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Comparative Insights for Investigation of Soil Fertility Degradation in a Piedmont Area which Cover the Anjamkhor Union of Baliadangi Upazila, Thakurgoan, Bangladesh

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Abstract: *A comparative study of plant nutrient changes between the years 1991 to 2012 in the north-eastern piedmont soils of Anjamkhor Union, Thakurgoan district, Bangladesh was done to determine soil fertility degradation status. Plant nutrient status was compared based on soil analytical data from soil survey program of the Soil Resource Development Institute (SRDI), Ministry of Agriculture, Bangladesh. This comparative study results revealed that soil fertility status was higher during the period 1990's. Afterwards, soil fertility status has been changed with time causing fertility decline. Soil acidity, organic matter content and some plant nutrients have been reached beyond their critical levels. Soil organic matter has increased by 1% from the years 1991 to 2012 but present OM status is still low and inadequate (mean 1.62%). During this period, soil acidity has become strongly acidic beyond a critical level causing acidity intrusion (mean pH 4.82). Soil phosphorus has been increased sharply in a very higher level (mean value 78.76 µg/gm). While the status of calcium has been decreased sharply (mean 0.30 meq/100 gm, 69% decline) but potassium (mean 0.29 meq/100 gm) and magnesium (mean 0.64 meq/100 gm) has been found to be increased. Sulphar was also found to be decreased sharply by 72% between years 1991 to 2012. Micronutrients zinc (64% decline) and boron (82% decline) has been almost depleted reaching their critical level during the time period 1991 to 2012, and are causing crop productivity and yield decline. These study findings are not comparable to within or between field variability of nutrients rather compared on the basis of landscape scale. But it is evident that soil fertility is declining in the study area under north-eastern Piedmont soil of Bangladesh.*

Key words: *Piedmont soils, plant nutrients, fertility, pH, organic matter, cations and micronutrients*

I. Introduction

Soil and land resource with adequate productivity are required to challenge the ever increasing demand of food in Bangladesh. Sustainable soil management is needed for the production increase in resource poor country like Bangladesh. But to meet up the demand of food intensive agricultural practices based on agro-chemicals have been dominating the cropping system since last few decades. The sustainability, environmental acceptability and land degradation have been greatly ignored to obtain increased food production. Thus, soil fertility has been declined remarkably specially in the areas where the landuse intensification is higher and inefficient. More specifically, the conventional intensified agriculture based on external inputs has caused the degradation of agricultural land and the environment greatly. Moreover, soils usually changed through the agricultural activities, including cultivation, tillage, weeding, terracing, sub soiling, deep ploughing, manure and fertilizer addition, liming, draining, irrigation and impoldering (Bridges and Bakker, 1997). As consequence, soil degradation occurs which is the loss of actual or potential productivity and utility, and soil degradation implies a decline in the soil's inherent capacity to produce economic goods and perform environmental regulatory functions (Lal, 1997). Now, it is imperative to determine plant nutrient status and or soil fertility changes for better understanding and sustainable use of soil resource for the future. The sustainability of permanent cropping system is largely affected by the judicious management of the soil chemical fertility. But the decision on justified soil management requires investigation of soil nutrient status. There is a need for soil fertility decline trend to ensure optimum nutrient management and to design sustainable cropping systems in Bangladesh.

There has been an intensification of land use and an expansion of crop cultivation in the studied area of Anjamkhor Union, Baliadangi, Thakurgoan, Bangladesh. As a result, the null hypothesis is that the soil fertility has declined and this decline is perceived to be widespread. The total amount of a nutrient in the soil declines when the output exceeds the input over a given period of time, soil depth and at a certain location. The input and output of nutrients consist of various factors governed by complex and interacting soil processes. Factors affecting soil fertility decline are additions, removals, transfers and transformations of nutrients (Hartermink, 2003). Furthermore, in agricultural ecosystems, nutrients are removed with the yield and residues, where as nutrients may be added with inorganic fertilizers or other amendments. Soil pH, Organic matter (OM), Phosphorus (P), Sulphur (S), Potassium (K), Calcium (Ca), Magnesium (Mg), Zinc (Zn) and Boron (B) are studied for their changes in this study. Because, intensive agriculture causes the soil fertility decline as evidenced by decline in crop productivity and economic yield. The study was undertaken to determine soil nutrients changes between a time span of 1991 to 2012. The initial and current soil fertility status will be compared and analyzed. Thus, the nature and extent of soil fertility degradation could be perceived. Findings will be helpful for efficient and justified soil management, and the development of a sustainable cropping system will be efficient and realistic.

