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ASSESSMENT OF SOIL QUALITY IN BANGLADESH WITH ORGANIC CARBON AS THE INDICATOR PROPERTY

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Abstract

In recent years, soil quality has become a burning issue in the management of agricultural lands all over the world. A lot of information on soil quality are available, presently most of which have been done by the soil scientists of the developed world. There exists no direct method of determining soil quality. Light on soil quality can be shed with the help of some key soil properties called indicators of soil quality. Organic matter in soil has assumed a central position in determination of soil quality. Unfortunately till to date, no serious thinking on soil quality has been attempted in Bangladesh. In this paper, an attempt has been made to report the results of assessment of soil quality using organic carbon as the indicator property. Results show that there is no significant change of organic matter contents in the studied soil over the years.

Introduction

With only eight million hectares of agricultural land, Bangladesh is making desperate strides in becoming self-sufficient in food for its gradually booming population. Most of the agricultural lands in Bangladesh have become multiple cropped, or are in the process of becoming so meaning thereby, that these are cultivated more than once every year for producing food crops[(1)]. The impacts of these multiple cropping on soil health has never been monitored carefully. The linkages between soil productivity and soil quality are logical because productivity is a critical function of innumerable reactions that constantly occur in soil[(2)]. The importance of soil productivity becomes clear when one considers that around 14 humans depend on the produce of one hectare of cultivated land for their sustenance[(3)]. A number of factors are responsible for the reduction of agricultural land in Bangladesh. The continuing increase of population that are taking away good productive land for urbanization is appearing as a big problem. On the other hand, loss of land due to river bank erosion is turning millions of people landless, shelterless and destitute thus intensifying poverty on the one hand and increasing dependence on the remaining land on the other. For long, soil organic matter (SOM) has been regarded as the best surrogate for soil quality, since SOM reflects the residual intake of plants and soil

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organisms that have lived and died in the soil. Innumerable functions of SOM include development and maintenance of soil structure, nutrients and organic carbon storage and maintenance of biological activity. The SOM is the primary source as well as sink for many plant nutrients in agro-ecosystems, maintenance of soil tilth, infiltration of air and water, promotion of water storage, reduction of erosion and controlling and fate of agrochemicals (Fig. 1). Threshold values or critical limits of some key soil properties may be useful in predicting soil quality[4]. Such mechanism must be based on long-term soil management experiments conducted on bench mark soil sites in principal agro-ecological regions[5].

The strategy here is to establish some pedochemical functions based on cause-effect relationships and yield response functions for some selected key soil properties. There is an urgent need for widespread realization that soil is a living and largely non-renewable resource and a framework for sustained soil quality assessment and maintenance mechanisms must be developed[2]. Gaunt[6] hinted at the development of an efficient soil quality monitoring system (SQMS) for Bangladesh for monitoring soil productivity on a sustainable basis. Gaunt (l.c.) warned that any failure to protect the productive capability of soil against degradation may bring about a catastrophe for the nation. For rating the agricultural soils and to measure their productivity potential, Bangladesh at present has no soil quality monitoring system (SQMS) in use. There is need, therefore, for developing a SQMS.

This paper attempts to discuss the concept of soil quality as well as to make an attempt to assess soil quality of some representative Upazilas of Bangladesh using organic carbon as the solo indicator property.

Concept of soil quality: Soil quality has been defined as the condition and capacity of soil, its environmental and biological properties, for purposes of production, conservation and management[7]. Maintenance of soil quality is considered as a fundamental element in discussion on sustainable agricultural production. Doran and Parkin[8] noted that soil quality is immensely important and should be monitored to provide early warnings of adverse trends or problems on land. As a complex functional state, soil quality is not directly measureable, but may be inferred from many measurable soil properties termed SQ indicator properties[9]. The choice of indicator properties is likely to be related to the context in which the investigator views soil quality and the available facilities. Productive and sustainable use of land resources requires development of quantitative soil quality indicators (SQI). Doran *et al.*[10] noted that the required information and database from which SQI's may be derived must be invented.

