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# Evaluation of Soil Fertility Level on Present Crop Practice in Munshiganj and Comilla Districts of Bangladesh

Mohammad Rezaul Karim*

Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki 305–8572, Japan

Crop productivity and soil management are dependent on and also affect soil fertility. Farmers apply fertilizer to boost production, but over time this can also lead to chemical imbalances in the soil, such as the accumulation of toxic elements or soil acidification, that reduce crop yields and cause farmers to react by increasing fertilizer application rates. Having observed this phenomenon in Bangladesh, I undertook the study reported herein in two districts of Bangladesh, where the main crop grown was potatoes in one district and rice in the other. The objective of the study was to evaluate soil fertility, nutrients, and organic matter. Ten samples were collected, one at each depth of 15 cm and 85 cm from five sites, three in Munshiganj and two in Comilla. The main soil textures were described and a suite of chemical properties was analyzed in the laboratory. The soil textures were silt clay loam to clay loam. The topsoil samples were strongly acidic to slightly acidic, with pH values ranging from 4.37 to 5.64. The cation exchange capacity (CEC) of the soil samples were high, ranging from 25.4 to 34.8 $cmol_c$ $kg^{-1}$. In general, high-CEC soils do not need to be limed as frequently as low-CEC soils; however, the low pH values at these sites suggest that liming is required to achieve optimal pH values. Exchangeable sodium was high, ranging from 5.85 to 76.72 $cmol_c$ $kg^{-1}$. Exchangeable calcium was low, ranging from 1.21 to 2.42. Exchangeable sodium percentage (ESP) levels were higher than 15%, indicating that the soils would be prone to dispersion, poor water infiltration, potential sodium toxicity to plants, and calcium deficiency. Soil organic carbon and total nitrogen content in topsoil samples ranged from 12.11 to 19.21 g $kg^{-1}$ and 1.35 to 2.25 g $kg^{-1}$, respectively. Overall, these results indicate that the soils have received excessive application of chemical fertilizer and that soil fertility had declined as a result through sodium toxicity and calcium deficiency. Regular soil sampling and communication of recommended application rates to farmers, as well as general awareness-raising activities on the subject of soil fertility, might help reduce the excessive application of fertilizer and lead to better soil fertility.

**Key words:** soil fertility, soil chemical properties, chemical fertilizer, crop practice, Bangladesh.

## Introduction

Bangladesh is a densely populated country in which the majority of the population is dependent on agriculture for food self-sufficiency and livelihood. Food production needs to be maximized to meet the increasing demands of the growing population. Rice and potatoes are the two main crops in Bangladesh in regard to both production and the human diet. Traditional farming systems and the indiscriminant use of artificial fertilizers and pesticides are degrading the soil and killing microorganisms, and this ultimately reduces soil respiration and soil fertility and has a direct negative influence on food production (Evanylo *et al*. 2009). Soil plays a vital role in the economy of the country, so information about soil quality is important to farmers, policy makers, and decision makers.

Soil of high quality is a prerequisite to ensuring stable food production. However, soil quality in Bangladesh has been degraded due to excessive use of chemical fertilizers, and hence farmers face difficulties in maintaining expected production levels. Of the total

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* Corresponding author: Executive Engineer (Admin), Local Government Engineering Department (LGED), 5th level, Agargaon, Sher - E-Bangla Nagar, Dhaka-1207, Bangladesh.
Tel: ＋88–01711–679101, E-mail: rezaullged@yahoo.com

nutrients used in the country, nitrogen alone constitutes 80%, which may lead to nutrient imbalance in the soil-plant systems. If this trend of fertilizer use continues along with intensive cultivation of high yielding crop varieties, the productivity of the soils is likely to be seriously affected (FRG, 2005).To address these problems, sustainable management options must be implemented to maintain soil fertility in the long term.

Conventional tillage involves intensive soil disturbance that promotes a rapid decline in soil organic matter and increases $CO_2$ emissions. It also leads to chemical, physical, and biological soil degradation processes that negatively affect crop productivity. In tropical and subtropical areas, where high temperatures and humidity accentuate soil degradation, a main goal of agricultural research should be the development of management systems that improve soil conservation and crop productivity (Bayer *et al*., 2000). Soil surveys can aid the development of management systems by providing an accurate and scientific inventory of soil types, their characteristics, and their distribution to inform management and to yield information on associated landforms, terraces, and vegetation (Brown *et al*., 1978).

A low pH value (high acidity) means the soil has many free hydrogen ions ($H^+$) in solution. These hydrogen ions make nutrients in the soil less available to plants. Lime (calcium or magnesium carbonate) is added to neutralize the acid in the soil. Cation exchange capacity (CEC) represents the total quantity of negative charge available to attract positively charged cations in the soil — primarily $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, and $Al^{3+}$. Cation exchange capacity is one of the most important chemical properties of soils and influences nutrient availability. Values of CEC can range from as low as 3 to 5 $cmol_c\ kg^{-1}$ for light sands to 20 to 50 $cmol_c\ kg^{-1}$ for clay loams and 50 to 100 $cmol_c\ kg^{-1}$ for organic soils (Deere and Company, 1997).

