowest under Shrimp-T.aman cropping pattern.

Degree and State of Aggregation: The highest degree and state of aggregation was found 26.67 and 20.00%, respectively under Fallow-Fallow-T.aman pattern and the lowest was zero under Fallow-Sweet gourd-T.aman cropping pattern (Table 3). Silt loam soils had the highest degree and state of aggregation whereas silty clay loam soils had the lowest degree and state of aggregation.

Table 03: Percentage of sand, silt, clay, SA, DA and DF in different texture under different management practices.

Soil series	Cropping pattern	%Sand	%Silt	%Clay	Texture	%SA	%DA	DF
Bajoa	Til-Fallow T.aman	14.19	55.07	30.74		3.81	4.44	0.00
Dumuria	Fallow-Fallow-T.aman	16.04	50.38	33.58		8.96	10.67	0.00
Dumuria	Shrimp-T.aman	13.25	51.40	35.35		2.75	3.17	0.00
Bajoa	Fallow-Sweet gourd-T.aman	20.00	46.74	33.26	Silty clay loam	0.00	0.00	30.07
Bajoa	Fallow-Fallow-T.aman	19.00	49.50	31.50		1.00	1.23	33.33
Garuri	Boro-Fallow-T.aman	16.60	47.08	36.32		4.40	5.28	0.00
Bajoa	Fallow-Fallow-T.aman	13.28	59.54	27.18		0.72	0.83	40.47
Jhalokathi	Fallow-Fallow-T.aman	15.12	48.32	36.56		9.88	11.64	0.00
Sara	Jute-Fallow-Vegetable	30.45	55.41	14.14		0.55	0.79	0.00
Gopalpur	Fallow-Fallow-T.aman	25.00	55.58	19.42	Silt loam	20.00	26.67	0.00
Ramgati	Fallow-Fallow-T.aman	21.50	57.56	20.94		3.50	4.46	0.00
Darshana	Fallow-Jute-T.aman	48.00	37.86	14.14	Loam	3.00	5.77	14.14
Pirojpur	Boro-Shrimp	13.79	36.37	49.84	Clay	16.21	18.80	0.00

Dispersion factor: The dispersion factor of soils under different cropping patterns varied from 0 to 40.47%. The dispersion factor was the highest under Fallow-Fallow-T.aman cropping pattern and the lowest value was found under different cropping patterns (Table 3).

Discussion

High lands, Medium high lands and low lands are commonly named as cropland with annually disturbed by human and agromachines. High cropping intensity under conventional cultivation commonly has a decrease in organic carbon content, because the amount of organic material returned to the soils is considerably lower and tillage enhance the decomposition of native soil organic matter (Dalal and Bridge, 1996). Paddy soils with periodic submergence were slightly higher in organic carbon content than upland soils.

In general, fine-textured soils maintain higher levels of SOC than coarse-textured soils. The percentages of SOC associated with different aggregates were the highest under Silty clay loam

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soils (Table 2) and were the lowest under Loam soils. Gami *et al.* (2006) reported that increases in SOC with increasing silt+clay content for all depths for both native and cultivated soils. Particularly, larger aggregate (2-0.25 mm) had higher organic carbon content in soils with macro-aggregation more than 0.25 mm diameter (Table 2). It could be considered that macro-aggregate formation could contribute the storage of organic carbon in soils (Carter and Gregorich, 1996). The fresh organic carbon that was derived from the crops were first incorporated to larger aggregates and then shunted to microaggregates after decomposition by soil microbes and this process was stimulated by disturbance by conventional tillage (Franzluebbers and Arshad, 1997; Elliot, 1986). The percentage of SOC associated with 2-0.25 and 0.25-0.05 mm aggregates increased with increasing clay percentages of soils. Wiseman and Puttmann (2005) described the importance of specific surface of clays rather than percentage of clays in SOC sorption. Wattel-Koekkoek *et al.* (2003) showed that smectites have large sorptive capacity for SOC. The existing reports on clay minerals of Ganges River Floodplain of Bangladesh concluded that illite is the dominant clay mineral of this floodplain (Ahmed *et al.*, 2004). The surface area of illite is about 70-120 m² g⁻¹ which is about 7-9 times less than montmorillonite (Bohn, 1979). So, the capacity of illite to sorb SOC at 0.25-0.05 mm scale may play an important role and it requires further research to conclude.

