

## Status and Spatial Variability of Trace Elements in the Low Ganges River Floodplain Soils of Bangladesh

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### Abstract

Soils of the Low Ganges River Floodplain encroaching Faridpur district of Bangladesh have immense contribution to crop production, while little information available focusing the spatial variability of trace elements in the area. Therefore, the study was conducted to quantify the trace elements collecting a total of 122 representative soil samples from rice fields of Faridpur district. Soil samples were analyzed and found that Cu, Fe, Mn, Zn and B were ranged from 0.80-6.80, 24-295, 10-129, 0.12-2.20 and 0.5-9.05 ppm, respectively. The pollution indexes are noteworthy features which revealed that only Mn may exhibit a risk for environmental pollution. The concentrations of trace elements, pH and organic carbon in soils displayed a significant spatial diversity because of anthropogenic and geogenic contribution. The distribution maps of soil pH, organic carbon and trace elements might be useful to farmers, researchers and planners in designing and planning agricultural programs in the study area.

**Key words:** Ganges river floodplain, Spatial variability and Trace elements

### Introduction

Availability of trace elements in soil affects crop growth, yield and quality directly. Some trace elements are heavy metals which may cause soil pollution if their concentrations in soils are excessively high. Study on spatial distribution of trace elements and their influencing factors are needed for effective management and protection of soil. Almost all soil nutrients including trace elements exhibit variability because of the dynamic interactions among the soil forming factors acting in different production environments or agroecological regions (Jenny, 1941). Bangladesh is divided into three broad physiographical units and thirty agroecological zones. The floodplain is one of the physiographical units comprising 80% of the total area of the country and nutrient contents including the trace elements varied significantly in different floodplains soils (Brammer, 2012). The Ganges Floodplain in Bangladesh represents a typical riverine landscape which covers about one-fifth of its total land area (BARC, 2012). The soils in the floodplain are known to be productive. However, with the intensification of agriculture, these soils have witnessed depletion of essential nutrients in Bangladesh soils which first appeared in 1960s following the introduction of high yielding rice varieties together with the excessive use of inorganic fertilizers (Islam, 1992). Although trace elements are needed by plants in only very small quantities their deficiencies in soils may result in severe reduction of plant growth and development as well as total crop failure (Cheng *et al.*, 2013). Trace elements such as Cu, Fe, Mn, Zn, B, Ni and Pb are potential soil pollutants. Soils consist of heterogeneous mixtures of organic and inorganic solid components as well as a variety of soluble substances. Thus, it is important to evaluate the spatial distribution of trace elements to establish soil management guidelines for potential toxic hazards and to understand chemical behavior and fate of trace elements in soils (Singh *et al.*, 2005; Krishna *et al.*, 2008). The

distribution of trace elements in the Ganges Floodplain soil is not uniform and well documented. This problem deserves special attention for its sustainable development. Few sporadic studies dealing with the variability of trace elements of the soils and sediments of the Gangetic alluvium in Bangladesh and India have been reported. Hence, more study is needed to know the trace elements variability of that soil and understand the soil productivity and also to understand the mineral transformations and degree of soil development. Since the floodplain soils are intensively used for growing paddy rice, the spatial variability of selected soil trace elements should be thoroughly studied for better understanding of maintaining sustainability in soil health as well as crop production. In recent years, the study of available trace nutrient has attracted more attention (Zhang *et al.*, 2005; Bityutskii *et al.*, 2012). Keeping the above views in mind the present study was undertaken to determine pH, organic carbon, copper, iron, manganese, zinc and boron contents and produce spatial distribution maps of the Low Ganges River Floodplain soils in the Faridpur district of Bangladesh.

### Materials and Methods

The study was conducted in the Low Ganges River Floodplain agroecological zone encroaching Faridpur district of Bangladesh within 23.04° – 23.41° N latitude and 89.00° – 90.08° E longitude (Fig. 1). All eight upazilas of Faridpur district viz. Faridpur Sadar, Alfadanga, Nagarkanda, Sadarpur, Char Bhadrasan, Bhanga, Boalmari and Madhukhali were considered for soil sampling sites (Fig. 2). The major land types of the study area were medium high, medium low and low where the cropping patterns were Boro - T. aman – fallow for the first one and Boro - fallow - fallow for the second and third. Boro and transplanted aman (T. aman) are two major rice in Bangladesh. Boro rice is cultivated in the dry season under full irrigation, while T. aman cultivated in the monsoon as mainly rainfed crop or supplemented by partial irrigation if needed.