II. Materials and Method

Study location: The experimental site covers the Anjamkhor Union of Baliadangi Upazila, Thakurgoan District, Bangladesh. The studied site covers an area of 3732 ha in the northwestern corner of the country and comprises gently sloping land at the foothills of the Piedmont area with colluvial and alluvial sediments derived from the hills deposited by rivers or streams (Brammer, 1996).

Soil nutrient changes: The study included soil nutrients data analyzed in the year 2012 and compared with the soil nutrient data analyzed in the year 1991. The trends of soil nutrient status were determined and interpreted, and the nutrients critical levels are shown in appendix according to FRG (2005). However, the rates of change in soil nutrient decline for different soils have been calculated following the formulae of Hartermink, 2003:

$$\Delta = \left(\frac{x_2 - x_1}{x_1}\right) \times 100\%$$

Where, Δ = the rate of change in %

x_1 = the initial value of the variable at sampling time t_1

x_2 = the final value of the variable at sampling time t_2

The soil samples where x_1 and x_2 were determined came from the studied sites of similar soil series and landuse. The period between the soil samplings t_2- t_1 varied from 2012 to 1991 years.

Soil sampling and analysis: Soil sampling was done in the year 1991 under the national soil survey program and in the year 2012 by the food security survey program of Soil Resource Development Institute, Bangladesh. 13 soil samples were collected in 1991 and 25 soil samples were collected in 2012. For the year 1991, 13 samples were collected each from 400 km^2 and while in 2012, 25 samples were collected each from 200 km^2. Samples were collected based on soil series and landuse. Composite samples were collected from the upper 0-15 cm of depth. Soil pH was measured as described by Jackson (1962). Organic matter was determined by wet oxidation method (Page *et al.*, 1982). Available P was extracted by Bray and Kurtz (1945) methodology. The P in the extract was then determined by developing blue color absorbance with Ammonium molybdate-ascorbic acid solution and measuring the color by Spectrophotometer at 890 *n*m wavelength (Petersen, 2002). Available S content was determined, as described by Petersen, 2002. The S content in the extract was determined turbidimetrically and the turbid was measured by spectrophotometer at 535 *n*m wavelength. Exchangeable K content was determined by extraction with 1M ammonium acetate, pH 7.0 solution followed by determination of extractable K by flame photometer. Exchangeable Ca and Mg content were determined by extraction with 1M ammonium acetate, pH 7.0 solution followed by measurement by atomic absorption spectrometer (Petersen, 2002).

III. Results and Discussion

Soil organic matter (SOM): The soil organic matter content has increased during the time span of 1991 to 2012 by 1% (Table 1). The mean soil organic matter in the year 1991 was 0.62 % which has become 1.62 % by the year 2012, SOM changed by +173% (Figure 1a). This OM content is still not adequate for agricultural systems. However, the increase in soil organic matter might be affected by landuse and agricultural practices of the area. During the 1990's agricultural lands were under one or two crop cultivation, some areas were remain as fallow or grazing lands. Vegetables were cultivated in some parts of highland areas. Mango orchard is also found in some parts of the studied areas. After the 1990's the demand of increased food, agricultural intensification has occurred in the area. Different high yielding varieties were introduced for cultivation and OM applied externally during crop cultivation.

Soil pH: The soil pH for the year 1991 was found between 5.4-6.0, while it was observed between 4.4-5.4 by the year 2012 (Figure 1b). There has been a noticeable increase in soil acidity in the studied area, soil pH changed by -15% (Table 1). The soil has become more acidic. This acidity status is critical for plant growth and nutrient uptake, thus hampering plant productivity greatly. The mean value for 1991 was 5.70 and for the 2012 mean was found 4.82 (Table 1). Such a decrease of soil pH value is crucial and need to be resolved for the optimum growth and productivity. The cropping pattern has become intensified from 1991 to 2012, which has caused the use of chemical and organic fertilizers to attain maximum yield. Imbalance and or excessive use of chemical fertilizers, mostly nitrogen based fertilizer, have caused the increase in soil acidity of the area. The decrease in soil pH is causing loss of base and nutrient content, consequently results in the decrease of crop yield and the long term soil fertility decline (Wang et al., 2010). It is inefficient to apply excessive chemicals for maximum yield. The inappropriate use of nitrogenous fertilizer and build up in organic matter has caused the increase in soil acidity of the studied area.