As noted above, the chosen soil quality indicators should be measureable soil attributes that influence the capacity of soil to perform crop production or environmental functions. Therefore, management sensitive attributes are most desirable in any experiment of soil quality assessment[11]. These authors further noted that in the major agro-ecological regions of Bangladesh the important agronomic soil attributes are soil depth, organic matter, respiration, aggregation, texture, bulk density, infiltration, available N, P, K and retention capacity.

Doran *et al*.[(10)] and Larson and Pierce[(12)] studied closely the problem of determining soil quality and proposed the concept of minimum data set (MDS) which encompass physical, chemical and biological indicators for screening the quality of soils. The physical indicators are texture, depth of soil for rooting, infiltration, bulk density and water holding capacity; the chemical indicators are soil organic matter, pH and extractable NPK and the biological indicators are microbial biomass, biomass carbon and nitrogen, potentially mineralizable N and soil respiration. Most often, texture is related to retention and transport of water and chemicals.

Going still further, Doran and Parkin[(8)] proposed a performance based index of soil quality that could be used to provide an evaluation of soil functions with regard to the major issues of sustainable productivity, environmental quality and human welfare as a whole. They proposed a soil quality index (SQ) as follows: SQ = f (SQE1, SQE2, SQE3, SQE4, SQE5, SQE6) where SQE1 is soil productivity, SQE2 is erosivity, SQE3 is ground water quality, SQE4 is surface water quality, SQE5 is air quality, SQE6 is food quality. Soil quality thus has been linked with human quality.

Among many other researchers, Schnitzer[(13)] and Monreal *et al.*[(14)] developed conceptual models emphasizing the role of SOM as a soil quality indicator encompassing environmental and socio-economic parameters (Fig. 1). Soil environmental conditions

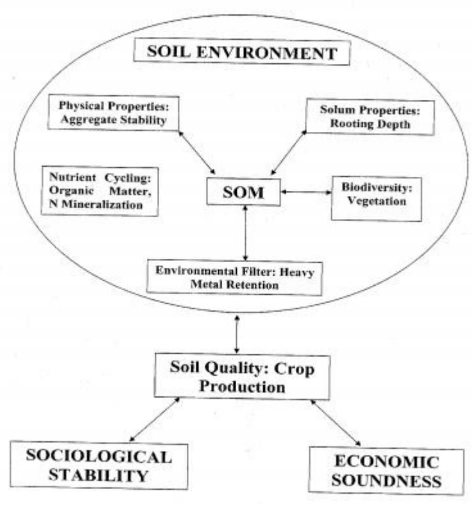

Fig. 1. A conceptual model for soil organic matter (SOM) as a soil quality indicator linking soil environment with socio-economic stability. (Modified from Schnitzen, 1995) and Monreal *et al*. 1998).

like soil structure, rooting depth, nutrient cycling, biodiversity and heavy metal retention etc. can be directly related to soil organic matter which, in turn, determines crop productivity as well as soil environmental quality. Thus, the quality of the soil has been related to the economic prosperity of the society. Therefore, the link between organic matter in soil and the socio-economic condition of the population is quite intimate.

Materials and Methods

Eight Upazilas in various areas and tracts of Bangladesh were selected in assessing soil quality on the basis of soil organic matter as the key indicator. The selected Upazilas belong to different physiographic regions and their soils were developed on various parent material types and moisture regimes. The information on these eight Upazilas studied for the assessment of soil quality has been presented in Table 1. The geographical location of these Upazilas is shown in Fig 2. Soil samples were collected from each Upazila on one kilometer grid basis. Each grid represents the cutting point of one minute

