Literature review on soil organic carbon assessment in Bangladesh

Bangladesh Forest Department

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1 LITERATURE REVIEW ON SOIL ORGANIC CARBON

1.1 Introduction

Soil organic matter is considered one of the primary indicators for agricultural productivity and its maintenance is key to promoting soil resilience (Huq and Shoaib 2013). However Bangladesh soils have some of the lowest amounts of organic matter in the world, averaging between 0.5 and 0.9%. The impediments to production have largely been addressed though increased access and utilization of inorganic fertilizers which has resulted in significant increases in the nation's agricultural production. A renewed focus on the importance of soil organic matter has emerged under the context of climate change acknowledging the vast potential of soils as both a source and a sink for carbon emissions and storage respectively.

Carbon stored in soils worldwide exceeds the amount of C stored in phytomass (plants) and the atmosphere. Despite the large quantity of carbon stored as Soil Organic Carbon (SOC), consensus is lacking on the size of global SOC stocks, their spatial distribution, and the carbon emissions from soils due to changes in land use and land cover. It is estimated that about two thirds of global soil carbon is held as SOC, the remainder is inorganic (Scharlemann*et al.*, 2014). Carbon turnover varies from ecosystem to ecosystem and processes operating also show variations. The diversity of Bangladesh's land cover which includes swaps, mangroves, terraced soil, hill slopes and vast alluvial plains mean the maintenance of organic matter and the associated flux of soil organic carbon will vary across the country.

The aim of this literature review is to understand the variations of SOC in Bangladesh and to examine the factors influencing its changes. A range of data is presented from various sourced examining SOC levels on different soil types and ecosystems. The second part of the report looks at bulk density and its influence on SOC. The findings of the report will assist the soil analysis component of the Bangladesh Forest Inventory which began in 2016 and will be completed in 2018.

1.2 Sources of Soil Organic Carbon

Photosynthesis is the driving process behind carbon storage in biomass, and the stored biomass eventually ends up in soils and dead organic matter pools. On the other hand respiration, decomposition and combustion (fire) release CO_2 and CH_4back into the atmosphere. Forests are a large carbon sink, but they are ecosystems that gain and loss carbon continually (Zu*et al*., 2010). The majority of C in croplands actually is held in the soil as annual litter additions which slowly decompose and become a part of soil organic matter. Grasslands/ shrublands are similar to croplands in that most of the carbon stock is stored in soil. Plant roots provide the primary input of carbon into grassland soils, but some of the carbon is oxidized by soil microbes and is released back into the atmosphere. Wetlands are terrestrial areas between uplands and aquatic ecosystems where carbon is stored mainly in the soil C pool, which is the result of saturated anaerobic soils that retard the decomposition of biomass production; however, both woody and nonwoody vegetation and sediments also contribute to sequestered carbon in wetlands. Carbon is lost from wetlands through methanogenesis in anaerobic soils and through oxidation of organic matter when wetlands are drained (Zhu*et al.*, 2010).

The carbon derived from decaying vegetation, fungal and bacterial growth, and metabolic activities of living organisms. Organic matter in the soil comes from the remains of plants and animals. This includes grasses, tress, bacteria, fungi, protozoa, earthworms and animal manures. All soils contain C in the form of organic matter, or humus. The formation of soils however is formed over geological time. Indeed the geological associations influence the distinct properties of soil which are then used for their classification. Different classification systems are used in different parts of the world however there is usually commonality between then. SRDI (unpublished) have harmonized the FAO-UNDP (1988) General soil types with the FAO-UNESCO 1974 classes. This process can assist comparison between different maps prepared at different times. It is important to note that one General soil types can relate to multiple FAO-UNESCO class.

Table 1: Harmonisation of two soil classification systems

ID	General soil types (FAO-UNDP 1988)	FAO-UNESCO 1974
1	Calcareous Aluvium (non-saline)	Calcaric Fluvisols
2	Noncalcareous Aluvium	Eutric Fluvisols
3	Calcareous Brown Floodplain Soils	Calcaric Gleysols
3	Calcareous Brown Floodplain Soils	Eutric Cambisols
4	Calcareous Grey Floodplain Soils	Calcaric Gleysols
5	Calcareous Dark Grey Floodplain Soils	Calcaric Gleysols
6	Noncalcareous Grey Floodplain Soils (non-saline)	Eutric Gleysols
6	Noncalcareous Grey Floodplain Soils (non-saline)	Dystric Gleysols
7	Noncalcareous Brown Floodplain Soils	Dystric Gleysols
7	Noncalcareous Brown Floodplain Soils	Eutric Gleysols
7	Noncalcareous Brown Floodplain Soils	Dystric Cambisols
8	Noncalcareous Dark Grey Floodplain Soils	Eutric Gleysols
9	Black Terrai Soils	Humic Cambisols
9	Black Terrai Soils	Umbric Gleysols
10	Acid Basin Clays	Dystric Gleysols
	Acid Basin Clays	Eutric Gleysols
10	Acid Basin Clays	Eutric Fluvisols
11	Acid Sulphate Soils	Thionic Fluvisols
11	Acid Sulphate Soils	Thionic Gleysols
12	Peat	Dystric Histosols
13	Grey Piedmont Soils	Dystric Gleysols
13	Grey Piedmont Soils	Eutric Gleysols
14	Brown Hill Soils	Dystric Cambisols
14	Brown Hill Soils	Dystric Regosols
16	Deep Red-Brown Terrace Soils	Ferric Alisols
17	Shallow Grey Terrace Soils	Eutric Gleysols
18	Shallow Grey Terrace Soils	Eutric Planosols
19	Deep Grey Terrace Soils	Eutric Gleysols
19	Deep Grey Terrace Soils	Eutric Planosols
20	Grey Valley Soils	Eutric Gleysols
34	Sundarban	Unidentified
35	Waterbodies	-
36	Urban (Man-made land)	Fimic Anthrosols
39	Reserved Forest	Unidentified
40	Kaptai Lake	-

Absolute amount of carbon vary considerably from one soil to another, beings as low as 1% or less in coarse-textured soils to as much as 3.5% in prairie grassland soils (eg. Mollisols; some soils of Meghna River Flood plain belong to Mollisols). Poorly drained soils (Aquepts) often have C contents approaching 10%. Many tropical soils, such as the Oxisols (very minor soils of Northern-Eastern Hills of Bangladesh) are notoriously low in organic C (Stevenson, 1986). Weiner (2000) reported that the amount of organic matter in typical mineral soils is generally between about 1 and 10%, but in typically less than 5%. In wetlands and peat-soils, it can approach 100%.

1.3 Factors Influencing the Organic Matter Content in Soil

Organic C does not accumulate indefinitely in well-drained soils. The process of soil formation also leads to considerable migration of organic carbon into the lower soil horizons often in association with clay or metal ions. In addition to leaching, organic matter can be transported downward in soil through the action of soil animals.