Fig. 1. Study area in map of Bangladesh



Fig. 2. Study area showing sampling points

A total of 122 representative soil samples from the above mentioned upazilas were collected following standard protocol (BARC, 2012). An equal sampling distance among sampling points were possibly maintained. Latitudes and longitudes of each sampling points were recorded using global positioning system (GPS). Soil samples were collected from 4 x 4 km grid from rice – rice cropping pattern and those points were plotted in the upazila map along with the mouza before going to sampling. If any point did not match with rice-rice system then nearest mouza with rice-rice cropping pattern was selected. From each of the selected mouza, three soil samples were collected diagonally considering 0-20 cm depth: one from near, one from middle and other from the tail end of the command area. Each sample was the composite of three sub-samples and GPS value was taken from the middle of the sub- samples. Information such as depth, cropping pattern, land type, etc of the sampling fields were also recorded.

The collected soil samples were air dried, sieved using 2 mm mesh sieve and kept in plastic pots with proper labeling. Soil pH was determined by Glass Electrode pH meter method, organic carbon by wet oxidation method, boron by Azomethine H colorimetric method and manganese, copper, zinc and iron by di-acid digestion method (Page *et al.*, 1982).

Pollution indexes (PIs) for each Cu, Fe, Mn and Zn were calculated using the ratio of its measured minimum and maximum concentrations (Cs) to the background concentration (Cb) in soil as mentioned below (Chen *et al.*, 2005; Wei and Yang, 2010):

$$PI = Cs/Cb$$

Where, the units of Cs and Cb were ppm. The soil background values of Zn and Cu were considered 86.5 and 31.1 ppm, respectively (CNEMC, 1990), while for Fe and Mn the values were 3700 ppm (Silva, 1996) and 100 ppm (Bowen 1966), respectively. The PI for metals were classified as low ( $PI \leq 1$ ), medium ( $1 < PI \leq 3$ ) and high contamination ( $PI > 3$ ).

All statistical analyses in this study were performed using SPSS software version 16.0 and Microsoft Excel. All the distribution maps of trace metals were prepared using the Arc GIS software.

### Results and Discussion

#### Soil pH

Soil pH was found neutral to slightly alkaline where the minimum and maximum values were recorded 6.75 and 8.39 in Nagarkanda and Faridpur sadar upazil, respectively (Table 1 and 2). Soil pH of the Low Ganges River Floodplain is varied from neutral to alkaline in range (BARC, 2012). The soil pH was found greater than 8.0 in the northeastern part of Bhanga, some part of Boalmari and Sadarpur upazila. On the other hand the lowest pH value was found in very small portion of the Boalmari upazila with pH less than 7.0 (Fig. 3). The most of the area of Faridpur district was found slightly alkaline having a soil pH range of 7.5-8.0. The soil pH has the greatest effect on the availability of trace metals in soil (Sauve *et al.*, 1997). The pH values with the ranges of 7.0-7.5 were found in most of the area of Nagarkanda and parts of Boalmari, Madhukhali and Faridpur sadar. Correlation coefficients indicated a moderate negative correlation between soil pH and all trace metals. In general, availability of trace elements in soils increases with the decrease of soil pH.

