*Original Research Article*

# Assessment of vertical distribution of water soluble boron in relation to physicochemical properties in lateritic soils of West Bengal, India

**Abstract**

The vertical distribution of water soluble boron and its relationship to certain soil properties was investigated from soil samples collected at various locations of lateritic soils of West Bengal during 2020-2021. In the lateritic zone of West Bengal, India, a total of 150 soil samples have been collected from 50sites within two blocks: Bolpur and Illambazar. According to the study, the majority of soils have a clay loam to sandy clay loam texture. The soil pH of the surface soils of the study area ranged from 4.33 to 6.69 with an average value of 5.62, indicating that the majority of soils are strongly acidic to moderately acidic in reaction. The organic carbon content (%) of the surface soils (0–20 cm) of Bolpur and Illambazar blocks varied from 0.32 to 0.58 and 0.33 to 0.99 respectively, and it was found that most of the soils have low to medium organic matter content. With depth, the soil pH increased and the organic matter content decreased in the study area. In the surface soils of the Bolpur block, the water soluble boron content ranged from 0.16 to 0.33 mg $kg^{-1}$ with its mean content of 0.24 ± 0.046 mg $kg^{-1}$, whereas in the soils of the Illambazar block, it ranged from 0.15 to 0.33 mg $kg^{-1}$ with a mean content of 0.25 ± 0.051 mg $kg^{-1}$.From the results, it is understandable that water soluble B status decreased across the depth and that most of the soils under study were deficient in water soluble B content. From the correlation study, it was found that, water soluble boron significantly and positively correlated with clay content, pH, OC content, CEC and amorphous Fe and Al, indicating the importance of managing these parameters to enhance the availability of soil B. The results of the study would be very helpful to extension workers in advising B application for fruitful crop development in the lateritic soils of the region.

**Comment [Pa1]:** Please check it,

**Keywords**: Water soluble B, Correlation, Lateritic, Organic carbon, West Bengal

## 1. Introduction

Boron (B) is a necessary micronutrient that plants need to grow and develop normally. Boron participation in plant structure and involvement in physiological function are unavoidable (Cakmak and Romheld, 1997). Boron is vital for membrane integrity, cell wall synthesis, and the indole acetic acid mechanism (Kobayashi et al., 2017). Furthermore, B has been associated with a wide range of processes, which include calcium uptake, cell division, flowering/reproductive phase, water relations, disease resistance, nitrogen metabolism, and the translocation of sugars, starches, and phosphorus (Rehman et al., 2018). Most plant species have a much higher boron requirement for reproductive growth than for vegetative growth (Dell and Huang, 1997). Even though B plays important roles in plant growth, plant uptake of B is dependent on the existing form and quantity of available B in soil (Sun et al., 2019). It is kept in soil as it is adsorbed onto mineral and humic particles and insoluble precipitates is formed (Goldberg and Glaubig, 1985).Understanding the true mechanisms of boron action and proper management may improve crop yield (Uluisik et al., 2018). Bioavailability and concentration of boron in soils are affected by several factors such as soil pH, soil texture, soil moisture, clay content, Al and Fe oxides and organic matter (Ahmad et al., 2012, Rehman et al., 2018). Among these, pH is the most important factor influencing B adsorption in agricultural soils (Santos et al., 2020). Parental rock forming material, textural class, types of clay, pH, application of lime, amount of organic matter present, and inter-relationship with other elements affects the B concentration in soil (Ahmad et al., 2012).