There are several factors that govern the SOC in different ecosystems. Climate is the most important single factor that determines the array of plant species at any given location, the quantity of plant material produced and the intensity of microbial activity in the soil and as a consequence this factor plays a prominent role in determining organic associations in some soils and the development of Alfisols (Northern-Eastern Hills and Hill Tracts of Bangladesh); a semi-arid climate leads to grassland associations and the development of Mollisols. Grassland soils exceed all other well-aerated soils in organic matter content; desert, semi desert and certain tropical soils have the lowest (Stevenson, 1986).Bashkin (2002) stated that the average turnover time of carbon in forest litter is about 1.5 years, although for tropical ecosystems with mean temperature above 30^{o}C, the litter decomposition rate is greater than the supply rate and so storage is impossible. Bashkin (2002) also reported that for colder climates, net primary production exceeds the rate of decomposition in the soil and organic matter in the form of peat accumulated. Average temperature at which there is a balance between production and decomposition is about 25^{o}C.

The effect of increasing rainfall on soil organic matter content is to promote greater plant growth and the production of larger quantity of raw material for humus synthesis. The quantity of parent material produced and subsequently returned to soil, can vary from a trace in arid and arctic regions to several metric tons per hectare in warm climates. The rates of decomposition, however, control their accumulation in soil.

Soils formed under restricted drainage (Histosols and Inceptisols) do not favour decomposition of organic matter over a wide temperature range and thus favour accumulation of it.

Textural properties have considerable effect on the accumulation of organic matter for any given climatic zone, provided vegetation and topography are constant. Thus heavy textured soils have higher carbon content then loamy soils, which in turn have higher carbon contents than sandy soils.

Topography or relief modify the moisture condition of soil and thus influence organic matter content of the soils. Soils occurring in depressions, where the climate in "locally humid" have higher carbon contents than those occurring on the Knolls, where the climate is "locally arid". Thus naturally moist poorly drained or seasonally flood soils are usually high in organic matter, because the anaerobic conditions that prevail during wet periods of the year prevent destruction of organic matter (Stevenson, 1986).

Soils located at lower elevation of the catena contain in general more organic matter than that of highlands and medium highlands. These soils remain under water for a considerable period of time of a year. These conditions do not favour the decomposition of organic matter and as a consequence organic matter accumulates. Moreover, growths of aquatic plants add organic matter to these soils. Irrigation improves the moisture status of the soil, which increases microbial activities and consequently the rate of decomposition of organic matter increases.

Marked changes, usually decline in organic C levels are brought about when soils are first placed under cultivation. Cultivation improves aeration and moisture status, thereby increasing microbial activity and the release of organic compounds to soluble form. A temporary increase in respiration rate occurs each time when an air-dried soil is wetted and since considerable amounts of fresh soil are subjected to repeated wetting and drying through cultivation, losses of organic matter by this process could be appreciable. Cultivation stimulates microbial activity through exposure of organic matter not previously accessible to microorganisms.

Green manuring or addition of crop residues and manures increase the numbers of microorganisms and there by the rate of oxidation of organic matter increases, as a consequence leads to decrease of SOC. Application of plant residues originated from different crops showed different effects. Also the rates of application have considerable effects on the SOM.

Organic matter contents of the soils of Bangladesh are of no exception. The most dominating effect of climate on microbial activities created pronounced influences on the content of organic matter.

1.4 Organic Matter Content of Agricultural Soils

The optimum level of organic matter that should be maintained in soil has never been determined, nor is it likely to be any single value. Soils, climates, and plant species make a multitude of different ecological and environmental conditions which vary the optimum organic matter concentration to fit each circumstance.

Tamhane*et al.* (1970) reported the values of organic matter based on the basis of analysis of 350 surface soils (0-15 cm) at 35 locations of Philippines (Table 1). The percentage of organic matter most frequent is 2 percent.

Data indicated that 65.8% soils of Philippines contained <1 to 3% soil organic matter which is comparable to the contents of SOM in the soils of Bangladesh. Data presented in Table 2 provide indication that except the Inceptisols and Mollisols, SOM content of other soils are more or less similar to the SOM content of the soils of Bangladesh.

Table 2 ***Organic carbon content of some soils of Philippines (Tamhane et al. (1970))***

Range in Percent OM	Percentage of soil samples in each range
<1.0	4.9
1.1-1.5	8.0
1.6-2.0	20.9
2.1-2.5	16.6
2.6-3.0	15.4
3.1-3.5	8.9
3.6-4.0	6.6
>4.0	18.9

The wide range of organic matter concentrations in soils (Table 2) (Donahue *et al.,* 1987) indicates the wide variations that occur in a single soil texture or in an area. Some cropping systems tend to cause greater soil organic matter changes than others. Tillage also affects organic matter contents. The more extensive the tillage the less the amount of humus that accumulates. Uncultivated soils are higher in total soil organic matter (on and in soil) than they are after cultivation. The obvious exception is arid soil that supported almost no plants before cultivation but due to irrigation, has an increase in humus content -resulting from moisture rather than tillage (Donahue *et al.*, 1987).

Table 3: Organic matter contents of surface soils from a variety of locations, under various plant cover, and in various climates (Donahue et al., 1987).

Soil and site description	Organic matter content (%)
India, 1000-1500mm (40-60th.) rainfall, cultivated	

Acid sulfate paddy soil, pH 6.2 ‘	0.75
Alluvial paddy soil, pH 6.3	2.88
Oxisol (clay) pH 5.2	5.52
Hawaii, USA, cultivated soil	
Oxisol (clay) from basalt, pH 5.9, 1100mm (45 in.) rainfall	0.7
Oxisol (clay) from basalt, pH 5.6, 2400mm (96 in.) rainfall	6.0
Inceptisol (loam) from volcanic ash, pH 5.1, 2500 mm (100 in.) rainfall	12.0
Iowa, USA, 800mm (32 in.) precipitation, cultivated	
Entisol (silt loam)	2.59
Mollisol (loam)	2.83
Mollisol (silty clay)	4.9
Nebraska, USA, 450-800mm (18—32 in.) precipitation, cultivated	
Mollisol (silty clay loam) (33 percent clay), pH 5.2	3.8
Entisol (loamy fine sand) (6 percent clay), pH 5.9	1.4
Liberia, Africa, 2000÷ mm (80+ in.) rainfall, virgin soils	
Ultisol (sandy clay loam) pH 4.9	3.45
Ultisol (sandy loam) pH 4.3	2.28
Turkey, Middle East, 900mm (36 in.) rainfall, cultivated	
Inceptisol (clay) (61 percent clay), calcareous	1,1
Vertisol (clay) (54 percent clay), calcareous	0.9
Mollisol (loam) (20 percent clay), 65 percent lime	4.3
Entisol (sandy loam) (6 percent clay), from volcanic ash	0.6
Costa Rica, low elevation, 1500-2000 mm (60-80 in.) rainfall	
Ultisol (clay) forested, pH 5.5, low elevation	3.74
Inceptisol (clay loam) forested, pH 5.2, from volcanic ash	3.97
Inceptisol (silty clay) forested, pH 4.1, from volcanic ash	18.94
Inceptisol (silty clay) forested, pH 6.2, from volcanic ash	10.25
Ultisol (clay) forested, pH 5.1, low elevation	4.34
Santa Barbara, California, 480mm (19 in.) rainfall	
Mollisol (loam) PH 7.3	7.85
Mollisol (very fine sandy loam) pH 7.8	11.3
Aridisol (silt loam) pH 7.9	6.23
Michigan-Indiana soils, cultivated, 750-1000mm (30—40 in.) rainfall	
Mollisol (sand) 2.9% clay, pH 6.6, imperfectly drained	6.15
Alfisol (sand) 3.4% clay, pH 7.5, well drained	1.81
Mollisol (loam) 198% clay, pH 6.3, imperfectly drained	8.24