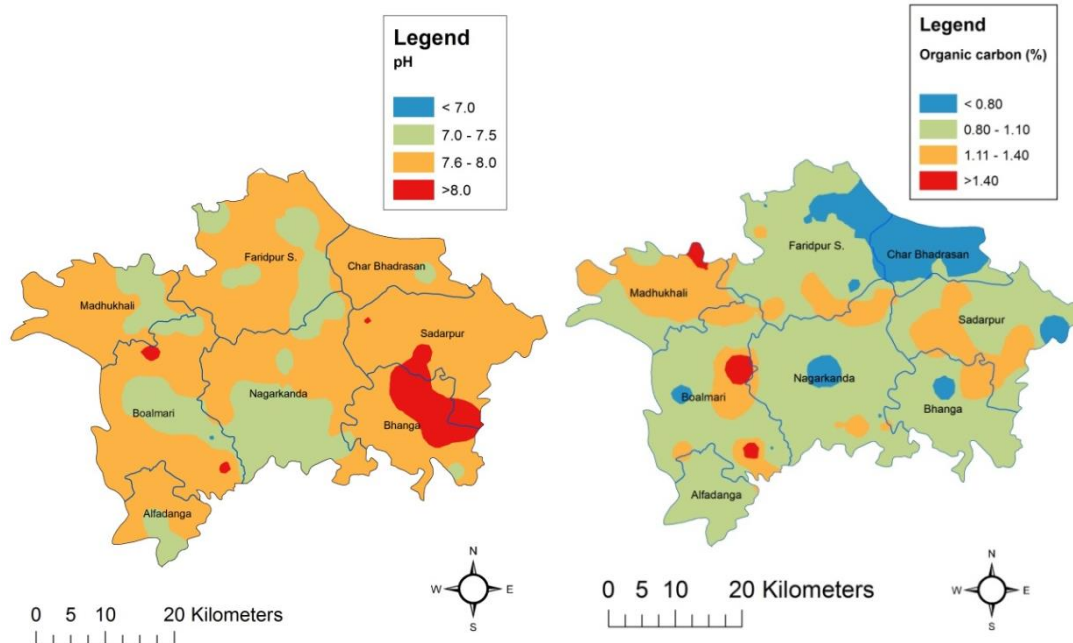


Fig. 3. Spatial distribution of pH in soils of Faridpur

Fig. 4. Spatial distribution of organic carbon in soils of Faridpur

Table 1. Minimum, maximum and mean values of different elements in soils collected from Faridpur district under Low Ganges River Floodplain agroecological zone

Elements	Minimum	Maximum	Mean±S.D.	Pollution index (PI)
pH	6.75	8.39	7.65±0.42	-
OC %	0.21	2.31	0.99±0.34	-
Cu (mg kg <sup>-1</sup> )	0.80	6.80	3.12±1.14	0.03-0.22
Fe (mg kg <sup>-1</sup> )	23.90	295.24	117.53±52.52	0.01-0.08
Mn (mg kg <sup>-1</sup> )	9.53	128.92	57.78±18.51	0.10-1.29
Zn (mg kg <sup>-1</sup> )	0.12	2.20	0.65±0.40	0.001-0.03
B (mg kg <sup>-1</sup> )	0.52	9.05	3.62±1.91	-

The area having calcareous in nature impedes phosphorus availability and thereby appeared as one of the problem soils in Bangladesh. In calcareous soils, inherent soil phosphorus or phosphorus applied as inorganic fertilizer might react with available calcium in soils and form insoluble calcium phosphate and thus gradually P availability reduces in soils for plant uptake. Therefore, phosphorus deficiency symptoms exhibited in plants, which need to be addressed through adoption of different management practices especially in the upland. Organic matter is considered as an inhibitor of P fixation in some extent and therefore, regular application of different available organic manures, composts, biochars and even green manuring is recommended to increase organic matter levels in soils. von Wandruszka (2006) reported that swine and chicken manure are rich in P and therefore, application of manures supply and mobilize P in soils. Organic acids released from organic matter block P sorption sites and form complex with exchangeable Al and Fe in the soil, which enhances P mobilization in soils. Periodic soil test for P and subsequent P fertilizer application may also be recommended in calcareous soils. In wetland rice culture such pH is not a problem

because of carbon dioxide absorption and subsequent drop down of pH from alkaline to neutral state.