Majority plants perform best in slightly acid soil with a pH between 6.0 and 7.0. When the pH falls below 6.0, the availability of nutrients, such as phosphorus, potassium, calcium, and magnesium were decreases. If the pH is allowed to drop below 5.5, the availability of manganese and aluminum is increased to the some extend that they could become toxic to plants (Mitchell, 2000) Again, Hydrogen is added in the form of ammonia- ($NH_4^+$), and urea-based [CO $(NH_2)_2$] fertilizers. Therefore, using fertilizers containing ammonium to a soil, or even large quantities of organic matter, will finally increase the soil acidity and lower the pH. Soils are treated with lime to mitigate the harmful effects of low pH (aluminum or manganese toxicity) and to add calcium and magnesium to the soil. The amount of lime needed to achieve a certain pH depends on (1) the pH of the soil and (2) the buffering capacity of the soil. The buffering capacity is related to the CEC. The higher the CEC, the more exchangeable acidity (hydrogen and aluminum) is held by the soil colloids. As with CEC, buffering capacity increases with the amount of clay and organic matter in the soil. Soil with a high buffering capacity requires larger amounts of lime to increase the pH than soils with a lower buffering capacity. Lime reduces soil acidity (increases pH) by changing some of the hydrogen ions into water and $CO_2$. A $Ca^{2+}$ ion from the lime replaces two $H^+$ ions on the cation exchange complex. The carbonate ($CO_3^-$) reacts with water to form bicarbonate ($HCO_3^-$). These react with $H^+$ to from $H_2O$ and $CO_2$. The pH increases because the $H^+$ concentration has been reduced (Mitchell, 2000).

Total nitrogen (TN) associated with soil organic carbon (SOC) plays a key role in building soil fertility and enhancing soil productivity. The primary factors affecting SOC and TN are climate, plant productivity, soil texture (and its influence on internal drainage and aeration), and agricultural management practices, especially those that affect the type and amount of organic matter inputs to the soil, and the extent of soil disturbance (Paul *et al*., 1997).

Excessive application of chemical fertilizer is causing a decline in soil fertility in Bangladesh because soil acidification is leading to Ca deficiency and soil sodicity. Regular soil sampling and promulgation of information on recommended fertilizer application rates could help farmers to arrest such declines in soil fertility. In addition, the use of organic fertilizer and farmer's awareness of soil fertility needs to improve. Thus, the objective of this study was to evaluate soil fertility, nutrients, and organic matter in Munshiganj and Comilla districts of Bangladesh.

## Materials and Methods

### Study site description

Bangladesh has been tentatively divided into 30 agro-ecological zones (Banglapedia, 2006). The study area comprises two districts, Comilla (between 23° 27′ 00″ N and 91° 12′ 00″ E, total area of 3,085 $km^2$, population 4,595,557) within agro-ecological zone 22 with Northern and Eastern Piedmont Plain and Munshiganj (between $23^\circ 37' 00''$N and $90^\circ 33' 00''$E, total area 3,085.0 $km^2$, population 1, 497, 464) within agro-ecological zone 19 with Old Megna Estuarine Flood Plain (Fig. 1). The soils are predominately silt clay loam to clay loam, occurring as soil units of Calcareous Floodplain and Estuarine Floodplain. The total cultivable land is 2,37,352 ha in Comilla and 64,946 ha in Munshigonj. Rice (primary crop), jute, wheat, vegetables, and potatoes are the most common crops in Comilla, whereas potatoes (primary crop), corn, rice, mustard, and vegetables are the major crops in Munshiganj. The current average yield of potatoes is 30 t/ha in Munshigonj, and the yield for rice is 3.35 t/ha in Comilla, which is relatively low by world standards. However, the farmers of the study sites use excessive amounts of chemical fertilizer, 2220 kg/ha/y for potatoes in Munshiganj and 560 kg/ha/y for rice in Comilla (Table 1).The recommended fertilizer dose is 214 kg/ha/y for rice and 352 kg/ha/y for potato. The communities in the study sites depend solely on agriculture.

## Climate and hydrology

The climate is hot and humid in the summer rainy season (May to October) and cool and dry in the winter (November to April). Rainfall exhibits considerable spatial variation within short distances, with a range in annual averages of 1200–4500 mm. About 85% of rainfall occurs between May and October. Mean annual temperature is about 25℃ with mean monthly temperatures varying between 17℃ in January and 30 ℃ in April to May (Fig. 2). Minimum and maximum temperatures vary between about 8° and 40℃. The most striking feature of the country's hydrology is the seasonal cycle of flooding and drainage. The heavy rainfall between June and September comes at a time when the major rivers are already conveying large volumes of water from their upper catchments, thus causing flooding in the study area and the country at large.