Hoque *et al.* (1991) studied the organic carbon contents of Bangladesh soils and found that organic carbon content of four surface soil of Madhupur Tract varied between 0.90 per cent in Noadda series and 3.66 per cent in Khilgaon series and that of sub-surface soils from 0.51 to 4.02 per cent in Kalma and Khilgaon series, respectively. In the same study they found that the organic carbon values of surface soils of Brahmaputra Alluvium which varied between0.72 per cent in Sonatala series, located at the higher elevation in the catena and 1.37 percent in Naraibag Series, located at the lower elevation of the catena; in the surface soils of Gangetic Alluvium, Sara series, located at the highest elevation of the catena contained 2.41 per cent organic carbon to 1.77 per cent in Kiranchi Series located at the lower elevation and the values of organic carbon of the sub-surface soils ranged between 0.70 and 0.77 per cent of the three soil series.

A study carried out by Hossain *et al.* (1985) with six forest and adjoining cultivated soils of Bangladesh and found that total organic carbon varied between 0.59 and 1.67 per cent on the surface soils.

Hossain *et al.* (1989) determined the organic carbon content of 29 benchmark soil series of Bangladesh and reported that the values ranged between 0.16 and 0.85 per cent.

Hossain *et al.* (1988) determined organic matter content 10 soil samples each of Sathgaon, Baraoora and Kurmah soils of tea growing areas, of Bangladesh. The values ranged from 1.04 to 2.73% in the soils.

The available reports indicate that most agricultural soils of Bangladesh have a low organic matter content. Data presented in Table 3 show that about 70% of net cultivable area in high and medium high land has organic matter below 2% (Islam 1993).

Table 4.*Organic Matter Status of Soils of Different Land Types of Bangladesh and Values used to Classify them.*

Land Type	Organic Matter (Content %)		Percent of the Net Cultivable Area
	Range	Mean	
High Land	0.87 - 2.26	1.53	37
Medium High Land	1.39 - 2.78	1.97	34
Medium Low Land	1.74 - 3.13	2.23	16
Low Land	1.77 - 3.48	2.49	12
Very Low Land	1.91 - 4.52	2.94	1
Very high - 5.5%, High- 3.4 - 5.5%, Medium - 1.7 - 3.4% Low - 1.0 - 1.7% and Very Low - <1.0% *			

*Fertilizer Recommendation Guide, 1985, BARC

Mandal and Islam (1978) reported the values of organic matter content of 20 surface soils of Bangladesh. The lowest value was 0.72% and the highest value was 3.60%.Ahmed *et al.* (1983) collected 23 samples from different parts of Bangladesh and determined the organic matter content and found that the values ranged between 1.16 and 2.61%.

Islam *et al.* (1980-81) reported the values organic matter of six surface soils of Bangladesh. The lowest value was 0.72% and the highest value was 3.80%.

Ahmed and Islam (1971) determined the organic matter content of surface soils of sixteen soil series of Bangladesh (East Pakistan) and found the values ranged from 1.42 to 6.19%.

Islam and Mandal (1977) stated that the organic matter content of surface soils of twenty soil series of Bangladesh ranged from 0.72 to 3.60%.

The organic matter status of the soils of Bangladesh has changed a little throughout the years (Appendix 1). Data presented here are collected from the compilationworks of BangladeshAgricultural Research Council (1985, 2005 and 2010)

Department of Soil Science of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (2014) determined the carbon stock of soils of 10 AEZs (AEZ 21 to AEZ 30). The values indicate very low levels of organic carbon content of the soils, higher values were obtained within the surface soils (Appendix 2).

Hasan and Rahman (2016) of Soil Resource Development Institute, Bangladesh reported average organic matter content based on the data of 46,500 soils samples according to land types of 30 AEZs (Appendix 3). Most of the values are around 2 per cent organic matter. The values are in the range of low to medium categories.

1.5 Organic Matter Contents of Forest Soils

Forest ecosystem is different from those of agro-ecosystems. There is plenty of scope for the accumulation of organic matter because little disturbance in soil environment is occurred due to agricultural practices.

Haque and Karmakar (2009) studied the organic matter dynamics under three plantationsof different ages and one natural forest in chittagong hilly regions of Bangladesh. They found that total accumulation of organic matter increased with plantation age, accompanying with a decrease of annual accumulation rate. Content of organic matter in four forest types (Table7) showed declining trend towards hill bottom from hilltop except in one site. Concentration of organic matter was in general higher in 0-4 cm depth than that of 4– 8 cm depth.

Table 5: Organic matter content at two soil depths on three hill positions in four forest types of Chittagong region in Bangladesh.

Forest type	Soil Depth (in cm)	Oranic matter		
		Top	Middle	Bottom
18-year mixed plantation	0-4	1.75	1.92	2.39
	4-8	1.17	1.19	1.75
15-year acacia plantation	0-4	1.87	1.47	0.81
	4-8	1.84	1.47	0.81
7-year acacia plantation	0-4	1.50	1.44	1.51
	4-8	1.10	1.19	1.35
Sitapahar natural Forest	0-4	1.42	1.79	2.16
	4-8	1.28	1.60	1.98

Islam *et al.*(2009) determined the organic matter content from six sites having different tree plantations as a part of their study of faunal population. Organic matter contents varied from 1,44 to 2,05% in the top slope, 1.38 to 2.27% in middle slope and from 1.29 to 2.05% in the level slope (Table 8)