Table 1. Status, critical level, mean differences and percent (%) changes in soil property and plant nutrients from the year 1991 to 2012 in the Anjamkhor union, Thakurgoan district of Bangladesh

Soil property	Mean		Critical Level*	Mean difference		Maximum		Minimum		Std. dev.	
	2012	1991		Change	(%)	2012	1991	2012	1991	2012	1991
pH	4.82	5.69	4.5-5.5	-0.87	-15%	5.40	6.10	4.40	5.40	0.26	0.18
OM	1.69	0.62	1.0-1.7	+1.07	+173%	2.52	1.20	0.97	0.20	0.46	0.32
P	78.76	18.67	5.0	+60.1	+322%	160	39.0	19.3	10.0	38.58	9.87
S	5.84	19.00	10	-13.2	-72%	20.5	34.0	2.20	9.00	5.02	8.33
K	0.29	0.08	0.12	+0.15	+188%	0.38	0.13	0.14	0.03	0.08	0.03
Ca	0.30	0.97	2.0	-0.67	-69%	0.49	1.60	0.12	0.50	0.08	0.35
Mg	0.64	0.40	0.5	+0.24	+60%	0.97	0.70	0.25	0.02	0.17	0.17
Zn	0.37	1.03	0.6	-0.66	-64%	0.76	2.20	0.18	0.40	0.15	0.57
B	0.20	1.13	0.2	-0.93	-82%	0.32	1.50	0.12	0.75	0.06	0.23

pH (1:2.5 soil: water); OM (%); $P_{bray \& karz}$, S, Zn, B (µg /gm); K, Ca, Mg (meq/100 gm). *Appendix

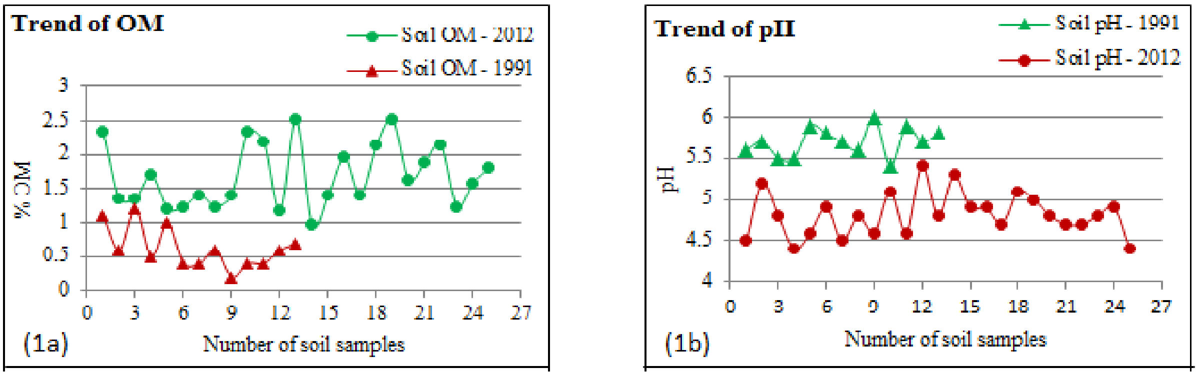

Figure 1a, 1b. Trends of soil organic matter (OM) and pH between the years 1991 and 2012 period

