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Land Use Pattern Influences the Aggregate Stability of Soil

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ABSTRACT

Soil samples collected from four land use patterns namely forest, tea garden, cultivated and uncultivated land were used for analyzing the physico-chemical parameters and aggregate stability of the soil. Result show that among the soils analyzed, soil texture varied from loamy sand to clay loam with mean clay content in order of cultivated> forest> tea garden> uncultivated land. Bulk density (BD) of the soil showed significant negative correlation with organic matter content, soil porosity, percent base saturation and maximum water holding capacity (MWHC). Maximum water holding capacity was higher in forest soil followed by tea garden soil and the minimum in uncultivated soil. Forest, tea garden and cultivated soils were strongly acidic to moderately acidic in nature, while uncultivated soils were slightly acidic. All soils were non-saline and have low to medium cation exchange capacity (CEC) ranged from 3.70 to 15.48 Cmol(P^+) kg^{-1}. The results of aggregate stability indicated that majority of the soils showed high values of mean weight diameter (MWD) in both dry and wet sieving. Mean weight diameter and water stable aggregates were greater in forest and tea garden soils compared to cultivated soil. Mean weight diameter (dry sieving) maintained significant positive correlation with organic carbon content and cation exchange capacity. Correlations were drawn between the physico-chemical properties of soil and also among the different physical properties of soils.

Key Words: Land Use Pattern; Soil Properties; Mean Weight Diameter; CEC; Maximum Water Holding Capacity

INTRODUCTION

Aggregate stability is a measure of soil resistance to breakdown by the destructive forces of water or wind. Consequently, aggregate stability is an important soil property used to evaluate the risk of soil erosion and deterioration of soil structure. Aggregate stability is dependent on many factors, particularly on organic matter, soil texture and Fe and Al oxide contents (Zhang and Horn 2001). Land use induced changes in nutrient availability may influence secondary succession and biomass production (Foster et al. 2003) and reduce Soil Organic Carbon (SOC) which plays a crucial role in sustaining soil quality, crop production and environmental quality (Doran and Parkin 1994). Land use pattern directly affects soil physical, chemical and biological properties viz., soil water retentionand availability, nutrient cycling, plant root growth and soil conservation (Gregorich et al. 1994). Reduction in SOC content changes distribution and stability of soil aggregates (Singh and Singh 1996) making the soilmore prone to erosion (Cambardella and Elliott 1993, Six et al. 2000). Cultivation practices disturb soil physical properties and release physically protected soil organic matter resulting to oxidation of soil organic matter (Plante and McGill 2002, Shang and Tiessen 2003). Stabilization of soil aggregate including aggregate formation has greater control on soil organic carbon content (Christensen 2001). The interaction of physical, chemical, and biological processes in soils manages aggregate formation and stabilization (McCarthy et al. 2008).

Cambardella and Elliot (1993) and Adesodun et al. (2007) reported higher proportions of microaggregate fractions when native grasslands were cultivated. Cultivated soils have a smaller WSA within >2 mm and 1-2 mm aggregate size fractions but a greater aggregation in <0.25 mm size fraction than the fallow is found. Tillage operations may increase the susceptibility of aggregates to disruption by wet-dry cycles that lead to a loss of C-rich macro aggregate fractions. The MWD and GMD have smaller values in the cultivated than the fallow soils indicating maximum disturbances through tillage and lower accumulation as well as protection of SOC in macro-aggregates (Gupta Choudhury et al. 2010).

Aggregate formation and stability depends strongly on the microbial gums produced by the breakdown of organic matter and acting as cementing agents. The smaller aggregates in the cropland soils are therefore consistent with the lower SOM content (Emadi et al. 2008). Loss of the larger aggregate sizes in cropland could also be due to tillage rapidly destroying live and decaying plant roots, fungal hyphae, earthworms and termites. These factors tend to favor the formation of larger sized aggregates (Tisdale and Oades 1982).Size distribution of aggregates is affected by the change in land use and management (Spaccini et al. 2001). The loss of large sized water stable aggregates under cultivation was also associated with a significant reduction in stability as measured by the MWD. The stability of intact WSA showed higher values in uncultivated soils than in cultivated soils. There were no significant differences in MWD between forest and pasture soils (Emadi et al. 2008)

Although the importance of organic matter to improve soil aggregate stability is well known (Chenu et al. 2000, Boix-Fayos et al. 2001, Six et al. 2004, Noellemeyer et al. 2008), theexperiments showing the beneficial effects of organic matter on aggregate stability have beenvaried. For instance, some workers (Chaney and Swift 1984, Christensen 1986) found a significant correlation between organic matter and aggregate stability, while others (Hamblin and Greenland 1977, Dormaar 1983, Li et al. 2010) reported a negative correlation. There are also differences in the results in term of the type of organic matter constituents responsible for aggregate stability (Mehta et al.1960). Therefore, the objective of the present study was to quantify the effects of different land use pattern on soil physical properties with a special reference to soil aggregate stability.