Table 6: Organic matter content under different vegetations and slope conditions

Site no.	Plant Species	Site Characteristics	Slope	OM %
1	*Accacia curniculiformis*	Very steep slope, Medium Hill	Level	1.32
			Middle	1.96
			Top	1.89
2	*Eucalyptus camaldulensis*	Steep slope, Medium Hill	Level	1.67
			Middle	1.84
			Top	1.99
3	*Lagerstroemia speciosa*	Steep slope, Medium Hill	Level	1.41
			Middle	1.62
			Top	1.44
4	*Tectona grandis*	Flat top of very steep slope, mediuml hill	Level	1.87
			Middle	2.27
			Top	1.55
5	*Accacia margium*	Gently sloped, low hill	Level	1.34
			Middle	1.38
			Top	1.65
6	*Dipterocarpus turbinatus*	Steeply sloping. Medium hill	Level	1.29
			Middle	2.05
			Top	2.05

Rahman *et al.* (2012) investigated the organic matter content from surface (0 – 10 cm) and sub-surface (10–30 cm) soil in a biodiversity conservation area (Tilagarh Eco-park) of North-eastern Bangladesh.They found that deforested site contained lower mean soil organic matter (0.31%) than that of Garjan (*Dipterocarpusturbinatus*), and Sal (*Shorearobusta*) plantations. The higher values of organic matter were found at surface soil in both the Sal (2.24%)

and Garjan (1.77%) plantations and 0.31% in deforested soil. The organic matter in both the plantations and deforested sites decreased with increase of soil depth: 1.41% in Sal, !.67% in Garjan and 0.23% in deforested area.

Working with the Tankawati natural forest of Bangladesh Ullah and Al-Amin (2012) found that the total carbon stock of the forest was 283.80 t ha^{-1} whereas trees produce 110.94 t ha^{-1}, undergrowth (shrubs, herbs and grass) 0.50 t ha^{-1}, litter fall 4.21 t ha^{-1} and soil 168.15 t ha^{-1} (up to 1 m depth). They also reported that the forest has a good capacity to stock carbon from the atmosphere.

Hossain *et al.* (2014) stated considerable variationsin organic matter content of forested hilly soils and the values were ranged between 1.0 and 2.44%. They found these data by analyzing 102 soil samples from surface and sub-surface from hill top, mid-slope and foot hill from 17 sites having different forest types (Table 9).

Table 7: Organic matter content under different tree species (Hossain *et al.*, 2014)

Site area	Sl	Tree	Elevation	Degree of slope			OM(%)
				Hill Top	Mid Hill	Foot Hill	
Rangamati	1	Teak	130	10	39	15	1.41
	2	Gamar	75	26	37	41	1.97
	3	Gamar	65	24	33	28	2.21
	4	Jarul	90	34	25	18	2.09
	5	Jarul	55	20	14	24	1.31
	6	Teak	68	15	29	27	1.20
	7	Teak	17	8	17	26	1.49
	8	Jarul	13	15	18	14	1.04
	9	Mahagani	29	7	13	26	1.88
	10	Teak	17	15	26	20	1.80
Bandarban	11	Teak	53	25	37	28	1.00
	12	Teak	15	26	30	30	2.00
	13	Gamar	91	16	30	25	2.41
Khagrachari	14	Teak	17	15	19	17	2.18
	15	Gamar	134	22	21	25	2.43
	16	Gamar	127	37	35	05	1.71
	17	Teak	294	30	26	16	2.44

Mukul*et al.* (2014) used available published data and reported that there is a great variability in carbon density in different forests and higher C stock in mangrove ecosystems., followed by hill forests and in inland Sal (*Shorearobusta*) forests in Bangladesh. Due to its coverage, degraded nature, and diverse stakeholderengagement, the hill forests can be used to obtain maximum REDD+ benefits. They also reported that globally about 60% ofthe carbon is stored in forests. They estimated that 251.8 million Mg of carbon is stored in Bangladesh forest ecosystems, with nearly 49.4% stored in the mangrove forests alone; 179.1 million Mg carbon in forest biomass and 72.7 million Mg carbon in soil; and hill forests have the highest potential for forest carbon enhancement and REDD+ in the country.

1.6 Conclusions

Soils of Bangladesh are under the influence of tropical monsoon climate. Optimum temperature and moisture regimes are in favour of the luxuriant growth of plants in summer and rainy seasons. High favourable temperature for the growth of mesophiles and water supply from rainfall favours the growth of microorganisms and the biomass added through plant and crop residues are decomposed rapidly. As a consequence, there is little chance to accumulate organic matter rather the conditions are influencing the depletion of soil organic matter which is evidenced in the report of the literature. The overall impacts of these factorsare the low to medium contents of SOM.

The organic matter status of the soils of Bangladesh is poor. The main reasons for depletion of SOC is the lack of organic recycling through addition of crop residues, animal wastes, and other organic sources. Due to intensive cropping, the soils are being disturbed through tillage operations, like plowing, puddling laddering and so on, leading to acceleration of decomposition of organic matter.

Relatively few research have so far been done on SOC turn over in forest ecosystem of Bangladesh. To know the dynamics of SOC in forest ecosystem extensive research work is needed.

2 LITERATURE REVIEW ON SOIL BULK DENSITY

2.1 Introduction

Bulk density is the mass (weight) of unit volume of dry soil, which includes both the solid and voids. The bulk density of a soil relative to that of water is called volume weight or apparent specific gravity. Bulk density is conveniently measured by determining the oven-dry weight (constant weight at 105^{o}C) of an undisturbed core of soil of known volume.

Bulk density varies on a soil's relative make up of sand, silt and clay, the combination of which is used to determine a soil's "structural" condition. These structural elements have implications for a soil's susceptibility for compaction and also on the amount of organic matter which in turn influence bulk density. For example, an non-compacted, loose and porous soils have low bulk density. .Cultural practices, such as ploughing, puddling etc also influence bulk density of soils.. For example puddling increases bulk density of soils.

Several studies found that bulk density tends to increase with soil depth. Karim *et al.* (1982) determined the bulk density in relation to depth of soils and found that soils bulk density values increased with depth of sampling up to 100 cm. Similarly Jashua and Rahman (1983) reported the values of soil bulk density of four soil series of the Ganges River Floodplains. In general, the bulk density values varied from 1.35 to 1.50 g cm^{-3}. The higher bulk densities were found in surface horizons of the medium textured soils of the upper slopes. This condition could be attributed to the structural breakdown and compaction of the soils due to ploughing under wet conditions (poor structural stability).

Faiz *et al.* (1975) found that the bulk densities in both 0-8 and 8-15 cm depths of the then Kashimpur soil were lower in cultivated phase compared to its fallow counterpart. The values were 1.47 and 1.45 gcm^{-3} in 0-8 cm and 8-15 cm depth, respectively, in cultivated phase and 1.60 and 1.68 g cm^{-3} in fallow soil. In Tejgaon soil bulk density values of surface and sub-surface horizons were 1.61 and 1.54 g cm^{-3} in cultivated phase and 1.56 and 1.54 g cm^{-3} in the fallow soils. The results indicated the effect of cultivation on the bulk density in the 8-15 cm depth.