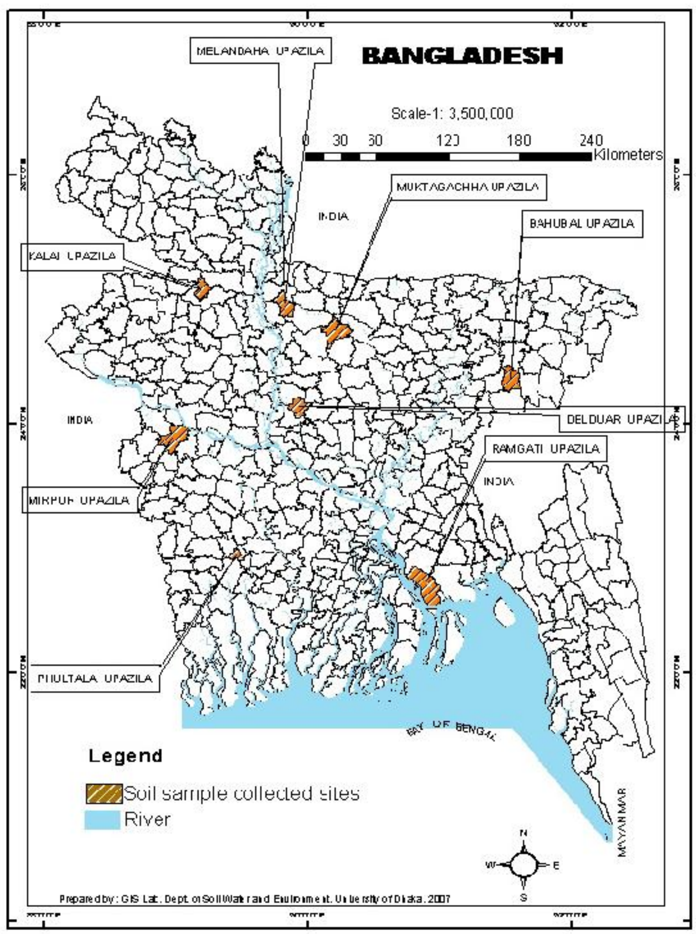

Fig. 2. Location map of selected eight Upazilas of Bangladesh for study of their soil quality.

longitude and latitude. The design and soil sampling sites in Delduar Upazila of Tangail district have been presented as an example in Fig 3. A total of 534 surface and 534 sub-surface soil samples were collected from the eight Upazilas. Soil samples were taken to the laboratory and analyzed for organic carbon (SOC) by wet oxidation method of Walkley and Black as described by Jackson(15). SOM was calculated by multiplying soil organic carbon values with 1.724 (Van Bemmelen factor). Mean organic carbon and organic matter in the surface and sub-surface soils of eight Upazilas were determined.

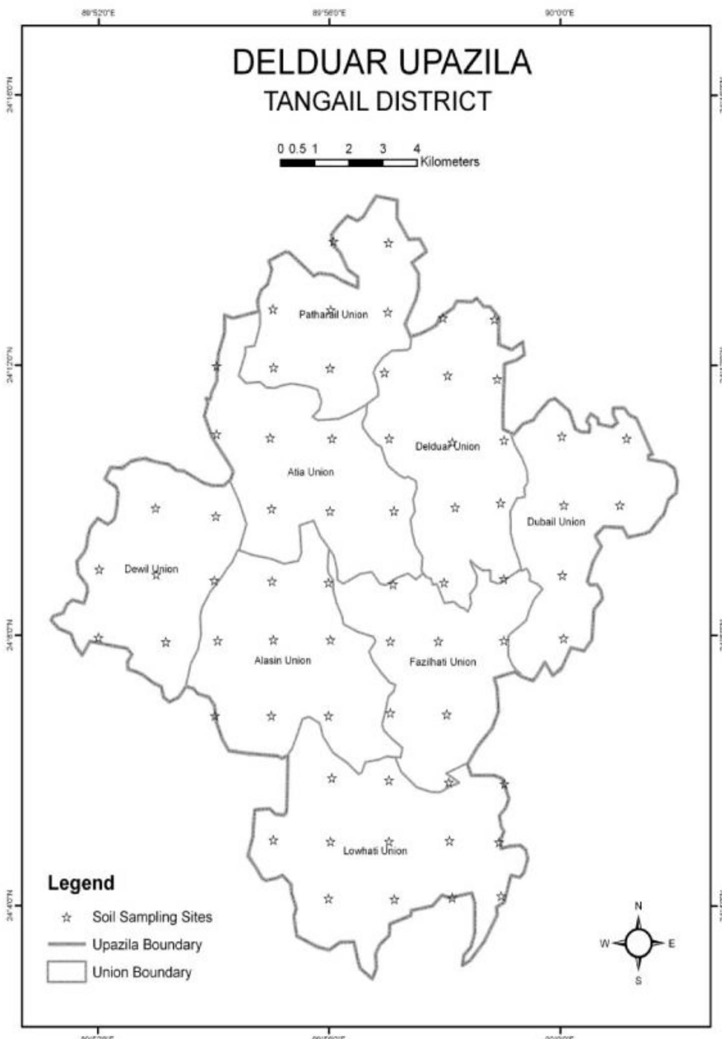

Fig. 3. Soil sampling sites in Delduar Upazila of Tangail district on grid basis.