## Soil sample analysis

Ten disturbed samples were collected by digging out box type hole (1.0 m×1.0 m×1.0 m), one at each depth of 15 cm and 85 cm from five sites, three in Munshiganj and two in Comilla. The sample sites location was selected through consultation meeting with

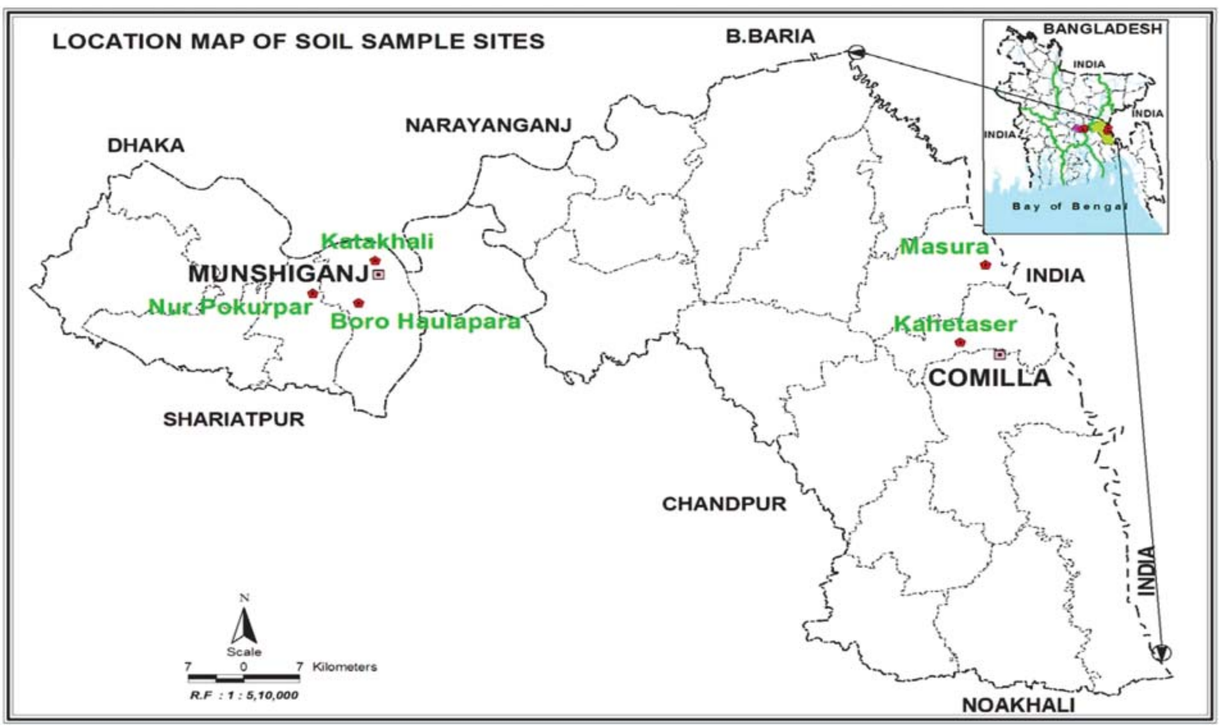


**Fig. 1.** Location map of soil sample sites.

**Table 1.** Key features of the study sites

| Inputs/Names | Munshiganj | Comilla |
|---|---|---|
| Land Size (ha) | 64,946 | 237,352 |
| Main crop grown | Potato | Rice |
| Current yield (t/ha) | 30.00 | 3.35 |
| Irrigation source | Ground and surface water | Groundwater |
| Soil Amendments (kg/ha/y) | 2220.0 (chemical fertilizer) | 560.0 (chemical fertilizer) |
| Soil texture | Silt clay loam | Clay loam |