Soil Phosphorus (P): There has been a sharp increase in soil phosphorus overtime, changed by +322% from the year 1991 to 2012 (Figure 2a). P mean value of the area was 15.08 for the year 1991 while it was found 78.76 in the year 2012 (Table 1). The status of P rises from almost a lower level to a very higher level. This might be caused due to the increase of soil acidity and for the inherent characteristics of the parent materials of the soils of studied area. The variability of P in the studied site is high as indicated by higher variance and standard deviation values (Table 1). This variation may be caused by soil pH, representative soil samples and residual effect of P based fertilizers of earlier season. However, the plant available P (orthophosphate form) is determined by the soil pH. Maximum plant available P occurs at approximately pH around 7.0. As pH changes in either direction, P availability is decreased. But, the current pH value of the studied area is around 4.5, which is detrimental for plant growth. In strongly acid soils, most of the P is bound and not released for plants. As for example, at a soil pH above 5.5 most of the phosphates react with calcium to form calcium phosphates. Below pH 5.5, aluminum is abundant and will react more readily with the phosphates. Calcium phosphates are relatively more water soluble than aluminum phosphates. For the studied site, it is evident that the status of soil P is very high, but unfortunately due to highly acidic nature of the soils, P remains unavailable for plants uptake. Ali et al., 1997 mentioned that the decrease in P availability in old Himalayan piedmont plain might be associated with fixation, plant uptake and inadequate phosphorus fertilization.

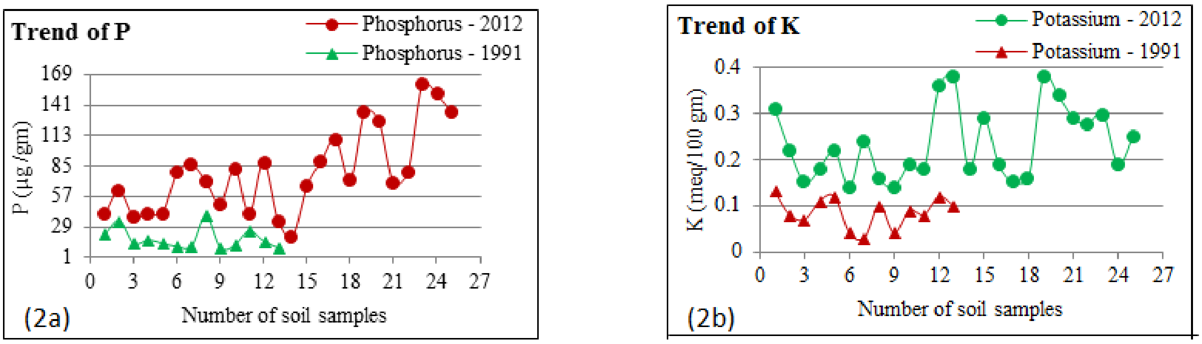

Figure 2a, 2b. Trends of Phosphorus (P) and Potassium (K) between the years 1991 and 2012 period.

Exchangeable Cations (Ca, K and Mg) and Sulphur (S): The status of Ca and S was found to be decreased but K and Mg status was found to be increased (Table 1). The level of Ca and S reduction is more evident, Ca changed by -69% and S changed by -72%. While the mean level of Mg increase was observed by 60%, which might be due to application of Mg during maize cultivation in the recent years. The initial K status was medium (mean 0.09) but soil K has been increased in optimum level, changed by +188% by the year 2012. The current mean value is 0.29 (Table 1). This might be caused due to the application of more inorganic fertilizers such MOP in the intensified agricultural systems of the area. In addition, the increase in the content of exchangeable K in the piedmont soil is usually affected by parent material and/or irrigation (Ali et al., 1997). The decrease in the exchangeable Ca and S level might be related to leaching losses (Cresser et al., 1993). Moreover, initial Ca status was in critical level. However, apart from leaching plant uptake played an important role in the depletion of these nutrient cations since Ca and S are not adequately applied in the soils, and partly explains the general decline of nutrient elements.