Karim and Khan (1982) reported the bulk density value of the 1.33 g cm^{-3} of a Grey Terrace soil of Bangladesh Agricultural Research Institute.

In Grey Terrace soil the values ranged from 1.38 g cm^{-3} at 10 cm depth; from 1.48 to 1.72 g cm^{-3} up to 50 cm depth in Grey Floodplain soil of Jamalpur; from 1.67 at 10 cm depth to 1.78 g cm^{-3} at 55 cm depth of Grey Floodplain soil of Rajbari (Dinajpur); and 1.43 g cm^{-3} at 23 cm depth to 1.76 g cm^{-3} in Dark Grey Calcareous Floodplain soil.

An increasing trend of soil bulk density with the increase in depth of soil was found by Khan *et al.* (1985). The values of bulk densities of Ishurdi soil under Dark Grey Calcareous Floodplain soil varied from 1.49 (0 - 23 cm depth) to 1.68 g cm^{-3} (60 - 80 cm); in Jessore soil under Calcareous Floodplain Soil varied from 1.38 to 1.53 g cm^{-3}; and in Dinajpur soil the values varied from 1.40 to 1.60 g cm^{-3}.

Khan *et al*. (1990) found an increasing trend of change in bulk densities with increasing depth of soil. The values ranged between 1.34 gcm^{-3} at 0.15 cm depth and 1.56 gcm^{-3} in Grey Terrace soil of Joydebpur. In Ishurdi soil under Dark Grey Calcareous Floodplain soil the values ranged between 1.30 gcm^{-3} (0-15 cm) and 1.36 gcm^{-3} at 80-105 cm depth.

Rahman and Islam determined the bulk density of Grey Floodplain Soil of Sonatala Series according to depth up to 90 cm. The values were 1.36 g cm^{-3} (0 - 15 cm), 1.42 (15 - 30 cm), 1.45 (30 - 45 cm), 1.48 (45 - 60 cm), 1.38 (60 - 75 cm) and 1.32 g cm^{-3} (75 - 90 cm).

Khan *et al*. (1991) reported that bulk density values in Hathazari soil under Grey Piedmont soil varied like other soils with depth. The lowest value of 1.40 gcm^{-3} was recorded at 45-60 cm depth. In Grey Floodplains soil of Rangpur the values of soil bulk density varied between 1.36 to 1.45 gcm^{-3}.

Islam *et al.* (1991) found the bulk density of 1.40 g cm^{-3} in a Red Brown Terrace soil of Sreepur.

Khan *et al*.(1990) found that bulk density values of Grey Floodplain soil varied from 1.30 gcm^{-3} (0-25) to 1.35 gcm^{-3} (75-100 cm) and the values in Grey Piedmonmt soil were 1.35 to 1.43 g cm^{3} at 0-25 cm and 75-100 cm depth, respectively.

Khan *et al.* (1998) found that in Grey Terrace Soil of Joydebpur the bilk density values ranged from 1.30 gcm^{-3} (0-25 cm depth) to 1.56 gcm^{-3} at 75-100 cm depth; the values of top layer (0-25) was 1.34 gcm^{-3} which increased further with depth increase in Calcareous Floodplain soil of Jessore; and in Grey Floodplain soil of Jamalpur the bulk density value of 1.40 gcm^{-3} was recorded at 0-25 cm which increased to 1.45 gcm^{-3} at 75-100 cm depth.

Khan *et al.* (1998) determined the bulk density depth wise from a soil of Tobacco Research Station of Bangladesh Agricultural Research Institute, located at Burirhat, Rangpur, representing Grey Floodplain soil. The lowest value of 1.39 gcm^{-3} was found at 0-15 cm depth and the highest value of 1.47 g cm^{-3} was found at 15-30 cm depth having sandy loam texture in both cases. With further increase of depth, the values were 1.42 and 1.44 gcm^{-3} at the 30-45 cm and 45-60cm depth respectively having silt loam texture.

2.2 Factors Affecting Soil Bulk Density

Bulk density, an important physical parameter is controlled a number of factors and also causes the changes in different soil parameters. Bulk density is altered by soil management and cropping practices. Intensive cultivation makes a soil more compact and increase the weight per unit volume. The addition of manures on the other hand, decreases bulk density. Tillage treatment has considerable influence on bulk density particularly in the surface and sub-surface layers. The decrease in bulk density in tilled treatment may be attributed to tillage which makes the soil loose and porous.

Tillage has considerable effects on soil bulk density. Soil physical property that is nearly always altered by tillage operation is bulk density. Soils having different properties respond to tillage treatment differently. Tillage leaves the soil loose would help to maintain low level of mechanical impedance for seed- environment.

Khan *et al*. (2000) found that bulk density varied at different depths due to different tillage treatments. Continuous minimum tillage practices resulted higher values of bulk density but conventional tillage in rice and deep tillage in wheat had little effects on soil bulk density. They also found that bulk density increased with depth in Chhiata Soil Series of Grey Terrace Soil (Madhupur Tract) having silty clay texture at the surface; and also in Darshana Soil Series of Calcareous Floodplain (Ganges Floodplain) Soil having silt loam texture at the surface.

Working with forest soils Haque and Karmakar (2009) determined soil bulk density four forest types and found that the values were ranged in between 1.13 and 1.95 g cm^{-3}, the exceptionally high value was found at 4 - 8 cm depth of 18-year mixed plantation (Table 10).

Table 8: Bulk Density at two soil depths on three hill positions in four forest types of Chittagong region in Bangladesh

Forest type	Soil Depth (in cm)	Bulk Density		
		Top	Middle	Bottom
18-year mixed	0-4	1.26	1.29	1.28

plantation	4-8	1.95	1.41	1.34
15-year acacia plantation	0-4	1.13	1.15	1.39
	4-8	1.15	1.28	1.47
7-year acacia plantation	0-4	1.20	1.37	1.32
	4-8	1.39	1.39	1.38
Sitapahar natural Forest	0-4	1.32	1.36	1.14
	4-8	1.35	1.39	1.32

Summarizing the values it can be said that Grey Terrace Soils have bulk density in between 1.30 to 1.56gcm^{-3}; Grey Floodplain Soils 1.30 to 1.78gcm^{-3}; Dark Grey Floodplain Soils 1.43 to 1.76gcm^{-3}; Dark Grey Calcareous Floodplain Soils 1.30-1.68gcm^{-3}; Calcareous Floodplain Soils 1.34 to 1.53gcm^{-3}; Non-calcareous Brown Floodplain Soils 1.40 to 1.60gcm^{-3}; Grey Piedmont Soils 1.35 to 1.56gcm^{-3}; and Red Brown Terrace Soil 1.40gcm^{-3}.