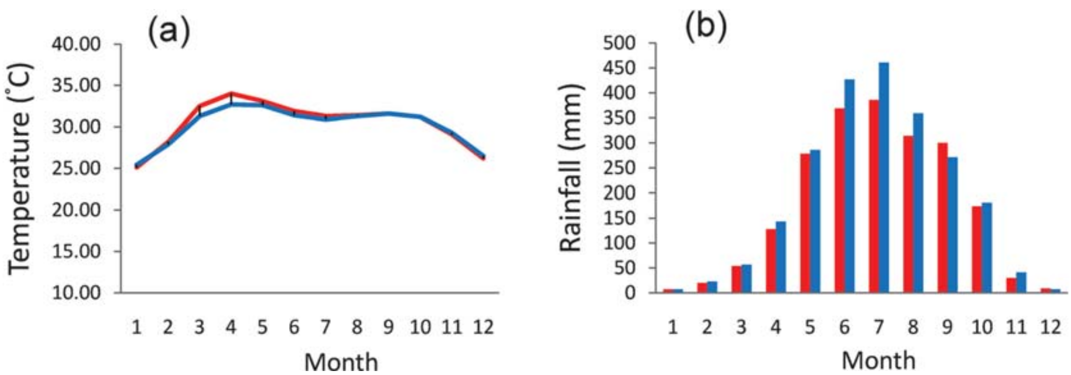


**Fig. 2.** (a) Monthly mean temperature in ℃ and (b) rainfall in (mm) in Munshiganj Comilla districts.

farmers and Agriculture extension officers of the two districts, where productivity of the crop was decreased day by day (Fig. 1). Four focus group discussion (FGD) was arranged in 4 sub-districts between farmers and agriculture extension officers and from the discussion it was found that the farmers of the study areas were using excessive chemical fertilizer in their field but they could not get expected production. Soil texture is one of the most important characteristics, which influences the physical properties of the soil and has great significance in land use and management. The soil field texture, consistency and soil color were determined by physical appearance and visual identification. The samples were air dried and sieved through 2 mm and 0.5 mm sieves. Identifiable crop residues, root material, and stones were removed during sieving and the sieved soil stored in 20 plastic containers. Samples of the soils were analyzed for soil pH, moisture content, CEC, exchangeable bases, soil organic carbon, total nitrogen, and soluble heavy metal content (Committee of Soil Environment Analysis, 1997). Soil sample pH values were measured in a 1 : 2.5 mixture of air-dried soil in distilled water and a 1 mol $L^{-1}$ KCl mixture using a glass electrode pH meter. Organic carbon and total nitrogen contents were determined with a Sumigraph NC-900 NC analyzer (Sumika Chemical Analysis Service, Tokyo, Japan). Exchangeable bases of $Ca^{2+}$, $Na^{+}$, $K^{+}$, and $Mg^{2+}$ were extracted with 1 mol $L^{-1}$ $CH_3COONH_4$ (pH 7.0) three times and quantified using inductively coupled plasma mass spectrometry (Optical Emission Spectrometer, Optima 7300 DV; PerkinElmer). Extractions were conducted with a soil-to-solution ratio of 1 : 5. To measure cation exchange capacity (CEC), the residues after exchangeable base extraction were washed with water and 80% ethanol. Samples were analyzed for $NH^{4+}$ by extraction three times with 1 mol $L^{-1}$ NaCl (pH 7.0) with a soil-to-solution ratio of 1 : 6, and quantification of extracted $NH^{4+}$ by a steam distillation method. Soluble heavy metals of Cu, Co and Ni were extracted with 1 mol $L^{-1}$ HCl for 1 h, and the extracts quantified using inductively coupled plasma mass spectrometry. The extractions were conducted with a soil-to-solution ratio of 1 : 10 (Committee of Soil Standard Analysis and Measurement, 1986).

## Results and Discussion

### Soil physical properties

The soil structure was found massive structure (coherent), where the entire soil horizon appears cemented in one great mass. This phenomenon was happened due to soils were sodic and contained high exchangeable sodium percentage (ESP) in all sites. The soils of the study areas ranged from silt clay loam to clay loam in both the topsoil and subsoil. Soil colors were determined for both dry and wet soil (Fig. 3). The color of the topsoil varied from gray to grayish yellow and the subsoil varied from light gray to dull yellow in a dry state and from olive black to yellowish brown in a wet state. The hardness of the soil samples was medium hard to very hard in a dry state in both topsoils and subsoils. The soil stickiness was slightly sticky to highly sticky in a wet state. There were no significant differences in soil texture, color, hardness and stickiness between topsoils and subsoils (Table 2).

### Chemical properties of the soil

### Soil pH

The pH ($H_2O$) of topsoils was strongly acidic to slightly acidic (4.37–5.64) and of subsoils, very slightly acidic to medium alkaline (5.92–7.97; Tables 3 & 4). The pH (KCl) of topsoils was also strongly acidic (3.04–5.04) and subsoil was strongly acidic to very slightly acidic (4.40–6.58). The pH ($H_2O$) values were higher than pH (KCl) values in both topsoil and subsoil samples.

The low pH values show that these soils had many free hydrogen ($H^+$) ions (high acidity) in the soil solution. Soil pH was influenced by parent soil materials and tends to decrease with time. Soils with low base ($Ca^{2+}$, $Mg^{2+}$, $K^+$, etc) status were sensitive to the acidifying effects of nitrogen fertilizers (including organic N sources). The addition of limestone is normally used to maintain soil pH in a desirable range. Lower or higher pH values could cause plant nutrient deficiencies (e.g., P, Mg, Zn, Cu, Fe, Mo) or elemental toxicities (i.e., Al, Mn), which had adverse effects on crop yield (Evanylo *et al*. 2009).

### Cation exchange capacity

The cation exchange capacity (CEC) ranged from 25.4 to 34.80 $cmol_c\ kg^{-1}$ in the topsoil samples and 9.20 to 41.80 $cmol_c\ kg^{-1}$ in the subsoil samples (Tables 3 & 4). Cation exchange capacity represents the total quantity of negative charge available to attract cations, primarily $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, and $Al^{3+}$, per unit mass of soil.