**Organic carbon contents**

Organic carbon contents in soils of different upazila under Faridpur district were found in a wider range which varied from very low (0.21%) to very high (2.31%) in Sadarpur and Boalmari upazila, respectively (Table 1 and 2). Organic carbon contents were found very low to low in ridges and medium to high/very high in basin areas. The study area comprises the eastern half of the Ganges River Floodplain which is low lying and therefore, organic matter content is generally found medium (BARC, 2012). General soil fertility of the Low Ganges River Floodplain region is medium, except phosphorus, which is low and obvious in calcareous soils. The concentration of organic carbon with the range of >1.40% was found in some northern part of Madhukhali and some eastern and southeastern part of Boalmari upazila (Fig. 4). This high level of organic carbon in soils is attributed from accumulation of runoff materials and other organic constituents. Land types of the above mentioned upazilas are mainly medium low and low where basin area receives organic materials from the upper ridge areas, therefore, soil becomes

enriched with organic matter. Such findings are endorsed by Franzluebbbers (2010).

**Table 2.** Minimum, maximum and mean values of different elements in soils collected from different upazila of Faridpur district

Upazila	Statistics	Properties of soils in different upazila under Faridpur district						
		pH	OC (%)	Cu	Fe	Mn (mg/kg)	Zn	B
Faridpur sadar	Min	6.89	0.55	1.20	39.20	28.39	0.32	1.18
	Max	8.39	1.35	6.00	198.47	75.35	2.20	4.95
	Mean	7.66	0.92	3.43	107.73	51.73	0.64	2.61
Alfadanga	Min	7.01	0.64	1.60	46.64	57.78	0.20	2.71
	Max	8.21	1.29	4.40	212.81	71.42	0.80	6.55
	Mean	7.76	0.92	3.01	96.96	63.57	0.42	3.69
Madhukhali	Min	6.85	0.66	1.60	23.90	43.12	0.16	1.82
	Max	8.12	2.17	6.80	295.24	128.92	1.28	8.12
	Mean	7.52	1.20	3.39	133.53	70.99	0.44	4.09
Char Bhadrasan	Min	7.12	0.34	1.00	47.58	29.04	0.44	1.35
	Max	8.20	0.78	2.40	132.58	66.77	1.50	4.14
	Mean	7.67	0.61	1.83	100.20	43.85	0.84	2.57
Sadarpur	Min	7.41	0.21	1.20	59.50	9.53	0.40	0.93
	Max	8.10	1.82	4.00	198.65	85.06	1.36	8.07
	Mean	7.91	1.09	2.55	117.50	42.26	0.65	3.39
Boalmari	Min	6.88	0.57	2.00	72.89	28.00	0.22	1.35
	Max	8.24	2.31	4.80	280.42	63.02	1.80	6.13
	Mean	7.66	1.11	2.91	154.91	49.31	0.63	3.64
Nagarkanda	Min	6.75	0.46	0.80	33.29	29.48	0.12	1.56
	Max	8.07	1.42	6.80	195.65	93.13	2.20	9.05
	Mean	7.45	0.94	3.03	103.92	69.68	0.76	4.33
Bhanga	Min	7.18	0.25	2.20	58.24	15.40	0.48	0.52
	Max	8.34	1.57	6.00	189.49	78.36	1.52	11.54
	Mean	7.88	1.02	3.93	118.84	57.64	0.81	4.19

The lowest organic carbon contents (<0.80%) was found in case of whole of Char Bhadrasan, very small part of Bhanga, Faridpur Sadar, Sadarpur, Nagarkanda and Boalmari upazila. The land types of these upazilas are mainly medium high and from this area organic materials are washed out and thus attributed comparatively to lower organic carbon than that of medium low and low lands. The organic carbon with the range of 1.11-1.40% was found in greater part of Madhukhali, some part of Bhanga, Faridpur Sadar, Sadarpur, Nagarkanda and Boalmari upazila. Organic carbon contents were found low to medium in a larger area of Faridpur district, where OC concentrations were

ranged from 0.80% to 1.10% in the whole of Alfadanga, most of the parts of Bhanga, Faridpur Sadar, Sadarpur, Nagarkanda and Boalmari upazila (Fig. 4). Organic matter plays a significant role in nutrient availability in soils. Organic carbon with iron and copper were found positively correlated, while the increment of organic carbon in soils was found nonresponsive to manganese, zinc and boron (Table 3). Halim *et al.* (2003) reported that decomposition of organic matter forms organic anions which may form metal complexes, thus it can either reduce metal availability in soil or increase through solubilization of the complexes in favorable soil environment.