In terms of micronutrients, boron (B) nutrition received particular attention due to the widespread B deficiencies in crops (Singh, 2012, Prasad et al., 2014). Several parts of the world have shown widespread B deficiency in the soil (Datta et al., 1998). In Indian soils, boron shortfall is the second most prevalent (on average 33%) micronutrient deficiency problem after zinc (Tiwari, 2006, Zhou et al., 2014). Because of intensive cropping and the use of high-yielding crops without a sufficient quantity of fertilizers, the soil's micronutrient reserves have been further depleted (Singh, 2008). Coarse texture, low pH, poor organic carbon, and leaching during heavy rains are other factors that impact boron shortage (Wimmer et al., 2015). Deficiency of B occurs under dry conditions and coarse textured soils (Bellaloui et al., 2015) where water soluble B readily leaches out of the soil profile and becomes unavailable to plants due to its non-ionic nature (Mandal and De, 1993). Light-textured acidic lateritic soils rich in Fe and Al oxides and hydroxides in West Bengal have been found to be B deficient. These oxides and hydroxides have an incredible capacity for retaining boron in unusable forms (Elrashidi and O'Connor, 1982). The yield of almost all crops grown in West Bengal is generally low due to soil B deficiency, despite the application of recommended doses of N, P, K, and Zn fertilizers. The range of B deficiency and toxicity in soil is very narrow (Reisenauer et al., 1973), and crops may encounter both deficiency and toxicity during a single growing season. As a result, managing this element in soils and evaluating the B status of soils for optimum crop nutrition is difficult and must be done with caution. It's reported that, boron deficiency affects photosynthetic activity of crops (Dell and Huang, 1997, Wang et al., 2007) by reducing chlorophyll content and decreasing photosynthetic areas (Cakmak and Romheld, 1997). It includes retarded growth and development, poor quality of fruits (Souri and Bakhtiarizade, 2019), failure in panicle formation (Rehman et al., 2014) and production of white and rolled leaves (Brdar-Jokanovic, 2020). Reduced supply of B restricts the germination of pollen and growth of pollen tube (Lordkaew et al., 2013). There is presence of equilibrium between adsorbed and water soluble B (Chaudhary et al., 2005) so maintaining B in the soil solution is critical for plant nutrition.

A powerful indication of how crops will respond to nutrients is the availability of those nutrients in the soil (Ali et al., 2013). Higher levels of available boron may be observed at the topmost layer (0–15 cm) of soil profiles containing significant quantities of organic carbon (Mandal et al., 2016). Understanding the vertical distribution of boron in soils is crucial because it reveals the pattern of B depletion and buildup, if any, within the soil profile. Furthermore, many crops have roots that extend below the top soil layers and draw their nutrients from the deeper layers. In light of this, the current study was carried out to investigate the depth-based distribution of water solubleB in lateritic soils of West Bengal, as well as the correlations with major soil characteristics.

**Comment [Pa2]:** The rather long introduction regarding the volume of the manuscript, please reduce it a bit

## 2. Materials and Methods

A total of 150 soil samples were collected from 50 locations and from 3 depths from two distinct blocks (Bolpur and Illambazar) in thelateritic region of West Bengal, India (Table 1, 3). The depth wise, i.e., surface (0–20 cm), mid-surface (20-40 cm), and sub-surface (40-60 cm) collected soil samples were processed and labeled for laboratory analysis. The hydrometer technique of Bouyoucos was used to measure particle size distribution (Bouyoucos, 1962). The pH of the soils was determined by using the soil-water suspension (1:2.5) method described by Jackson (1973). Walkley and Black''s (1934) wet digestion technique was used to measure oxidizable organic carbon (OC) content. The cation exchange capacity (CEC) was determined by the method as suggested by Schollenberger and Simon (1945). By the method of McKeague and Day (1966), amorphous iron (Amr-Fe) and aluminium oxides (Amr-Al) were extracted using 0.02 M ammonium oxalate, pH 3.0 (soil: extractant = 1:30). Soil samples were analyzed for extractable water soluble B by the hot water method (Berger and Truog, 1939). The intensity of the yellow colour generated by the Azomethine-H reagent was assessed at 420 nm on a visible range spectrophotometer in order to quantify the content of B in the soil extracts (Wolf, 1974).