2.3 Recent Data on Soil Bulk Density

Though in Bangladesh there is very limited research or work done on soil bulk density, Department of Soil Science of Bangabandhu Sheikh Mujibur Rahman Agricultural University of Bangladesh (2010-2013) determined the bulk density of soils from 10 AEZ (AEZ 21 to 30). The results are presented in Table 11.

Table 9: Soil Bulk Density (g/cc) at Different Depth (cm) of Soils in Different Agro-ecological Zone of Bangladesh (2014).

AEZ No.	Land type	Depth (cm)	Soil Bulk Density (g/cc)	AEZ No.	Land type	Depth (cm)	Soil Bulk Density (g/cc)
21	Medium Highland	0-5	1.31	26	Medium Highland	0-5	1.39
		5-10	1.49			5-10	1.41
		10-15	1.70			10-15	1.56
		15-20	1.62			15-20	1.67
	Medium Lowland	0-5	1.29	27	Highland	0-5	1.34
		5-10	1.27			5-10	1.50
		10-15	1.37			10-15	1.64
		15-20	1.34			15-20	1.58
	Lowland	0-5	1.13		Medium Highland	0-5	1.28
		5-10	1.18			5-10	1.45
		10-15	1.15			10-15	1.66
		15-20	1.19			15-20	1.58
22	Medium Highland	0-5	1.29		Medium Lowland	0-5	1.34
		5-10	1.37			5-10	1.59
		10-15	1.47			10-15	1.61
		15-20	1.49			15-20	1.65
	Medium Lowland	0-5	1.24	28	Highland	0-5	1.37
		5-10	1.28			5-10	1.45
		10-15	1.29			10-15	1.53
		15-20	1.28			15-20	1.58
	Lowland	0-5	1.02		Medium Highland	0-5	1.35
		5-10	1.03			5-10	1.46
		10-15	1.15			10-15	1.56
		15-20	1.16			15-20	1.60

AEZ No.	Land type	Depth (cm)	Soil Bulk Density (g/cc)	AEZ No.	Land type	Depth (cm)	Soil Bulk Density (g/cc)
23	Highland	0-5	1.39		Medium Lowland	0-5	1.23
		5-10	1.47			5-10	1.30
		10-15	1.55			10-15	1.42
		15-20	1.51			15-20	1.47
	Medium Highland	0-5	1.24		Lowland	0-5	1.03
		5-10	1.37			5-10	1.07
		10-15	1.47			10-15	1.10
		15-20	1.49			15-20	1.12
24	Highland	0-5	1.29	29	Highland	0-5	1.42
		5-10	1.36			5-10	1.45
		10-15	1.37			10-15	1.46
		15-20	1.32			15-20	1.50
25	Highland	0-5	1.54		Medium Highland	0-5	1.24
		5-10	1.65			5-10	1.28
		10-15	1.73			10-15	1.38
		15-20	1.73			15-20	1.38
	Medium Highland	0-5	1.12	30	Highland	0-5	1.41
		5-10	1.38			5-10	1.45
		10-15	1.42			10-15	1.46
		15-20	1.48			15-20	1.49
26	Highland	0-5	1.34		Medium Highland	0-5	1.27
		5-10	1.53			5-10	1.47
		10-15	1.64			10-15	1.49
		15-20	1.62			15-20	1.37

2.4 Conclusion

In Bangladesh little works have been done on soil bulk density. Most of the works have been done as part of research specially for obtaining PhD, MPhil or MS degree. A very few data on soil bulk density have been generated in SRDI. Other than research for degree, Department of Soil Science of Bangabandhu Sheikh Mujibur Rahman Agricultural University of Bangladesh (2010-2013) determined the bulk density of soils of 10 Agro Ecological Zones (AEZ 21 to 30) of Bangladesh. Most of the data generated by different agencies showed that soil bulk density of the soils of Bangladesh is near to typical bulk density that is 1.33 g/cc.

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Appendix 1. Agro-ecological Zone and Soil Organic Matter Status of Bangladesh

AEZ No.	Name of AEZ	1985	2005		2012	
		SOM status	Major Land Type	SOM	Major land Type	SOM
1	Old Himalayan Piedmont Plain	Mostly Med. to High and very High	High land (58%)	L-M	High land (58%)	L-M
			Medium Highland (34%)	L-M	Medium Highland (34%)	L-M
2	Active Tista Floodplain	Low	Medium Highland (72%)	L	Medium Highland (72%)	L-M
3	Tista Meander Floodplain	Low to Medium	High land (35%)	L	High land (35%)	L-M
			Medium Highland (51%)	L	Medium Highland (51%)	L-M
4	Karatoya-Bangali Floodplain	Low to Medium	High land (23%)	L	High land (23%)	L-M
			Medium Highland (44%)	L	Medium Highland (44%)	L-M
			Medium Lowland (14%)	L	Medium Lowland (14%)	L-M
5	Lower Atrai Basin	Medium	Medium Lowland (21%)	M	Medium Lowland (21%)	L-M
			Lowland (65%)	M	Lowland (65%)	L-M
6	Lower Punarbhaba Floodplain	Medium to High	Lowland (14%)	M	Lowland (60%)	L-M
7	Active Brahmaputra-Jamuna Floodplain	Low	Medium Highland (37%)	L	Medium Highland (37%)	L-M
			Medium Lowland (20%)	L	Medium Lowland (20%)	L-M
8	Young Brahmaputra - Jamuna Floodplain	Low to Medium	Highland (18%)	VL-L	Highland (18%)	L-M
			Medium Highland (42%)	VL-L	Medium Highland (42%)	L-M
			Medium Lowland (19%)	L	Medium Lowland (19%)	L-M
9	Old Brahmaputra Floodplain	Low to Medium	Highland (28%)	L	Highland (28%)	L-M
			Medium Highland (35%)	L	Medium Highland (35%)	L-M
			Medium Lowland (25%)	L	Medium Lowland (20%)	L-M
10	Active Ganges	Low	Highland (12%)	L	Highland (12%)	L-M