MATERIALS AND METHODS:

Twenty nine surface soil samples (0-15cm) from different land use patterns viz. forest, tea garden, cultivated and uncultivated land belonging to different soil series of West Bengal were collected (Table. 1). The soil samples were collected in moisture box with the help of core sampler for estimating the bulk density of the soil. The samples were processed for further analysis of different physic-chemical parameters viz. pH, oxidisable organic carbon, available nitrogen, available phosphorus, available potassium etc. The pH of the soils were estimated by taking soil: water :: 1:2.5 soil suspension (Jackson 1973); oxidisable organic carbon determined by the Walkley and Black method (Jackson 1973); cation exchange capacity (CEC) by ammonium saturation method (Jackson 1973) and clay content by hydrometer method (Deuis and Freitas 1984). Mechanical analysis of the soil samples was carried out by using Bouyoucos hydrometer (Jackson 1973). The size distribution of soil aggregates was measured by both dry and wet sieving method following standard protocol.

The model of Van Bavel (1950) as modified by Kemper and Rosenau (1986) used to determine the Mean Weight Diameter (MWD) of water stable aggregates. Thus,

$$\text{MWD} = \sum_{i=1}^{n} X_i W_i$$

where; X_i = Mean diameter of each size fraction (mm) W_i = Proportion of the total mass in the corresponding size fraction after deducting the weight of stones (Upon dispersion and passing through the same sieve)

The change in Mean Weight Diameter (CMWD) was calculated as the difference between two MWD as obtained by wet sieving method.

Geometric Mean Weight Diameter (GMD) was calculated as follows;

$$GMD = \exp \sum_{i=1}^{n} Wi \log Xi \,/\, \sum_{i=1}^{n} Wi$$

where; W_i = Weight of aggregates in a size class

X_i = average diameter of each size fraction

Simple statistical analysis was done between different soil physico-chemical properties of soil following the Pearson correlation coefficient method.

Table 1. Detailed locations of sampling sites for the present study

Landuse & No.	Site of collection	District
Tea garden		
S_1	Boxa Tea Estate	Jalpaiguri
S_2	Riyabati Tea Agro pvt ltd	Jalpaiguri
S_3	Cooch Behar Tea Estate	Cooch Behar
S_4	Mathura Tea Estate	Jalpaiguri
Forest		
S_5	Boxa Forest	Jalpaiguri
S_6	Jaldapara Forest	Jalpaiguri
S_7	Chilapata Forest	Jalpaiguri
Cultivated		
S_8	Near Boxa Tea Estate	Jalpaiguri
S_9	Near Boxa Forest	Jalpaiguri
S_{10}	Near Jaldapara Forest	Jalpaiguri
S_{11}	Block Seed Farm	Dakshin Dinajpur
S_{12}	RRS Majhian	South Dinajpur
S_{13}	Instructional Farm Palli Siskha Bhavan	Birbhum
S_{14}	Medinipur	Medinipur (East)
S_{15}	Gopalpur	Purulia
S_{16}	Gottoria	Bankura
S_{17}	Near Cooch Behar Tea Estate	Cooch Behar
S_{18}	U.B.K.V. Instructional Fram	Cooch Behar
S_{19}	District Seed Farm	Cooch Behar
S_{20}	Near Mathura Tea Estate	Jalpaiguri
S_{21}	Near Chilapata Forest	Jalpaiguri
Uncultivated		
S_{22}	Gopalpur	Purulia
S_{23}	Gottoria	Bankura
S_{24}	U.B.K.V. Farm	Cooch Behar
S_{25}	Horticulture Farm	Cooch Behar
S_{26}	RRS Majhian	Dakshin Dinajpur
S_{27}	Mathura	Jalpaiguri
S_{28}	Chilapata	Jalpaiguri
S_{29}	District Seed Farm	Cooch Behar