In Bangladesh, SRDI Staff(18) studied soils for more than half a century through various projects. They collected and determined organic carbon in surface soils only from the above eight Upazilas of Bangladesh in their work on 'Land and Soil Resource Utilization

Table 1. Information on the eight selected Upazilas in Bangladesh studied for assessment of soil quality.

Name of Upazilas(16)	Name of districts	Location (Latitude, longitude)	Total annual rainfall (mm)(17)	Physiographic units	Area (ha)	Popula-tion	Population density (persons/ha)
Bahubal	Habiganj	24° 16′ & 24° 27′ N 91° 29′ & 91° 38′ E	4279	Piedmont plain and Surma-Kushiara floodplain	24,861	1,37,402	6
Delduar	Tangail	24° 03′ & 23° 14′ N 89° 51′ & 90° 02′ E	1606	Brahmaputra floodplain	18,097	1,48,718	8
Fultala	Khulna	22° 54′ & 23° 01′ N 89° 23′ & 89° 31′ E	1842	Gangetic floodplain and Peat	7,438	90,341	12
Kalai	Joypurhat	24° 58′ & 25° 11′ N 98° 08′ & 98° 17′ E	1692	Barind tract	16,636	1,14,183	7
Melandah	Jamalpur	24° 51′ & 25° 04′ N 89° 33′ & 89° 54′ E	2075	Old and Young Brahmaputra floodplain	23,992	2,06,917	9
Mirpur	Kushtia	23° 47′ & 24° 01′ N 88° 51′ & 89° 07′ E	1458	Gangetic floodplain	30,454	1,99,903	7
Muktagacha	Mymensingh	24° 36′ & 24° 52′ N 90° 05′ & 90° 21′ E	2267	Brahmaputra floodplain and Madhupur tract	31,290	2,56,906	8
Ramgati	Lakshmipur	22° 30′ & 22° 52′ N 90° 46′ & 91° 04′ E	3205	Coastal Plain	48,358	3,35,243	7
Total/Mean	-	-	2303	-	2,01,126	1,489,613	8

Guides' (LSRUG), popularly known as the 'Upazila Nirdeshika'. Organic carbons in 501 soil samples from the selected eight Upazilas were determined by SRDI Staff. Results of soil organic carbon (SOC) from the LSRUG reports of the above eight selected Upazilas were compiled and the mean SOC and SOM were computed. The computed SOC and SOM results of SRDI were compared with those results determined by the present Land Quality Assessment (LQA) project[(3)]. Soil quality in the eight selected Upazilas was thus inferred by comparing the results of LQA project with those of the SRDI. Statistical analysis of the results regarding SOC and SOM were done by t-test using SPSS.

Results and Discussion

Results of the mean SOC and SOM contents of the soils of the eight studied Upazilas have been presented in Table 2. This table embodies quite a large storehouse of information on organic carbon in soils under study. The grand mean of the organic carbon of all the eight Upazilas for the surface and sub-surface soils were 1.18 and 0.75%, respectively. While in terms of organic matter, the grand mean of all the eight Upazilas for the surface and sub-surface soils were 2.03 and 1.28%, respectively. Universally, the SOC and SOM contents in the mineral soils are higher in the surface and decreases slowly with depth. The results show that no significant changes in organic carbon and organic matter contents in the studied soils have taken place over time (Table 2). The comparison of the SOC contents of SRDI with those of LQA project has also been shown in Fig 4. Compared with the SRDI results, soil organic carbon contents in the LQA project show a slight increase in all but one soil. But the differences are not statistically significant (t = 0.773, Table 2). One conclusion from these results is that in spite of the multiple cropping there is no decrease of organic carbon in the soils.