AEZ No.	Name of AEZ	1985	2005		2012	
		SOM status	Major Land Type	SOM	Major land Type	SOM
	Floodplain		Medium Highland (33%)	L	Medium Highland (33%)	L-M
			Medium Lowland (18%)	L	Medium Lowland (18%)	L-M
11	High Ganges River Floodplain	Low to Medium	Highland (43%)	L	Highland (43%)	L-M
			Medium Highland (32%)	L-M	Medium Highland (32%)	L-M
			Medium Lowland (12%)	L-M	Medium Lowland (12%)	L-M
12	Low Ganges River Floodplain	Low to Medium	Highland (13%)	L	Highland (13%)	L-m
			Medium Highland (29%)	L-M	Medium Highland (29%)	L-M
			Medium Lowland (31%)	L-M	Medium Lowland (31%)	L-M
			Lowland (14%)	L	Lowland (14%)	M
13	Ganges Tidal Floodplain	Medium to High	Medium Highland (78%)	L-M	Medium Highland (78%)	L-M
14	Gopalganj-Khulna Beels	Medium to High	Medium Highland (13%)	H	Medium Highland (13%)	H
			Medium Lowland (41%)	H	Medium Lowland (41%)	H
			Lowland (28%)	H	Lowland (28%)	H
			V. Lowland (11%)	H	V. Lowland (11%)	H
15	Arial Beel	Medium	Medium Lowland (13%)	M-H	Medium Lowland (13%)	M
			Lowland (73%)	M-H	Lowland (73%)	M
16	Middle Meghna River Floodplain	Low	Medium Lowland (29%)	L-M	Medium Lowland (29%)	L-M
			Lowland (25%)	M	Lowland (25%)	L-M
			V. Lowland (11%)	M	V. Lowland (11%)	L-M
17	Lower Meghna River Floodplain	Low to Medium	Highland(14%)	L-M	Highland(14%)	M
			Medium Highland(28%)	L-M	Medium Highland(28%)	L-M
			Medium Lowland(31%)	L-M	Medium Lowland(31%)	L-M
18	Young Meghna Estuarine Floodplain	Low	Medium Highland(45%)	L-M	Medium Highland(45%)	M-Opt
19	Old Meghna		Medium	L-M	Medium Highland(24%)	L-M

AEZ No.	Name of AEZ	1985	2005		2012	
		SOM status	Major Land Type	SOM	Major land Type	SOM
	Estuarine Floodplain	Medium	Highland(24%)			
			Medium Lowland(33%)	M	Medium Lowland(33%)	L-M
			Lowland(21%)	M	Lowland(21%)	L-M
20	Eastern Surma-Kusiyara Floodplain	Medium	Medium Highland(25%)	L-M	Medium Highland(25%)	L-M
			Medium Lowland((20%)	L-M	Medium Lowland((20%)	L-M
			Lowland (36%)	M	Lowland (36%)	L-M
21	Sylhet Basin	Medium	Medium Lowland(19%)	L-M	Medium Lowland(19%)	L-M
			Lowland(43%)	M	Lowland(43%)	M
			Very Lowland(32%)	M	Very Lowland(32%)	M
22	Northern and Eastern Piedmont Plains	Low to Medium	Highland(33%)	VL-L	Highland(33%)	L-M
			Medium Highland(31%)	VL-L	Medium Highland(31%)	L-M
			Medium Lowland(16%)	L	Medium Lowland(16%)	L-M
23	Chittagong Coastal Plain	Low to Medium	Highland(17%)	L-M	Highland(17%)	L-M
			Medium Highland(43%)	L-M	Medium Highland(43%)	L-M
			Medium Lowland(13%)	M	Medium Lowland(13%)	L-M
24	St. Martin's Coral Island	Low to Medium	Highland(33%)	VL-L	Highland(33%)	VL-L
			Medium Highland(63%)	VL-L	Medium Highland(63%)	VL-L
25	Level Barind Tract	Very low	Highland(30%)	VL-L	Highland(30%)	L-M
			Medium Highland(55%)	VL-L	Medium Highland(55%)	L
26	High Barind Tract	Low	Highland(93%)	VL-L	Highland(93%)	L-M
27	North Eastern Barind Tract	Low	Highland(36%)	VL-L	Highland(36%)	L-M
			Medium Highland(56%)	VL-L	Medium Highland(56%)	L-M
28	Madhupur Tract	Low	Highland(56%)	L	Highland(56%)	L-M
			Medium	L	Medium Highland(18%)	L-M

AEZ No.	Name of AEZ	1985	2005		2012	
		SOM status	Major Land Type	SOM	Major land Type	SOM
			Highland(18%)			
29	Northern and Eastern Hills	Low	Highland(92%)	L-M	Highland(92%)	L-M
30	Akhaura Terrace	Low	Highland(55%)	VL-L	Highland(55%)	L-M
			Medium Highland(11%)	VL-L	Medium Highland(11%)	L-M
			Medium Lowland(10%)	VL-L	Medium Lowland(10%)	L-M
			Lowland(15%)	VL-L	Lowland(15%)	L-M

Note: Very high - 5.5%, High- 3.4 - 5.5%, Medium - 1.7 - 3.4%, Low - 1.0 - 1.7% and Very Low - <1.0%.

Appendix 2. Organic Carbon Content (%) and Organic Carbon Stock (t/ha) at Different Depth (cm) of Soils in Different Agro-ecological Zone of Bangladesh (2014).

AEZ No.	Land type	Depth (cm)	Organic Carbon Content (%)	Organic Carbon Stock (t/ha)
21	Highland	-	-	-
	Medium Highland	0-5	0.91	5.96
		5-10	0.80	5.96
		10-15	0.72	6.25
		15-20	0.62	5.04
	Medium Lowland	0-5	0.96	6.07
		5-10	0.90	5.59
		10-15	0.82	5.61
		15-20	0.74	4.83
	Lowland	0-5	1.15	6.29
		5-10	1.05	6.02
		10-15	0.97	5.48
		15-20	0.87	5.06
22	Highland	-	-	-
	Medium Highland	0-5	1.05	6.68
		5-10	0.90	6.07
		10-15	0.77	5.55
		15-20	0.66	4.58
	Medium Lowland	0-5	0.95	5.73
		5-10	0.79	4.85
		10-15	0.78	4.69
		15-20	0.77	4.55
	Lowland	0-5	1.39	7.09
		5-10	1.38	7.11
		10-15	1.36	7.82
		15-20	1.11	6.44
23	Highland	0-5	0.31	2.15
		5-10	0.26	1.89
		10-15	0.22	1.67
		15-20	0.19	1.45
	Medium Highland	0-5	0.57	3.88
		5-10	0.42	2.80
		10-15	0.33	3.35
		15-20	0.27	1.96
24		0 -5	0.41	2.61

AEZ No.	Land type	Depth (cm)	Organic Carbon Content (%)	Organic Carbon Stock (t/ha)
	Highland	5-10	0.38	2.60
		10-15	0.35	2.42
		15-20	0.30	2.00
25	Highland	0 - 5	0.75	5.77
		5-10	0.59	4.80
		10-15	0.42	3.58
		15-20	0.32	2.76
	Medium Highland	0 - 5	1.02	5.50
		5-10	0.73	4.81
		10-15	0.58	3.93
		15-20	0.46	3.24
26	Highland	0 - 5	0.64	4.23
		5-10	0.45	3.31
		10-15	0.27	2.15
		15-20	0.21	1.64
	Medium Highland	0 - 5	0.65	4.48
		5-10	0.51	3.58
		10-15	0.33	2.61
		15-20	0.24	1.89
27	Highland	0 - 5	0.88	5.76
		5-10	0.62	4.55
		10-15	0.42	3.44
		15-20	0.36	2.77
	Medium Highland	0 - 5	0.89	5.68
		5-10	0.70	4.99
		10-15	0.42	3.46
		15-20	0.35	2.74
28	Highland	0 - 5	0.79	6.40
		5-10	1.07	6.83
		10 -15	0.48	3.64
		15-20	0.38	3.01
	Medium Highland	0 - 5	0.97	6.49
		5-10	0.78	5.61
		10 -15	0.55	4.24
		15 - 20	0.38	3.04
	Medium Lowland	0 - 5	1.17	7.11
		5 -10	1.07	6.83
		10-15	0.93	6.51
		15 -20	0.83	5.97