RESULT AND DISCUSSION

Bulk Density and Organic Carbon

Bulk density (Mg m^{-3}) of soil varied from 1.23 to 1.47 (mean 1.38), 1.17 to 1.37 (mean 1.27), 1.25 to 1.79 (mean 1.56) and 1.45 to 1.78 (mean 1.60) in tea, forest, cultivated and uncultivated soil respectively (Table. 2).Bulk density of the soils followed the order forest < tea garden< cultivated < uncultivated soil. The lowest value of bulk density in forest soil is due to higher amount of organic matter content because of higher amount of residue addition, increased root growth, better aggregation and increased volume of micropores.This result is in line with the findings of Saha and Mishra (2007).Bulk density of soil maintained significant and positive correlation with percent base saturation (r=0.70**) and it was negatively correlated to porosity of soil (r= -.99**), maximum water holding capacity (r= -0.90**) and organic matter (r= -0.74**) (Table 4). The organic carbon content ranged from 2.9 g kg-1 to 2.14 g kg^{-1}. The soils of forest land was found be higher in organic carbon content than the other land use possibly because of higher addition of biomass. There was an intimate relationship between the soil organic carbon content and bulk density of the soils indicating porosity, MWHC and organic matter content increase with decrease in bulk density.

Soil Porosity-

The total pore space of soil in tea garden, forest, cultivated and uncultivated land were 43.46 to 50.80 (mean 45.92), 46.06 to 52.24 (mean 49.30), 33.46 to 50.59 (mean 40.45) and 33.83 to 43.14 (mean 38.94) respectively. Percent pore space was more in forest soils followed by tea soils and lowest in uncultivated soils. The variations of pore space were mainly due to variation of bulk density which was related to organic matter content of soil. The higher organic matter content supported high microbial activity resulting stable aggregate formation and improving macro-pores and continuity of pores. Porosity was positively correlated to maximum water holding capacity (r=0.88**)and negatively correlated to coarse sand fraction(r= -0.61**).

Maximum Water Holding Capacity

Maximum water holding capacity (%) of soils varied from 55.53 to 61.09 (mean 58.14), 60.22 to 65.90 (mean 62.94), 32.15 to 55.46 (mean 45.68) and 34.33 to 52.35 (mean 43.23) in tea, forest, cultivated and uncultivated soils respectively (Table 2). It was highest in forest soils followed by tea garden soil and lowest in the uncultivated soil. This was due to the

Table 2. Physical properties of the selected soils for the study

Land use		BD Mg m^{-3}	PD Mg m^{-3}	TP (%)	MWHC (%)	Sand (%)	Silt (%)	Clay (%)	Textural class
Tea	Mean	1.38	2.55	45.92	58.14	48.80	29.6	18.4	Silty loam-
(n=4)	Range	1.23-1.47	2.50-2.60	43.46-50.80	55.53-61.09	36.00-69.60	16.00-46.40	14.40-22.40	Loam
	SD	0.11	0.04	3.36	2.68	13.76	12.56	3.33	
Forest	Mean	1.27	2.5	49.3	62.94	45.60	33.6	20.8	Silty loam-
(n=3)	Range	1.17-1.37	2.45-2.54	46.06-52.24	60.22-65.90	34.40-53.60	24.00-41.60	16.00-24.00	Loam
	SD	0.10	0.05	3.10	2.85	9.99	8.91	4.23	
Cultivated	Mean	1.56	2.61	40.45	45.68	45.5	29.89	22.57	Silty loam-
(n=14)	Range	1.25-1.79	2.53-2.69	33.46-50.59	32.15-55.46	15.20-71.20	8.00-46.40	11.20-44.80	Clay Loam
	SD	0.17	0.06	5.33	8.79	17.11	12.71	9.72	
Fallow	Mean	1.6	2.62	38.94	43.23	57.74	19	18	Sandy loam-
(n=8)	Range	1.45-1.78	2.55-2.69	33.83-43.14	34.33-52.35	40.80-87.20	6.40-38.40	3..20-24.00	Clay Loam
	SD	0.12	0.05	3.36	6.72	15.64	10.93	7.04	

Note: Bulk density (BD), Particle density (PD), Total porosity (TP) & Maximum water holding capacity (MWHC)

Table 3. Aggregate stability of soils under study

Land use		MWD		GMD		CMWD
		Dry sieving	Wet sieving	Dry sieving	Wet sieving	
Tea (n=4)	Mean ± SD	5.94 ± 0.26	5.14 ± 0.26	0.70 ± 0.09	0.55 ± 0.12	0.81 ± 0.20
	Range	5.56-6.12	4.89-5.50	0.56-0.75	0.46-0.73	0.62-1.04
Forest (n=3)	Mean ± SD	6.32 ± 0.07	5.55 ± 0.10	0.78 ± 0.02	0.64 ± 0.06	0.77 ± 0.04
	Range	6.27-6.40	5.45-5.65	0.76-0.80	0.57-0.69	0.74-0.82
Cultivated (n=14)	Mean ± SD	5.59 ± 0.74	4.71 ± 0.90	0.67 ± 0.15	0.53 ± 0.19	0.87 ± 0.29
	Range	3.78-6.45	2.98-6.10	0.30-0.80	0.14-0.73	0.35-1.49
Fallow (n=8)	Mean ± SD	1.03 ± 0.10	1.21 ± 0.20	0.19 ± 0.64	0.20 ± 0.47	0.22 ± 0.90
	Range	3.35-6.17	2.21-5.46	0.29-0.77	0.18-0.68	0.70-1.22