**Table 3.** Different trace elements concentration under different category of organic carbon in Low Ganges River Floodplain soils

Elements (mg kg <sup>-1</sup> )	Category of OC (%)		
	<1.0	1-1.5	>1.5
Cu	2.82	3.53	3.58
Fe	113.16	121.46	135.21
Mn	56.80	61.08	53.18
Zn	0.67	0.64	0.58
B	3.65	3.64	3.38

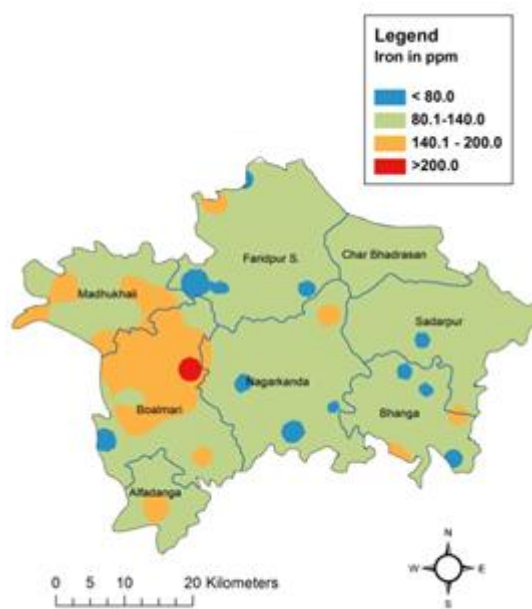
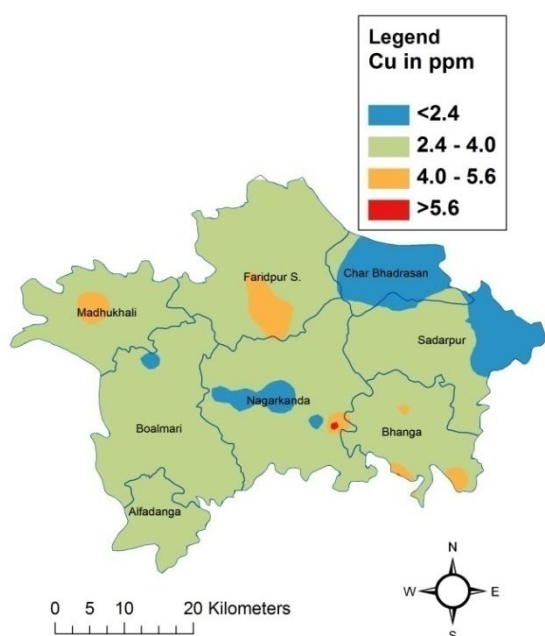
**Trace element concentrations and spatial distribution**

Concentrations of Cu, Fe, Mn, Zn and B in the soils of Low Ganges River Floodplain in Faridpur district

varied from very low to very high (Table 1 and 2). The fashion of element variations depends on Floodplain ridges and basins, land types, irrigation, fertilization and other soil and crop management practices.

The concentrations of Cu varied from 0.80 to 6.80 ppm with an average value of 3.12 ppm (Table 1 and 2). In soil fertility ranking provided by BARC (2012) it is mentioned that copper content when crossed 0.75 ppm it is ranked as very high. As minimum copper content in soils of the Low Ganges River Floodplain was found 0.80 ppm, therefore, its fertility might be rated as very high. The highest of Cu concentration (>5.6 ppm) was found in a small area of northern part of Nagarkanda (Fig. 5). In the whole of Char Bhadrasan, middle of

Nagarkanda and eastern part of Sadarpur upazila Cu contents were <2.4 ppm (Fig. 5). The overall Cu concentration was very high in whole study area due to discharge of maximum dissolved Cu on the surface soil and due to lithogenic sources and dumping of industrial wastes and also due to unclassified anthropogenic actions. Occurrence of higher concentration of Cu in the underground irrigation water can also be attributed to the high level of copper in the area. Natural weathering of soil and discharges from industries and sewage-treatment plants might have positive contribution to higher copper contents in the study area of Low Ganges River Floodplain area (Hutchinson, 1988; Wu *et al.*, 2001).