The reason for no appreciable change in organic matter contents over the years in the studied soils may be higher intake of organic carbon in the form of crop residues. Because of multiple cropping, the organic matter intake occurs several times from every crop in a year. It is noticeable that although significant changes have not taken place, the overall level of organic matter in the studied soils is quite low, like many other tropical soils. A good soil should have at least 2.5% organic matter, but in Bangladesh most of the surface soils have <1.5% and some soils even have <1% organic matter.[(19)]. Karim and Iqbal[(20)] reported that the organic carbon level in most of the arable mineral soils of Bangladesh is generally low and its quantity is believed to be gradually decreasing. They reported that the SOM contents ranged from 0.3 to 1.5% in the upland areas, 1.5 to 2.0% in the medium lowland area and 2.0 to 3.5% in the lowland areas. Thus, in general low organic matter content is a problem in most agricultural soils of Bangladesh. This is due to its tropical location where both moisture and temperature is high (Table 2).

Table 2. Soil organic carbon (SOC) contents in the soils of eight selected Upazilas in Bangladesh.

Name of Upazilas	Sampling year		Sampl-ing depth	No. of soil samples		Organic carbon (%)			Mean organic matter (%)		Diff. of means (%)
	SRDI*	LQA**		SRDI	LQA	Mean SRDI	Mean LQA	Diff. of mean	SRDI	LQA	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bahubal	1992	2005	S[1]	67	41	1.45	1.47	+0.02	2.50	2.53	+0.03
			SS[2]		41		0.8			1.38	
Delduar	1990	2003	S	36	66	1.51	1.31	-0.2	2.60	2.25	-0.35
			SS		66		0.58			0.99	
Fultala	1989	2004	S	27	26	1.37	1.55	+0.18	2.36	2.67	+0.31
			SS		26		1.12			1.93	
Kalai	1997	2006	S	40	54	0.86	1.04	+0.18	1.48	1.79	+0.31
			S		54		0.81			1.40	
Melandah	1991	2003	S	61	84	0.84	1.03	+0.19	1.44	1.77	+0.33
			SS		84		0.98			1.68	
Mirpur	1992	2004	S	66	96	0.66	0.74	+0.08	1.13	1.27	+0.14
			SS		96		0.49			0.84	
Muktagacha	1993	2003	S	75	84	0.72	1.24	+0.52	1.24	2.13	+0.89
			SS		84		0.61			1.05	
Ramgati	1997	2005	S	129	83	0.93	1.05	+0.12	1.60	1.80	+0.20
			SS		83		0.58			0.99	
Total/	-	-	S	**501**	**534**	**1.04**	**1.18**	**+0.14**	**1.79**	**2.03**	**+0.24**
Grand mean			SS		**534**		**0.75**			**1.28**	

[1] S = Surface soils (0 - 15 cm), [2] SS = Sub-surface soils (15 - 30 cm); ($t = 0.771$, $df = 14$, $p = 0.453$).
*SRDI = Soil Resources Development Institute, **LQA = Land Quality Assessment Project, D.U.

The mean of organic carbon in the studied upazilas differ from one another (column 7 and 8 of Table 2). This is true for the results of both SRDI and LQA projects (Table 2 and Fig 4). Highest organic carbon is found in Fultala and the lowest in the Mirpur upazilas. This variation may be due to the differences in soil management practices.