### Exchangeable base cations $Na^+$, $K^+$, $Ca^{2+}$ and $Mg^{2+}$

The exchangeable base cations in the topsoil samples ranged from 5.85 to 76.72 for $Na^+$, 4.84 to 6.62 for $K^+$, 1.21 to 2.42 for $Ca^{2+}$ and 0.89 to 10.25 for $Mg^{2+}$. The values of exchangeable base cations in the subsoil samples ranged from 16.65 to 27.20 for $Na^+$, 5.29 to 6.36 for $K^+$, 0.73 to 3.65 for $Ca^{2+}$ and 2.32 to 20.17 for $Mg^{2+}$ (Tables 3 & 4), which is to say that there were no pronounced differences between the topsoils and the subsoils. The concept of base cations is important because the relative proportion of acids and bases on the exchange sites determines the soil's pH. As the number of $Ca^{2+}$ and $Mg^{2+}$ ions decreases, the number of $H^+$ and $Al^{3+}$ ions increases, and the pH

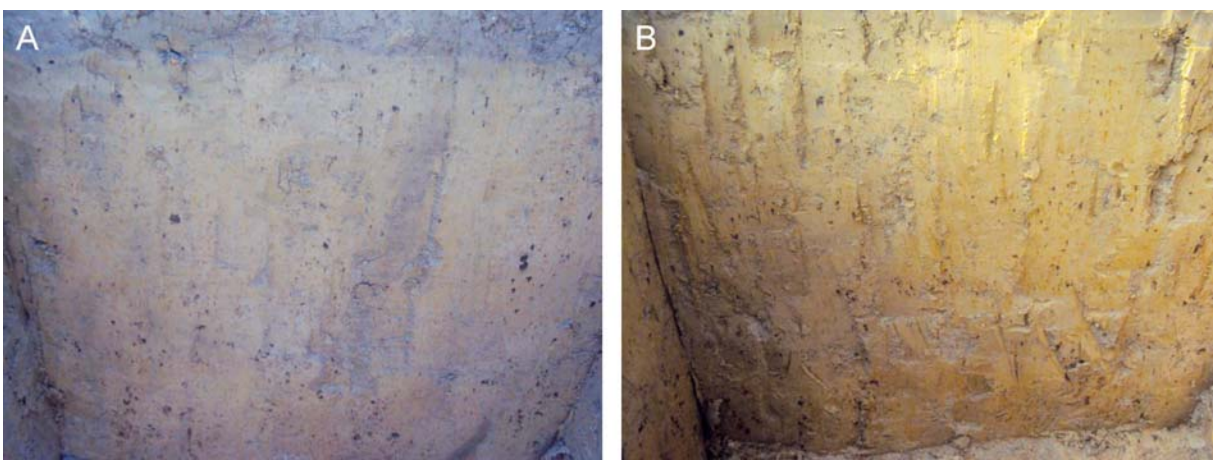


**Fig. 3.** Photographs of soil profiles in (A) Munshiganj and (B) Comilla Districts.

**Table 2.** Soil description(topsoil and subsoil) at each site

| Sample location (district, sub-district, village name) | Sample No. (depth 15 and 85 cm) | Dry condition | | Wet condition | | Soil structure, texture and consistence |
|---|---|---|---|---|---|---|
| | | Color chart No. | Soil color | Color chart No. | Soil color | |
| Munshiganj Sadar, Katakhali potato field | 1. Topsoil | 5Y 6/1 | Gray | 5Y 3/1 | Olive black | Massive, Silt clay loam, medium hard dry, Slightly sticky wet |
| | 1. Subsoil | 5Y 7/2 | Light gray | 5Y 4/2 | Grayish olive | Massive, Clay loam, Very hard dry, Highly sticky wet |
| Munshiganj Sadar, Katakhali, boro haula para potato field | 2. Topsoil | 5Y 6/1 | Gray | 5Y 3/2 | Olive black | Massive, Silt clay loam, Slightly hard dry, Slightly sticky wet |
| | 2. Subsoil | 5Y 7/2 | Light gray | 5Y 5/2 | Grayish olive | Massive, Clay loam, Very hard dry, Sticky wet |
| Munshiganj, Tongibari, Nurpokurpar paddy field | 3. Topsoil | 5Y 5/1 | Gray | 5Y 3/3 | Olive black | Massive, Silt clay loam, very hard in dry, Slightly sticky wet |
| | 3. Subsoil | 2.5Y 7/4 | Light yellow | 2.5Y 5/4 | Yellowish brown | Moderate, Sandy loam, Soft dry, Non sticky wet |
| Comilla, Sadar, Kahetaser paddy field | 4. Topsoil | 2.5Y 6/3 | Dull yellow | 2.5Y 4/3 | Olive brown | Massive, Silt clay loam, Hard dry, Sticky wet |
| | 4. Subsoil | 5Y 7/1 | Light gray | 5Y 4/2 | Grayish olive | Massive, Clay loam, Hard dry, Highly sticky wet |
| Comilla, Burichang, Masura paddy field | 5. Topsoil | 2.5 Y 6/2 | Grayish yellow | 2.5Y 5/4 | Yellowish brown | Massive, Clay loam, Very hard dry, highly sticky wet |
| | 5. Subsoil | 2.5Y 6/4 | Dull yellow | 2.5Y 5/4 | Yellowish brown | Massive, Clay loam, Very hard dry, Highly sticky wet |