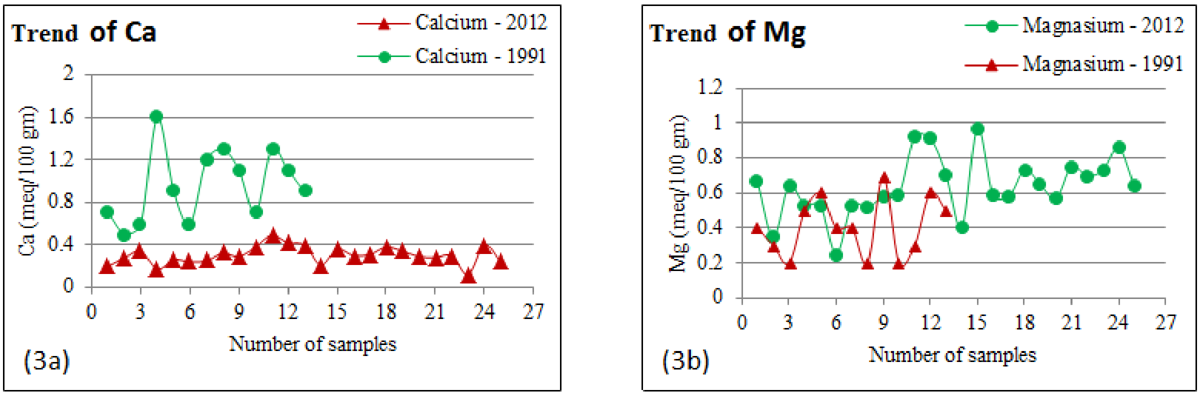

Figure 3a, 3b. Trends of Calcium (Ca) and Magnesium (Mg) between the years 1991 and 2012 period.

Micronutrients (Zn and B): The status of Zn in the year 1991 was optimum (mean 1.01) while the status of B was even in a higher level (mean 1.13). Overtime from 1991 to 2012, soil Zn and B reserve have been depleted, changed by -64% and -82% respectively (Table 1). For both the micronutrient, a sharp decreased is noticed. This might be caused due the intensive agriculture and without any further nutrient supplements. In the year 2012, the status of Zn has been found to be very low (mean 0.37) and the status of B found even lower than Zn (mean 0.20). Micronutrients are the essential elements required by plants though required in low concentrations (Prasad et al., 2006). Patal and Singh (2009) mentioned that the driver for higher agricultural production without balanced fertilizers has created problems of soil fertility exhaustion and plant nutrient imbalances not only for major but also of secondary and micronutrients. This could be a case for this studied area.

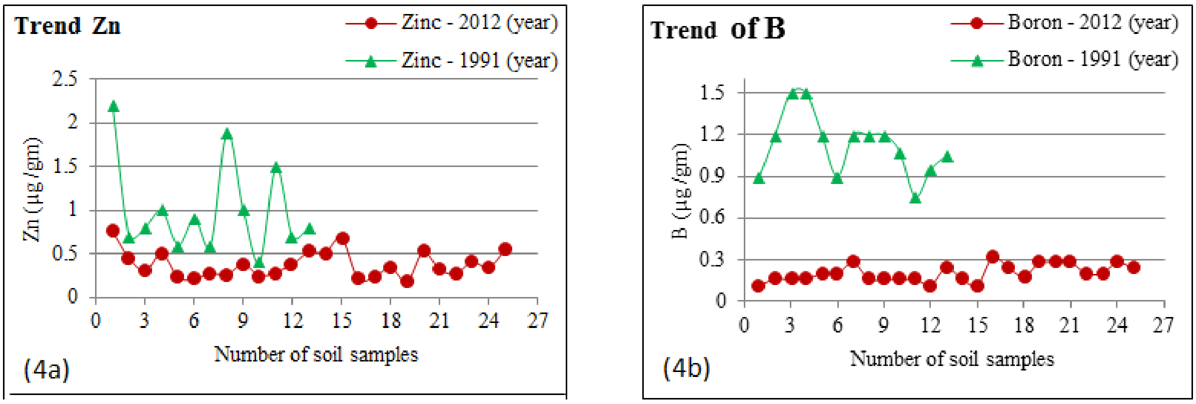

Figure 4a, 4b. Trends of Zinc (Zn) and Boron (B) between the years 1991 and 2012 period.

IV. Conclusion

Soil nutrients data of the study revealed that soil characteristics have been changed unfavorably to limit plant productivity and yield. Soil organic matter has increased by 1%, though it is insufficient for agricultural systems. Soil acidity has been increased in a critical level towards acidity intrusion (mean pH 4.82). Soil phosphorus has been increased sharply in a very high level (mean value 78.76 µg/gm) and remains unavailable for plant uptake due to acidity intrusion and fixation. While the status of calcium and sulphur has been decreased sharply (mean 0.30 meq/100 gm, 69% decline and mean 5.84 meq/100gm, 72% decline respectively) from the year 1991 to 2012. But potassium (mean 0.29 meq/100 gm) and magnesium (mean 0.64 meq/100 gm) has been found to be increased to nearly optimum level, which might be due to use of chemical fertilizer during crop cultivation. Soil zinc (64% decline) and boron (82% decline) has been almost depleted from the study area during 1991 to 2012 causing crop productivity and yield decline. Although, these findings are not comparable for within field variability neither between field variability rather comparable at landscape scale or soil series or soils under similar cropping pattern. However, the depletion of soil fertility in the studied area is mainly due to intensive exploitation of soils and or soil nutrients beyond its bearing/replenish capacity by the high yielding varieties without proper replenishment and unbalanced doses of fertilizers. The findings of this study revealed that the derivative processes of soil fertility degradation in the piedmont soils of Bangladesh are progressing. This is an indication for the need to reverse or restore the soil natural fertility status from current critical nutrients status to increase crop productivity and efficient farming.