Table 4. Correlation among different properties of soil under study

	pH	OC	CEC	BD	TP	MWHC	Sand	Silt	Clay	MWD	MWD	GMW	GMW	CMWD
pH	1													
OC	-.505**	1												
CEC	-.251	.755**	1											
BD	.735**	-.744**	-.438*	1										
TP	-.739**	.720**	.438*	-.996**	1									
MWHC	-.790**	.719**	.460*	-.902**	.885**	1								
Sand	.155	-.255	-.551**	.116	-.132	-.176	1							
Silt	-.358	.318	.360	-.322	.320	.377*	-.886**	1						
Clay	.239	.031	.581**	.263	-.227	-.225	-.688**	.274	1					
MWD Dry	-.463*	.528**	.742**	-.551**	.555**	.649**	-.740**	.661**	.501**	1				
MWD Wet	-.395*	.526**	.744**	-.537**	.539**	.621**	-.730**	.642**	.511**	.976**	1			
GMW Dry	-.290	.360	.586**	-.422*	.425*	.543**	-.643**	.564**	.452*	.836**	.840**	1		
GMW Wet	-.356	.493**	.631**	-.530**	.525**	.559**	-.637**	.615**	.361	.841**	.889**	.799**	1	
CMWD	.002	-.303	-.448*	.266	-.265	-.271	.399*	-.316	-.334	-.494**	-.671**	-.508**	-.686**	1

**. Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level.

variations in organic carbon content of these land use. A higher content of organic carbon resulted stable aggregate formation and improve pore space which ultimately enhance the water holding capacity. Maximum water holding capacity was negatively correlated with coarse sand fractions (r= -0.59**) and particle density (r= -0.90**) of soil. The result indicated that the soils with higher amount of coarse sand fractions have poor water holding capacity.

Mechanical Analysis-

The coarse sand content (%) varied from 0.44 to 6.72 (mean 2.57), 1.24 to 2.87(mean 1.87), 0.16 to 35.46 (mean 9.05) and 2.84 to 43.80 (mean 17.23) in tea garden, forest, cultivated and uncultivated land respectively. The lowest content of coarse sand was found in forest soil followed by tea garden soil. Fine sand content of soils under different land use pattern varied from 35.56 to 62.88 (mean 49.43), 32.88 to 50.76 (mean 43.73), 10.40 to 56.76 (mean 38.49) and 30.60 to 84.36 (mean 45.47)in tea garden, forest, cultivated and uncultivated soil respectively. Silt content in tea garden, forest, cultivated and uncultivated soils were varied from 16.00 to 46.40 (mean 29.60), 24.00 to 41.60 (mean 33.60), 8.00 to 46.40 (mean 29.89) and 6.40 to 38.40 (mean 19.00) respectively. The clay content ranged from 14.40 to 22.40 (mean 18.40), 16.00 to 24.00 (mean 20.80), 11.20 to 44.80 (mean 22.57) and 3.20 to 22.40 (mean 18.00) in tea, forest, cultivated and uncultivated soil respectively (Table 2).

Soil Aggregation-

Aggregate stability of soils under different land use pattern were determined by taking different indices viz., MWD (Dry sieving and wet sieving), GMD (Dry sieving and wet sieving) and Change in Mean Weight Diameter (CMWD). The results showed that mean weight diameter (MWD) of dry sieving obtained in soils of tea garden, forest, cultivated and uncultivated land varied from 5.56 to 6.12 (mean 5.94), 6.27 to 6.40 (mean 6.32), 3.78 to 6.45 (mean 5.59) and 3.35 to 6.17 (mean 5.10) respectively (Table 3). The sequence of mean weight diameter were forest >tea > cultivated > uncultivated soil. Mean Weight Diameter (Dry sieving)maintained significantly positive correlation with organic carbon content (r=0.53**), cation exchange capacity (r=0.74**) and clay content of the soil (r=0.50**) (Table 4).These indicated that clay content and organic matter content greatly influence the MWD (dry sieving).