falls. Adding lime causes the acidic hydrogen and aluminum cations to be replaced by the basic calcium and magnesium cations, which increases the pH level. The ideal proportions for the base cations are 65–85% $Ca^{2+}$, 6–12% $Mg^{2+}$, 2–5% $K^+$ and 1% $Na^+$ (Johnston, 2006). The exchangeable sodium percentage (ESP) in this study ranged from 38% to 77%, meaning that the soils are sodic. Soils with high levels of exchangeable sodium (Na) and low level of total salts are called sodic soils. Exchangeable sodium percentages (ESP) higher than 15% indicate that sodic soils tend to develop structure and drainage over time because sodium ions on clay particles cause the soil particles to deflocculates, or disperse. Sodic soils are hard and cloddy when dry and trend to crust and have poor water infiltration, and possible Na toxicity to plants (Davis *et al*., 2011).

The recommendation for the amelioration of sodic soils is the application of various amendments to replace the exchangeable sodium by Ca ions. The main amendments used for this purpose is gypsum-calcium sulphate ($CaSO_4$ $H_2O$). The amount of gypsum applied varies considerably depending on the amount of exchangeable sodium, expressed in centimoles/kg of soil, to be replaced. Soils contained 1 centimole of exchangeable sodium per kg, the amount of gypsum required to replace the exchangeable sodium in one hectare of land was 1.3 tonnes. Soil having 20% exchangeable sodium and an exchange capacity of 20 centimole/kg the gypsum requirement would be 5.2 t/ha. On the other hand, sodic soil with a pH value less than 6, calcium carbonate ($CaCO_3$) has been successfully used as an amendment (Quirk, 1994). Exchangeable $Ca^{2+}$ percentage was very low ranged from 1.56 to 11.05%, indicating $Ca^{2+}$ deficiency because approximately 25 to 30% exchangeable

**Table 3.** Chemical properties of soils at the study sites (topsoil)

| Items | | Units | Munshiganj District | | | Comilla District | |
|---|---|---|---|---|---|---|---|
| | | | Site-1 | Site-2 | Site-3 | Site-4 | Site-5 |
| Depth | | (cm) | 0–25 | 0–25 | 0–25 | 0–25 | 0–25 |
| pH | | ($H_2O$) | 4.37 | 4.89 | 5.14 | 4.83 | 5.64 |
| | | (KCl) | 3.66 | 4.22 | 4.06 | 3.03 | 5.04 |
| Soil organic carbon | | (g $kg^{-1}$) | 14.62 | 12.51 | 19.21 | 13.78 | 12.11 |
| Total nitrogen | | (g $kg^{-1}$) | 1.90 | 1.47 | 2.25 | 1.58 | 1.35 |
| C/N | | | 7.70 | 8.51 | 8.53 | 8.85 | 8.96 |
| Cation Exchange Capacity (CEC) | | ($cmol_c$ $kg^{-1}$) | 26.40 | 34.80 | 28.80 | 28.40 | 25.40 |
| Exchangeable Base | $Na^+$ | ($cmol_c$ $kg^{-1}$) | 5.85 | 7.69 | 7.83 | 8.55 | 76.72 |
| | $K^+$ | | 5.46 | 6.15 | 6.62 | 4.87 | 4.84 |
| | $Ca^{2+}$ | | 1.27 | 1.81 | 1.21 | 2.42 | 1.44 |
| | $Mg^{2+}$ | | 4.02 | 3.25 | 0.89 | 3.67 | 10.25 |
| % Base Saturation | | | 62.88 | 54.31 | 57.47 | 68.70 | 367.13 |
| Ca: Mg ratio | | | 0.31 | 0.55 | 1.35 | 0.65 | 0.14 |
| Micro element of soil | Ni | (mg $kg^{-1}$) | 16.24 | 15.07 | 16.20 | 14.09 | 13.11 |
| | Cu | | 17.88 | 16.82 | 23.48 | 8.99 | 10.37 |
| | Co | | 13.87 | 13.33 | 13.84 | 12.76 | 16.37 |