References

[1]. Ali, Md. Mohsin, S.M. Saheed, Daisuke Kubota, Tsugiyuki Masunaga & Toshiyuki Wakatsuki, 1997. Soil degradation during the period 1967–1995 in Bangladesh, Soil Science and Plant Nutrition, 43:4, 879-890.
[2]. Brammer, H. 1996. The Geography of the soils of Bangladesh. The University Press Limited, Dhaka, Bangladesh.
[3]. Bray, R. H. and Kurtz, L. T. 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Science 59: 39-45.
[4]. Bridges, E.M. and de Bakker, H. 1997. Soils as an artefact: human impacts on the soil resource. The Land 1, 197–215.
[5]. Hartemink, Alfred E. 2003. Soil fertility decline in the tropics: with case studies on Plantations. CABI Publishing, UK.
[6]. FRG, 2005. Fertilizer Recommendation Guide, 2005. Bangladesh Agriculture Research Council (BARC), Dhaka, Bangladesh.
[7]. Jackson, M.L. 1962. Soil Chemical Analysis. Prentice Hall Inc., Engle wood, Clift, N.J.p 143.
[8]. Lal, R. 1997. Soil quality and sustainability. In: Lal, R., Blum, W.H., Valentin, C. and Stewart, B.A. (eds) Methods for Assessment of Soil Degradation. CRC Press, Boca Raton, pp. 17–30.
[9]. Page, A. L., Miller, R. H. and Keeny, D. R. 1982. Methods of Soil Analysis. Part-I and Part-II. 2nd Ed. Ani. Soc. Agron. Inc. Madi., Wis., USA.
[10]. Patel, K.P. & Singh, M.V. 2009. Scenario of micro - and secondary - nutrients deficiencies and their management in soils and crops of arid and semi- arid regions of Gujarat. The Proceedings of the International Plant Nutrition Colloquium XVI, Department of Plant Sciences, UC Davis, UC Davis.
[11]. Petersen, L. 2002. Soil Analytical Methods. Soil, Water, Plant Material, Fertilizer. Soil Resource Management and Analytical Services. Soil Resource Development Institute, Danida Kampsax, Dhaka.
[12]. Prasad, M.N.V. 2006. Trace elements in the environment: Biogeochemistry, Biotechnology and Bioremediation. CRC Press pp.726.
[13]. Wang Dingyong AB, Shixing LiA and Xiaojun ShiA, 2010. Effect of agricultural practices on soil acidification in acid precipitation area. 19th World Congress of Soil Science, Soil Solutions for a Changing World 1 – 6 August 2010, Brisbane, Australia.

Appendix

Interpretation of soil test values based on critical limits, and critical status of pH and organic matter

Nutrient Element	**Critical limit**	**Method of extraction**
P (µg/g)	7.0	Bray & Kurtz method (Acid soils)
S (µg/g)	10.0	Calcium dihydrogen phosphate extraction
K (meq/100g)	0.12	N NH4OAc method
Ca (meq/100g)	2.0	N NH4OAc method
Mg (meq/100g)	0.5	N NH4OAc method
Zn (µ/g)	0.6	DTPA extraction
B (µg/g)	0.2	Calcium chloride extraction
Soil property	**Level**	**Status and Method of extraction**
pH	4.6-5.5	Strongly acidic, 1:2.5 soil:water
Organic matter (%)	1.0-1.7	Low status, Wet oxidation method

Source: Fertilizer Recommendation Guide (FRG), 2005 and Soil Resource Development Institute (SRDI) Bangladesh.