**Fig. 5.** Spatial distribution of Copper in soils of Faridpur district **Fig. 6.** Spatial distribution of Iron in soils of Faridpur

The iron concentrations varied from 24 to 295 ppm with an average value of 118 ppm where both minimum and maximum values were observed in soils of Madhukhali upazila (Table 1 and 2). Iron contents are considered very high when its concentrations exceeded 15 ppm (BARC, 2012). The both minimum (24 ppm) and maximum (295 ppm) concentrations of Fe in soils of the Low Ganges River Floodplain region were found in the southwestern and northern part of Boalmari upazila (Fig. 6). The concentrations of Fe were in the ranged of 80.1-140.0 ppm found in most of the area of Faridpur Sadar, Madhukhali, Nagarkanda, Bhanga, Sadarpur and whole of Char Bhadrasan upazila. On the other hand, the lowest Fe concentrations were found in the smaller area of the Faridpur Sadar, Sadarpur, Bhanga, Nagarkanda and Boalmari upazila which ranged from <0.80 ppm (Fig. 6). Iron concentrations ranged from 140.1-200.0 ppm were found in most of the areas of

Boalmari and some part of Nagarkanda, Alfadanga and Bhanga upazila (Fig. 6). The very high level of Fe concentration in the research area mainly results from weathering of iron ores (Koc and Deger, 1991). Iron is also accumulated in soils of the study area from the underground irrigation water abstracted from shallow and deep aquifer by shallow and deep tube-wells. The high levels of iron in soils might be a problem for phosphorus acquisition by crops. Phosphorus applied or inherent soil phosphorus may react with iron and transformed into complex iron-phosphate that make phosphorus unavailable for crops.

The manganese concentrations varied from 10 to 129 mg kg<sup>-1</sup> with an average value of 58 ppm where minimum and maximum values were observed in soils of Sadarpur and Madhukhali upazila, respectively (Table 1 and 2). As per soil fertility ranking (BARC, 2012) manganese contents are considered very high

when its concentrations exceeded 3.75 ppm. The presence of high levels of Fe and Mn in soils of the region might reduced the availability of soil phosphorus for plant uptake because insoluble complex formation of P with Fe and Mn. The highest concentration of Mn was found in a small area of western part of Madhukhali, northern part of Boalmari and southwestern part of Nagarkanda upazila with the range of greater than 80.0 ppm (Fig. 7). On the other hand, the lowest concentration of Mn was found in the eastern part of Sadarpur and a very small part of Faridpur Sadar upazila with the range of <40 ppm (Fig. 7). The soils of the whole area of Char Bhadrasan, a greater part of

Faridpur, Sadarpur, Boalmari and some part of Bhanga upazila contain Mn ranged from 40.1-60 ppm (Fig. 7). The spatial diversities of Mn in the study area are comparatively small, differing from the other elements. The spatial distributions of Mn in the study area are mainly controlled by natural factors. Manganese may be derived from industrial sources, although several studies have shown the elevated Mn concentration in soil mainly attributed to natural sources (Wang and Qin, 2007). The elevated amount of Mn may react with P and form complexes which ultimately resulted to obligatory deficiency of P in soils.