**Table 4.** Chemical properties of soils at the study sites (subsoil)

| Items | | Units | Munshiganj district | | | Comilla district | |
|---|---|---|---|---|---|---|---|
| | | | Site-1 | Site-2 | Site-3 | Site-4 | Site-5 |
| Depth | | (cm) | 75–100 | 75–100 | 75–100 | 75–100 | 75–100 |
| pH | | ($H_2O$) | 7.18 | 7.97 | 6.81 | 5.92 | 7.37 |
| | | (KCl) | 5.48 | 6.58 | 5.20 | 4.40 | 4.77 |
| Soil organic carbon | | (g $kg^{-1}$) | 4.05 | 4.72 | 1.18 | 3.17 | 7.66 |
| Total nitrogen | | (g $kg^{-1}$) | 0.47 | 0.70 | 0.15 | 0.36 | 1.08 |
| C/N | | | 8.54 | 6.77 | 8.11 | 8.84 | 7.07 |
| Cation Exchange Capacity (CEC) | | ($cmol_c$ $kg^{-1}$) | 42.20 | 30.80 | 9.20 | 19.60 | 41.80 |
| Exchangeable Base | $Na^+$ | ($cmol_c$ $kg^{-1}$) | 16.65 | 21.15 | 27.20 | 17.72 | 17.00 |
| | $K^+$ | | 6.27 | 5.29 | 5.59 | 5.29 | 6.36 |
| | $Ca^{2+}$ | | 3.65 | 1.69 | 1.22 | 0.73 | 1.92 |
| | $Mg^{2+}$ | | 13.35 | 6.24 | 2.32 | 7.73 | 20.17 |
| % Base Saturation | | | 94.59 | 111.57 | 394.89 | 160.54 | 108.73 |
| Ca: Mg ratio | | | 0.27 | 0.27 | 0.52 | 0.09 | 0.09 |
| Micro element of soil | Ni | (mg $kg^{-1}$) | 21.75 | 20.27 | 17.98 | 17.35 | 23.94 |
| | Cu | | 21.85 | 20.37 | 10.51 | 9.74 | 13.97 |
| | Co | | 19.19 | 17.52 | 17.27 | 10.75 | 43.87 |

$Ca^{2+}$ is considered adequate for supplying the $Ca^{2+}$ requirements of most plants. Many acid soils have low levels of exchangeable $Ca^{2+}$. At such low levels of available $Ca^{2+}$, the uptake of nutrients may be further inhibited by $Al^{3+}$. An important function of $Ca^{2+}$ in the plant is the formation of cell walls of crops and

**Table 5.** Recommended soil nutrient values in agricultural soils (Loganathan, 1987)

| Nutrients | Very low | Low | Moderate | High | Very high |
|---|---|---|---|---|---|
| N<br>Total N% | <0.05 | 0.05–0.15 | 0.15–0.20 | 0.20–0.30 | >0.30 |
| K<br>(exchangeable K, meq/100 g) | <0.2 | 0.20–0.30 | 0.30–0.60 | 0.60–1.0 | >1 |
| Ca<br>(exchangeable Ca, meq/100 g) | <2 | 2–5 | 5–10 | 10–20 | >20 |
| Mg<br>(exchangeable, meq/100 g) | <0.30 | 0.3–1 | 1–3 | 3–8 | >8 |

**Table 6.** Interpretation of CEC and exchangeable Ca: Mg ratio (Hazelton and Murphy, 2007).

| Cation Exchange Capacity (cmol$_c$ kg$^{-1}$) | |
|---|---|
| Range | Interpretation |
| <6 | Very low |
| 6–12 | Low |
| 12–25 | Moderate |
| 25–40 | High |
| >40 | Very high |
| Ca: Mg ratio | |
| <1 | Ca deficient |
| 1–4 | Ca low |
| 4–6 | Balanced |
| 6–10 | Mg low |
| >10 | Mg deficient |

fruits (Mitchell, 2000). The experimental results indicated that accumulated Na and low Ca declined the soil fertility and occurred due to imbalance application of chemical fertilizer.

**Soil organic carbon and total nitrogen concentration**

Soil organic carbon (SOC) and total nitrogen (TN) concentration was lower in the subsoil than in the topsoil at all sites. SOC ranged from 12.11 to 19.21 g kg$^{-1}$ in the topsoil and 1.18 to 7.66 g kg$^{-1}$ in the subsoil. Total nitrogen concentrations ranged from 1.9 to 2.25 g kg$^{-1}$ in topsoils and 0.15 to 1.08 g kg$^{-1}$ in the subsoils (Tables 3 & 4). The TN concentrations followed trends similar to those of SOC. Across the sites, SOC and TN concentrations were higher in the topsoil than in the subsoil. Soil organic carbon is the main source of energy for soil microorganisms and therefore influences the availability of essential plant nutrients. The concentrations of SOC at the study sites were considered adequate and unlikely to be contributing any negative effect on plant growth and productivity. On the other hand, the C: N ratio of the topsoil ranged from 8 : 1 to 9 : 1 and that of the subsoil ranged from 7 : 1 to 9 : 1. The C: N ratio was lower in the subsoil than in the topsoil (Tables 3 & 4). Carbon to nitrogen ratios of different plants and farm materials vary greatly, ranging from 15 to 30 for N-rich materials, such as legume residues and farm manure were easily decomposed in to the soil. The soils of the study areas were found N rich. Fertilizer added to soil contained more nitrogen, microorganisms have an abundance of N available in the substrate and do not need to obtain mineral N from the soil, and tend to generate additional soil mineral N through the mineralization process. The results of my study indicate that it is not require using more urea fertilizer in the soil as recommended dose.