The lower NSI indicated that the aggregates were not water stable. The NSI of Silty clay loam and clay loam soil was higher due to their higher clay content. Rabbi *et al.* (2004) reported that aggregate stability of soils of Ganges River and Tidal Floodplains increased with increasing clay percentage of soils. In the present study the NSI increased with decreasing cropping intensity. Soils under Fallow-Fallow-T.aman cropping pattern had higher NSI. The cultivation of rice in boro and kharif-2 season also decreased NSI of soils. Six *et al.* (1999) reported that conventional tillage with high cropping intensity caused maximum destruction of soil. The cultivation of rice twice a year accelerates the aggregate destruction rate. Adiku *et al.* (2008) concluded that soils under rice base cultivation were more prone to degradation. The inclusion of shrimp in land use markedly decreased the NSI may be due to application of saline water in soil. Bhuiyan and Rabbi (2007) reported that shrimp culture can deteriorate the tilth of soil.

Relationship among soil properties: Sand percentage had negative correlation with SOC associated with the aggregates of 0.25-0.05mm size range (Table 4). Soil organic carbon associated with the aggregates of 8-2 mm size range had positive correlation with SOC associated with the aggregates of 2-0.25 and 0.25-0.05 mm size range. Soil organic carbon associated with the aggregates of 2-0.25mm size range had positive correlation with SOC associated with the aggregates of 0.25-0.05 mm size range. Percentage of SA had positive correlation with % DF.

Table 4 Correlations among selected soil properties

Correlations: %Sand, %Silt, %Clay, SOC-1, SOC-2, SOC-3, %SA, %DA, DF, NSI

	%Sand	%Silt	%Clay	SOC-1	SOC-2	SOC-3
%SA	%DA					
%Silt	-0.300					
	0.319					
%Clay	-0.751	-0.405				
	0.003	0.170				
Soc-1	-0.430	-0.062	0.455			
	0.142	0.841	0.118			

SOC-2	-0.193	0.096	0.119	0.634			
	0.527	0.756	0.699	0.020			
SOC-3	-0.615	0.151	0.485	0.713	0.621		
	0.025	0.622	0.093	0.006	0.024		
%SA	-0.118	-0.222	0.267	-0.270	-0.029	0.054	
	0.701	0.467	0.378	0.372	0.925	0.860	
%DA	-0.025	-0.213	0.171	-0.320	-0.015	0.007	
0.993							
	0.936	0.485	0.576	0.286	0.961	0.982	
0.000							
%DF	0.019	0.072	-0.068	0.115	0.057	0.189	-
0.499	-0.481						
	0.950	0.815	0.824	0.708	0.852	0.535	
0.082	0.096						
NSI	-0.220	-0.181	0.336	0.473	0.057	0.459	
0.045	0.002						
	0.470	0.554	0.261	0.103	0.854	0.115	
0.884	0.995						
	%DF						
NSI	0.376						
	0.206						

Cell Contents: Pearson correlation
P-Value

SOC-1: Soil organic carbon associated with the aggregates of 8-2 mm size range.

SOC-2: Soil organic carbon associated with the aggregates of 2-0.25 mm size range.

SOC-3: Soil organic carbon associated with the aggregates of 0.25-0.05 mm size range.

Conclusion

Soil organic carbon content largely depends on the amount of organic inputs according to vegetation types and organic amendments. Aggregate stability and soil organic carbon was correlated each other, provided the method of stability test was properly chosen considering the characteristics of aggregate formation-breakdown in different land use types. It could be considered that, aggregate stability test with verified method is useful for assessing organic carbon and aggregation in soils. In addition, it can be concluded that shifting to no tillage agriculture presents the best option for increasing soil organic carbon stocks and the percentage of SOC associated with different aggregates increased with increasing clay percentages of soils.

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