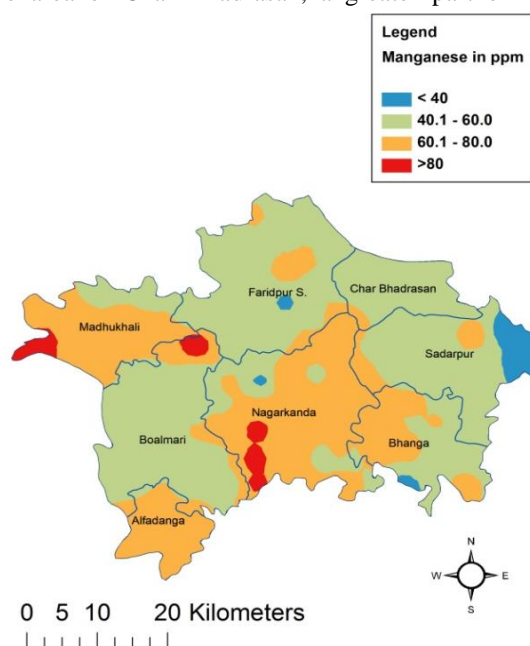


Fig.7. Spatial distribution of Manganese in soils of Faridpur district

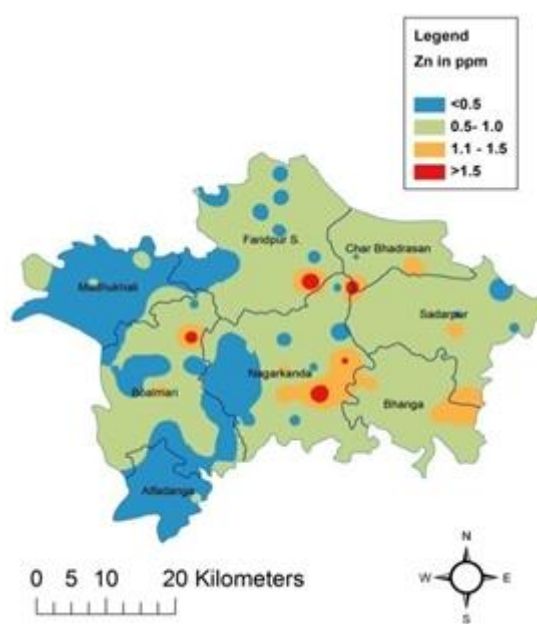


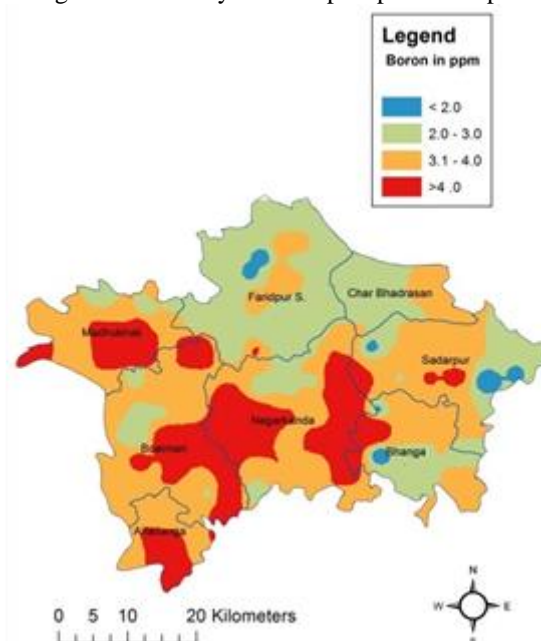
Fig. 8. Spatial distribution of Zinc in soils of Faridpur district

The concentrations of zinc did not follow the trends as observed in case of other nutrients. Zinc contents varied from 0.12 to 2.2 ppm with an average value of 0.65 ppm where minimum and maximum values were observed in soils of Nagarkanda and Faridpur Sadar upazila, respectively (Table 1 and 2). Zinc status is considered very low and very high when its concentrations are below 0.45 and above 2.45 ppm, respectively (BARC, 2012). Therefore, zinc status of the Low Ganges River Floodplain soils were found very low to high. The lowest Zn concentration was found <0.5 ppm in the whole area of Madhukhali and Alfadanga and a greater part of Nagarkanda, some part of Boalmari and Faridpur Sadar upazila (Fig. 8) These areas are under medium high land and Zn moved towards the lower elevation through surface runoff and therefore, Zn concentration was found low. The low Zn concentration may be due to high pH in the study area as well. The highest Zn concentration was found in small area of Nagarkanda, Faridpur Sadar and Boalmari upazilas where the land types are medium low and during monsoon run off of Zn occurred from the ridge