AEZ No.	Land type	Depth (cm)	Organic Carbon Content (%)	Organic Carbon Stock (t/ha)
	Lowland	0 - 5	1.33	6.84
		5 - 10	1.33	7.10
		10- 15	1.17	6.44
		15- 20	1.04	5.86
29	Highland	0 - 5	0.76	5.00
		5 - 10	0.67	4.78
		10 - 15	0.60	4.35
		15 - 20	0.53	3.96
	Medium Highland	0 - 5	1.02	6.23
		5 - 10	0.98	6.14
		10 - 15	0.82	5.56
		15 - 20	0.71	4.84
30	Highland	0 - 5	0.78	5.44
		5 - 10	0.59	4.22
		10 - 15	0.49	3.52
		15 - 20	0.45	3.27
	Medium highland	0 - 5	0.96	6.04
		5 - 10	0.71	5.06
		10 - 15	0.66	4.65
		15 - 20	0.59	3.56
Very high - 5.5%, High- 3.4 - 5.5%, Medium - 1.7 - 3.4% Low - 1.0 - 1.7% and Very Low - <1.0% *				

*Fertilizer Recommendation Guide, 1989, BARC

Appendix 3. Land Type -wise Average status of Soil Organic Matter (SOM) in Different Agro Ecological Zones (AEZ) of Bangladesh (Hasan and Rahman, 2016).

AEZ Number	Agro Ecological Zones	Land Type	OM (%)
01	Old Himalayan Piedmont Plain	High land	2.18
		Medium high land	2.22
		Medium Low land	2.22
02	Tista Floodplain Active	High land	1.99
		Medium high land	2.03
		Medium low land	1.96
03	Meander Floodplain Tista	High land	2.18
		Medium high land	2.14
		Medium low land	2.19
		Low land	1.80
		Very Low land	1.61
04	Karatoya-Bangali Floodplain	High land	2.20
		Medium high land	2.15
		Medium low land	2.32
		Low land	2.54
		Very Low land	3.79
05	Lower Atrai Basin	High land	2.32
		Medium high land	2.14
		Medium low land	2.26
		Low land	2.12
		Very Low land	3.39
06	Lower Purnabhaba Floodplain	High land	2.55
		Medium high land	1.74
		Medium low land	2.07
		Low land	2.27
		Very Low land	1.49
07	Active Brahmaputra JamunaFloodplain	High land	1.91
		Medium high land	2.14
		Medium low land	2.10
		Low land	2.14
		Very Low land	8.29
08	Young Brahmaputra and JamunaFloodplain	High land	2.06
		Medium high land	2.19
		Medium low land	2.14
		Low land	2.11
		Very Low land	2.09
09	Old Brahmaputra	High land	2.22

AEZ Number	Agro Ecological Zones	Land Type	OM (%)
	Floodplain	Medium high land	2.34
		Medium low land	2.04
		Low land	2.02
		Very Low land	1.90
10	Active Ganges Floodplain	High land	1.82
		Medium high land	2.21
		Medium low land	2.23
		Low land	1.98
		Very Low land	2.01
11	High Ganges River Floodplain	High land	2.18
		Medium high land	2.23
		Medium low land	2.14
		Low land	2.20
		Very Low land	1.98
12	Low Ganges River Floodplain	High land	2.08
		Medium high land	3.39
		Medium low land	1.20
		Low land	1.63
		Very Low land	2.01
13	Ganges Tidal Floodplain	High land	2.20
		Medium high land	2.04
		Medium low land	2.08
		Low land	1.86
14	Gopalganj-Khulna Beds	High land	2.08
		Medium high land	2.27
		Medium low land	2.02
		Low land	I .91
		Very Low land	1.70
15	ArialBeel	Medium high land	1.81
		Medium low land	2.21
		Low land	1.81
		Very Low land	1.72
16	Middle Meghna River Floodplain	High land	0.90
		Medium high land	2.19
		Medium low land	1.94
		Low land	2.22
		Very Low land	1.95
17	Low Meghna River Floodplain	High land	1.76
		Medium high land	2.05
		Medium low land	2.13
		Low land	2.37
		Very Low land	1.20

AEZ Number	Agro Ecological Zones	Land Type	OM (%)
18	Young Meghna Estuarine Floodplain	High land	1.59
		Medium high land	1.93
		Medium low land	1.90
		Low land	1.90
		Very Low land	1.96
19	Old Meghna Estuarine Floodplain	High land	2.12
		Medium high land	2.09
		Medium low land	2.18
		Low land	2.03
		Very Low land	1.98
20	Eastern Surma-Kushiara Floodplain	High land	1.83
		Medium high land	2.04
		Medium low land	2.06
		Low land	2.01
		Very Low land	1.94
21	Eastern Sylhet Basin	High land	2.22
		Medium high land	2.06
		Medium low land	1.92
		Low land	2.00
		Very Low land	1.93
22	Northern and Piedmont Floodplain	High land	2.11
		Medium high land	2.10
		Medium low land	1.94
		Low land	2.11
		Very Low land	2.50
23	Chittagong Coastal Plain	High land	1.97
		Medium high land	2.30
		Medium low land	2.17
		Low land	2.82
24	Saint Martin's Coral Island	High land	0.59
25	Level Barind Tract	High land	2.09
		Medium high land	2.09
		Medium low land	2.08
		Low land	2.76
26	High Barind Tract	High land	2.00
		Medium high land	2.17
		Medium low land	2.79
		Low land	2.05
		Very Low land	1.38
27	North - Eastern Barind	High land	2.19

AEZ Number	Agro Ecological Zones	Land Type	OM (%)
	Tract	Medium high land	2.20
		Medium low land	2.47
		Low land	2.03
28	Madhupur Tract	High land	1.97
		Medium high land	2.13
		Medium low land	2.01
		Low land	1.99
		Very Low land	1.96
29	Northern and Eastern Hills	High land	1.96
		Medium high land	1.98
		Medium low land	1.94
		Low land	1.85
		Very Low land	1.94
30	Akhaura Terrace	High land	2.40
		Medium high land	1.59
		Medium low land	2.15
		Low land	2.35
		Very Low land	1.85
Very high - 5.5%, High- 3.4 - 5.5%, Medium - 1.7 - 3.4% Low - 1.0 - 1.7% and Very Low - <1.0% *			