## 3. Results and Discussion

### *3.1. Physicochemical properties of soil*

As illustrated in Table 1 to 4, among the physico-chemical characteristics, those that directly control or impact B availability in the soil were considered. These characteristics included pH, clay content, organic carbon, amorphous Fe, and amorphous Al-oxides. From the textural analysis, it was found that, clay content (%) of the surface 0-20 cm soil depth of Bolpur block ranged between 14.16 to 54.13% with an average of 33.81±11.39%, whereas the soils collected from Illambazar block was ranged between 20.56 to 52.88% with a mean of 33.54 ±10.42%. In the mid-surface soils (20–40 cm), the clay content of all the soils studied varied from 16.88 to 63.60%. However, the clay content of sub-surface (40–60 cm) layers varied from 19.60 to 61.60% in the whole soils studied. The silt content of the study area was ranged between 5.28 to 32.72%, 8.16 to 32.72% and 8.72 to 34.0% at 0–20 cm, 20–40 cm and 40–60 cm soil depths, respectively. The percentage of sand content of the surface soils were ranged from 20.56 to 75.12%, in mid-surface soils, it varied from 19.83 to 72.40%; and in deep soils, it varied from 16.75 to 68.40%. The majority of the soils fall into the clay loam to sandy clay loam. It was noted that clay content in the study area increased depth-wise. The studied soils were categorized into strongly acidic to moderately acidic in pH. The pH of soil samples collected from Bolpur block was ranged between 4.33 to 6.26, 4.48 to 6.77 and 4.68 to 6.91 respectively, on the surface, mid-surface, and sub-surface soil. The surface soil pH of Illambazar soil ranged from 5.02 to 6.69. Higher values of soil pH were observed in sub-surface soils in Vidyadarpur village of Bolpur block, whereas the lowest pH was observed in surface soils in MulaRupur village of the same block. In the research region, it was discovered that the pH of soil in the mid-surface and sub-surface layers was greater than that of surface soil layer. High rainfall may have resulted in leaching of bases and percolating water, as well as plant uptake of basic cations from the surface soil layers could have contributed to a rise in soil pH as depth increased. Similar findings also reported by Mandal et al., (2016), Paramaniket al., (2012).The organic carbon content (%) of the surface soils (0–20 cm) of Bolpur and Illambazar blocks varied from 0.32 to 0.58% and 0.33 to 0.99% respectively. The higher values of OC were observed in surface soils of all the soils studied. These finding were in good agreement with Chaudhary and Shukla, (2004), Niaz et al., (2007), Debnath and Ghosh, (2009), Saha et al., (2017) and Satish et al., (2021). The CEC of the studied soils were varied from 5.90 to 26.47 C mol ($P^+$)$kg^{-1}$ withthe mean of 15.06 C mol ($P^+$) $kg^{-1}$. The average value of amorphous Fe (g $kg^{-1}$) content in the surface soils of the Bolpur block were 6.78 ±1.22 g $kg^{-1}$, while in the mid surface and sub-surface layer it was 5.65 ± 1.17 g $kg^{-1}$ and 4.11± 1.32 g $kg^{-1}$ respectively. The mean values of amorphous Fe content were 6.47 ±1.67, 5.06 ± 1.28 and 3.50 ± 0.92 g $kg^{-1}$, respectively, for surface, mid-surface to sub-surface soil layer. The average values of amorphous Al content observed were 3.92, 2.76, and 2.09 g $kg^{-1}$ in respective depths in the soils of Bolpur block and in Illambazar block, however, their values were 4.13, 2.95 and 1.91 g $kg^{-1}$ respectively. The identical results were also reported by Satish et al.(2021).

### *3.2. Water soluble B content*

The vertical distribution of water soluble boron content in the study area is presented in the table 2 and 4. The range and average of water soluble boron content in the surface soils of Bolpur block were 0.16 to 0.33 and 0.24 ± 0.046 mg $kg^{-1}$ respectively, whereas in soil samples collected from Illambazar block recorded its content in the same soil depth ranging from 0.15 to 0.33 mg $kg^{-1}$with the mean value of 0.25 ± 0.051 mg $kg^{-1}$. Again, in the mid-surface soils of Bolpur and Illambazar blocks, the mean water soluble boron contents were 0.14 ± 0.03 and 0.15 ± 0.043 mg $kg^{-1}$ respectively. The B contents in the sub-surface soils ranged from 0.04 to 0.13 mg $kg^{-1}$. Considering < 0.30 mg $kg^{-1}$ as the deficiency, almost all the soils under the study area showed a deficiency in water soluble boron content. The highest value of water soluble boron content (0.33 mg $kg^{-1}$) was observed in the surface soils of Binuria village of Bolpur block and Nohana village of Illambazar block. The lowest value (0.04 mg $kg^{-1}$) was observed in the lower layer of Sarpungadanga villages in Bolpur block. As a result of the leaching of B in light-textured lateritic soil, the values of water soluble boron show sharp declines through the depth. Arora and Chahal (2005) and Chaudhary and Shukla (2004) also reported a comparable trend in depth-based profile B status.