Similarly mean weight diameter (MWD) by wet sieving ranged from 4.89 to 5.50 (mean 5.14), 5.45 to 5.65 (mean 5.55), 2.98 to 6.10 (mean 4.71) and 2.21 to 5.46 (mean 4.20) tea garden, forest, cultivated and fallow respectively. The sequence of mean weight diameter of wet sieving was same as that of dry sieving. Wet sieving MWD was significantly correlated with organic matter (r=0.53**), cation exchange capacity (r=0.74**) and clay content of the soil (r=0.50**) (Table 4). Clay and organic carbon content have an intimate relationship with the mean weight diameter (MWD) of wet sieving (Figures1a and 1b).

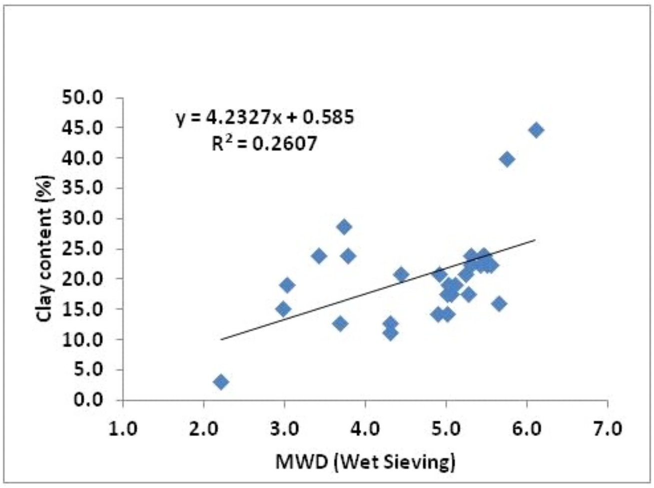

Figure1a. Relationship between clay content (%) and MWD (Wet Sieving)

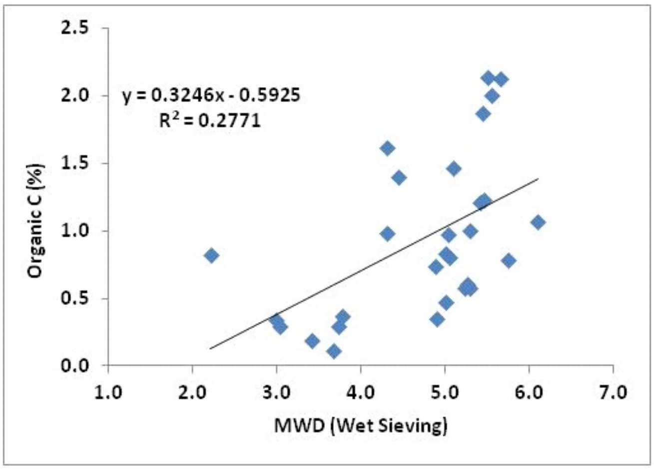

Figure1b. Relationship between organic C (%) and MWD (Wet Sieving)

The lower values of MWD in cultivated soil than forest soil were due to higher disturbance through tillage operation and poor sequestration of carbon in macro-aggregates. Similar results reported by Gupta Choudhury et al. (2010). The results indicated that soil having high clay and organic matter content had higher wet MWD values. Similar trend was observed for GMD. This might be due to the binding activity of organic matter and clay resulting stable aggregate formation.The MWD and GMD were highly correlated with CEC of the soil. The soils having higher CEC value showed higher aggregate stability.

Change in mean weight diameter (CMWD) which the difference between MWD of dry sieving and MWD of wet sieving. Change in mean weight diameter (CMWD)of soils in tea garden, forest, cultivated and uncultivated land varied from 0.62 to 1.04 (mean 0.81), 0.74 to 0.82 (mean 0.77), 0.35 to 1.49 (mean 0.87) and 0.70 to 1.14 (men 0.90) respectively (Table 3). The sequence of CMWD was uncultivated> cultivated> tea garden> forest soils. This was because of higher organic matter content in forest and tea garden soils which maintained the aggregate stability of these soils. But some soils in cultivated and uncultivated land had good aggregate stability which may be due to either high amount of clay or presence of oxides of free Fe and Al. The CMWD is negatively correlated with CEC (r= -0.45**) of the soil.

CONCLUSION

Results from the present study demonstrate that different type of land use pattern exerts a profound influence on soil organic carbon content and ultimately the stability of the aggregates in soils. Accordingly, cultivated soils had lower amounts of organic carbon than other land use and thus having lower aggregate stability, maximum water holding capacity. The low carbon input from the agricultural crop could not compensate for the large mineralization of organic matter in cultivated fields. Forest soils maintain higher organic carbon status among all the land use maintaining a good aggregation of soil.

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