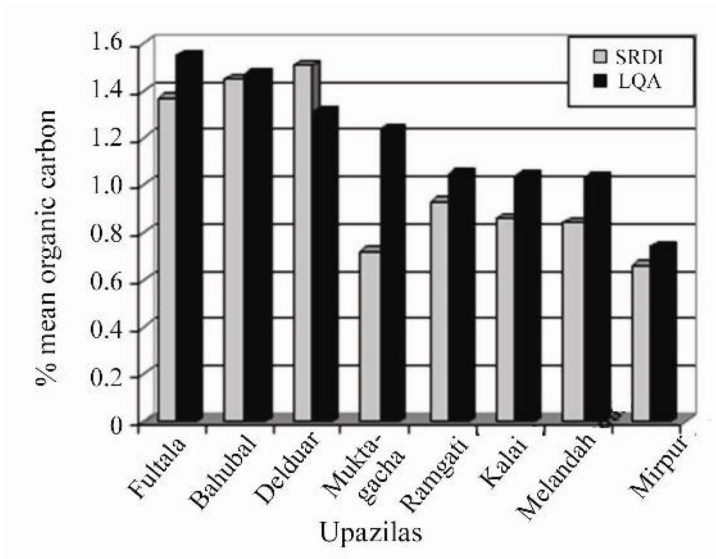

Fig. 4. A comparison of means of percent organic carbon in soils from eight selected Upazilas as analyzed by the SRDI and LQA project.

Rice is the most extensive crop and is grown over 90 per cent of the agricultural soils in these eight Upazilas. Small areas are used for growing other crops. The contents of organic matter in the soils of these eight Upazilas can be treated as representative for other soils in Bangladesh. The addition of organic matter and its humification under wet condition are influenced by (i) rate of biomass addition through litter fall and crop residues, (ii) root biomass and its distribution with depth, (iii) biomass organic carbon especially activity of soil macro-fauna, e.g. earthworms, termites, and (iv) soil fertility management including use of inorganic fertilizers and organic amendments. Soil degradation processes decrease SOM and increase the magnitude of its decomposition. The processes leading to a decline in the SOM content are (i) mineralization and oxidation of organic substances, (ii) soil erosion, and (iii) leaching. The equilibrium level of SOM depends on the balance between processes that are responsible for increase and decrease organic matter contents[14]. The rate of change of organic matter in soil depends on its amount and the management practices[21].

The introduction of high yielding varieties like Boro rice has helped in increasing total grain crop production while the SOM remains unchanged. SRDI[22] also reported that organic matter trends show a slight increase in some rice-rice cropping areas under water logged conditions. Although the SOC in the rice soils of Bangladesh is low, these have high potential as a carbon sink. Similar views have been reported by Paustian *et al.*[23] in some soils in the United States. It is possibly true that the declining productivity of the country's soils is the result of depletion of organic matter due to increasing cropping intensity, higher rates of decomposition of organic matter under the prevailing hot and humid climate, use of lesser quantities of organic manure, little or no use of green manure practices[20]. Crop residues and animal manure are widely used as fodder and fuel, respectively in Bangladesh and thus are not returned to the soil. Eighty one per cent of the crop residues are used as fuel for domestic cooking[24].

Management of soils is important in accumulation and sequestration of organic matter. In Bangladesh at present the cropping intensity is gradually increasing. Under changing cropping intensity no sustainability in soil condition is possible. Under this situation, equilibrium in organic matter level in soil cannot be established[25]. As noted before in Bangladesh, most of the single cropped land has already been or is being turned into double cropped land and double cropped land into triple cropped land. In this transitional stage of soil management practices organic carbon level will remain unstable. In this connection, Cheng[26], Cassman *et al.*[27] and Nambiar[28] reported that soil organic matter levels tend to increase under irrigated rice cropping practice in soils.

Under condition of continuous cultivation for a long time, organic residues are decomposed and the SOC content tends to reach an equilibrium level[29]. The magnitude of SOC at the equilibrium states depends on many factors including climate, land use and cropping system. At present, in the agricultural soils of Bangladesh the management pattern is undergoing change (from mono- to triple cropping with rice-rice pattern). Soil management pattern is in a transitional stage. It will take time to establish an equilibrium under the existing condition. The traditional rice varieties have been replaced by HYV and hybrid rice which is cultivated throughout the year, i.e., twice or thrice a year, creating a virtual year round anaerobic soil condition which helps in slowing down organic matter decomposition. The important message that the results in Table 2 presents is that the SOM contents in Bangladesh soils do not shows any tendency to decrease in spite of multiple cropping. It is suggested that more work on the state of soil quality in Bangladesh should be initiated with no loss of time as the issue is ultimately related to food production capacity as well as overall food security for a population of 160 million.

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