area and deposit in the basin area and thus soil becomes enriched with Zn. The Zn concentration with the range of 0.5-1.0 ppm was found in most of the area of Faridpur Sadar, Sadarpur, Bhanga, Nagarkanda, Char Bhadrasan and Boalmari upazilas. The Zn concentration with the range of 1.1-1.5 ppm was found in some eastern part of Nagarkanda and Bhanga upazilas and very small area of Faridpur sadar, Sadarpur, Bhanga, Nagarkanda, Char Bhadrasan and Boalmari upazila. The availability of Zn in soils depends on pH, organic matter, organic and inorganic colloids and other physico-chemical and biological conditions in the root zone. Land use practices and soil type may bring the heterogeneity in distribution of Zn in soils. Zinc is generally more available to plants in acid soils, while its availability decreases with the increased soil pH. Most pH-induced Zn deficiencies occur in neutral and calcareous soils, although not all these soils exhibit Zn deficiency because of increased availability from chelation of Zn. At high pH, Zn precipitates in soils as insoluble amorphous which reduces Zn availability in soil. Other metal cations i.e.  $Cu^{2+}$ ,  $Fe^{2+}$  and  $Mn^{2+}$  may

inhibit  $Zn^{2+}$  uptake by plants, possibly because of competition for the same carrier site. High P availability

can induce Zn deficiency by the formation of zinc-phosphate complex.



**Fig. 9.** Spatial distribution of Boron in soils of Faridpur district

Boron concentrations varied from 0.5 to 9.05 ppm with an average value of 3.6 ppm where both minimum and maximum values were observed in soils of Bhanga upazila (Table 1 and 2). Like copper, boron status followed the same range in fertility ranking i.e. it is very high when boron content is above 0.75 ppm. The highest concentration of B (>4.0 ppm) was found in the western and eastern part of Nagarkanda, eastern part of Boalmari southern part of Alfadanga, middle part of Madhukhali and a small area in Sadarpur upazila (Fig. 9). While the lowest B concentration (< 2.0 ppm) was found in some part of Sadarpur, a small part of Bhanga and a very small part of Faridpur sadar upazila (Fig. 9). Boron concentration 2.0-3.0 ppm was found in the greater area of Faridpur Sadar, Char Badrasan, Bhanga and Sadarpur upazila. The overall B concentration was very high in the whole study area.

**Pollution index**

The pollution indexes of Cu, Fe, Mn and Zn were ranged from 0.03-0.22, 0.01-0.08, 0.10-1.29 and 0.001-0.03 respectively (Table 1). It was observed that except Mn, the loading indexes of other three metals were far below from the level ( $\leq 1$ ) to be considered as minimum pollution. Therefore, though the present levels of concentration of Cu, Fe and Zn in soils of the Low Ganges River Floodplain areas are higher in terms of soil fertility, but much lower in terms of soil pollution. The concentration of Mn in the major part of study area attributed to medium pollution. The concentrations of Mn in soils of Alfadanga, Nagarkanda, Bhanga and Madhukhali upazilas were found very high and contributed to increase pollution index.

**Conclusions**

The Low Ganges River Floodplain comprises typical meander landscape of broad ridges and basins. Soils of the study area are calcareous in nature having neutral to alkaline in reaction. Organic carbon contents were found very low to low in ridges and medium to very high in basin areas. The concentrations of Cu, Fe, Mn, Zn and B in soils were ranged from 0.80-6.80 ppm, 24-295 ppm, 10-129 ppm, 0.12-2.20 ppm and 0.5-9.05 ppm, respectively. As per soil fertility ranking Cu, Fe and Mn contents are rated as very high, Zn very low to high and B optimum to very high. The pollution indexes of Cu, Fe, Mn and Zn were ranged from 0.03-0.22, 0.01-0.08, 0.10-1.29 and 0.001-0.03, respectively. It was observed that except Mn, the loading indexes of other three metals were far below from the minimum level ( $\leq 1$ ) to be considered as least pollution. The pollution indexes revealed that only Mn may exhibit a risk for environmental pollution. The concentrations of trace metals, pH and organic carbon in surface soil of the study area displayed a significant spatial diversity and distribution maps might be useful for different stakeholders for sustainable agriculture.

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