**Heavy metal microelement (Ni, Cu and Co) concentrations**

The values of the heavy metal microelements Ni, Cu and Co in topsoils ranged from 13.11 to 16.24 mg kg$^{-1}$ for Ni, 8.99 to 23.48 mg kg$^{-1}$ for Cu and 12.76 to 16.37 mg kg$^{-1}$ for Co, and in subsoils ranged from 17.35 to 23.94 mg kg$^{-1}$ for Ni, 9.74 to 21.85 mg kg$^{-1}$ for Cu and 10.75 to 43.87 mg kg$^{-1}$ for Co (Tables 3 & 4). The maximum recommended values for Ni, Cu and Co are 75, 4300 and 85 mg kg$^{-1}$, respectively (USEPA, 1993), indicating that the heavy metal concentrations in the topsoils and subsoils sampled were not likely to had any adverse effects on crop growth and productivity.

**Table 7.** Present fertilization practices and crop yields in the study area.

| Crop | Fertilizer application kg/ha/y (Extension off, Munshiganj and Comilla, unpublished data) | | | | | Yield t/ha |
|---|---|---|---|---|---|---|
| | TSP | Urea | MOP (Potash) | Gypsum | Total | |
| Rice (paddy) HYV, Irrigation | 130 | 270 | 130 | 60 | 590 | 4 |
| Rice (paddy) Local, Rain fed | 120 | 250 | 110 | 50 | 530 | 2.7 |
| Potato | 700 | 750 | 650 | 120 | 2220 | 30 |
| Wheat | 180 | 200 | 50 | 120 | 550 | 2.5 |
| Corn | 260 | 500 | 220 | 260 | 1240 | 5.9 |
| Vegetable | 135 | 220 | 125 | 40 | 520 | 16 |
| Recommended fertilizer dose kg/ha/y (FRG, 2005) | | | | | | |
| Rice (Paddy) | 20 | 130 | 36 | 28 | 214 | |
| Potato | 40 | 158 | 110 | 44 | 352 | |

### Overall interpretation

The study showed that the pH of the topsoil was mostly acidic and the subsoil was neutral to slightly alkaline in water and acidic to slightly acidic in KCl. The exchangeable sodium percentage of the topsoil indicated that the soils at both locations were strongly sodic and that a risk of sodicity existed. On the other hand, these soils were deficient in Ca. The low pH of the topsoil, high Na and low Ca indicate poor soil fertility. However, the high nitrogen and potassium contents suggested that the soils are subjected to excessive application of urea and potash fertilizers, which contain nitrogen and potassium, respectively (Tables 5 & 6). Present fertilizer application practices in the study areas suggest that excessive amounts of urea and potash fertilizer (NPK fertilizers) are being applied to soils (Table 7). The excessive use of NPK chemical fertilizer has declined soil fertility and accumulated Na over the years. Unfortunately, information on the physical and chemical properties (soil fertility and soil nutrient content) of the soil is not readily available to farmers. The farmers were not conscious about applying lime ($CaCO_3$) to the soil. Application of 2–3 t/ha of lime to any soils that have pH values of 4.6–5.5 could increase soil pH levels and reduce Ca deficiency (FRG, 2005). Handling lime was difficult due to hard and stony structure which was difficult to break or soak in the water. While soaking, usually temperature increases and farmers are afraid to use lime and they fell better to use gypsum. It could be easy to apply lime in a granular form spreading into soil. Maintaining soil fertility of agricultural soils is of paramount importance for the present and the future. Soil analysis and its interpretation is an important management tool in assessing the appropriateness of fertilizer regimes and the possible need for increasing or decreasing the application of fertilizer or other soil amendments like lime and gypsum to maintain soil fertility.

## Conclusions and Recommendations

This study revealed that the top plow layer of the studied soils was acidic, that exchangeable $Na^{+}$ was generally very high, and exchangeable $Ca^{2+}$ was very low. These detrimental soil chemical properties are considered to be due to the excessive use of chemical fertilizer over many years, indicating that agricultural practices have not been sustainable. To address these problems, sustainable management options to maintain soil fertility over a long period have to be implemented. I recommend that adequate amount of lime and gypsum application to cultivated fields could be used to increase soil pH values, improve soil Ca deficiency, and remove soil sodicity (Sodium rich). After improving these acute conditions, long-term improvements could be gained by the use of green manure crops, rotational-cropping, reduced use of chemical fertilizer, and the introduction of organic farming.

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