### *3.3. Correlation between water soluble B and soil properties*

The correlation between water soluble B and soil physico-chemical properties is presented in Table 5. From the correlation analysis, it was observed that soil pH doesn't show a significant correlation with water soluble B, except in the surface soils of the Illambazar block (r= 0.457, $P \leq 0.05$). The results indicated that water soluble boron decreases with increases in soil pH. Regardless of the block or soil depth, the clay content exhibited a strong and significant relation with the water soluble boron. The positive relationship between extractable B and clay level showed that the fine-textured soils contained more B than the coarse-textured soils. Boron leaching is probably more prevalent in sandy soils and leads to less boron availability (Da Silva et al., 2018). The organic carbon showed positive correlation with water soluble boron content and a significant and positive correlation was observed in the surface soils of both Bolpur (r=0.470, $P \leq 0.05$) and Illambazar (r= 0.405, $P \leq 0.05$ $P \leq 0.05$). This implies that one of the principal sources of readily accessible B is organic matter. Findings of Mathur and Sudan (2011) were in the same line. Positive and significant correlations were observed between CEC and water soluble B. Both amorphous–Fe and Al showed positive correlation with water soluble boron, significant and positive correlation was observed in the surface soils of both Bolpur (r= 0.412, $P \leq 0.05$) and Illambazar (r= 0.428, $P \leq 0.05$) blocks. Similarly, the surface soils of Bolpur showed significant and positive correlation between amorphous-Al and water soluble boron content (r= 0.409, $P \leq 0.05$). Similar relationships also reported by Mandal et al., (2016) and Satish et al., (2021).

## ***4. Conclusion***

From the study, it can be concluded that, majority of the studied lateritic soils have a clay loam to sandy clay loam texture and strongly acidic to moderately acidic in soil pH. The majority of soils fall in the low to medium range in OC content. The water soluble boron content of the soils was insufficient and showed a decreasing trend along depth. The major physicochemical properties like clay content, pH, OC content, CEC, and amorphous Fe and Al alone or in combination, greatly influence boron availability. The soils in the studied lateritic region should be taken into consideration for adopting an integrated soil management practices for upkeeping soil fertility, with an attention on the application of boron.

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**Table 1. Depth-wise variation of clay, silt, sand content and textural classes of soils collected from different sampling sites of Bolpur block**

| S.L. No.* | Name of the sampling village | Clay (%) content at depth (cm) | | | Silt (%) content at depth (cm) | | | Sand (%) content at depth (cm) | | | Textural Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0–20 | 20–40 | 40–60 | 0–20 | 20–40 | 40–60 | 0–20 | 20–40 | 40–60 | |
| S1 | MulaRupur | 14.16 | 16.88 | 19.6 | 10.72 | 10.72 | 12 | 75.12 | 72.4 | 68.4 | Sandy Loam |
| S2 | Bindra | 43.6 | 46.88 | 49.6 | 12.72 | 8.72 | 8.72 | 43.68 | 44.4 | 41.68 | Sandy Clay |
| S3 | Binuria | 52.88 | 53.41 | 54.31 | 22.72 | 20.31 | 19.24 | 24.4 | 26.28 | 26.45 | Clay |
| S4 | Ballapur | 53.6 | 54.88 | 55.28 | 22 | 20.72 | 20 | 24.4 | 24.4 | 24.72 | Clay |
| S5 | Danga Para | 21.63 | 22.26 | 22.84 | 22.74 | 20.3 | 19.25 | 55.63 | 57.44 | 57.91 | Sandy Clay Loam |
| S6 | Shadipur | 21.16 | 23.6 | 24.96 | 12.72 | 12 | 11.16 | 66.12 | 64.4 | 63.88 | Sandy Clay Loam |
| S7 | Monoharpur | 22.46 | 24.16 | 25.84 | 14.02 | 13.3 | 12.34 | 63.52 | 62.54 | 61.82 | Sandy Clay Loam |
| S8 | Sonachuri | 24.34 | 25.81 | 26.62 | 17.16 | 15.03 | 12.51 | 58.5 | 59.16 | 60.87 | Sandy Clay Loam |
| S9 | SonachuriPalli | 34.28 | 35.28 | 36.11 | 27.16 | 26.12 | 24.88 | 38.56 | 38.6 | 39.01 | Clay Loam |
| S10 | Kanalpara | 32.56 | 34.06 | 36.03 | 14.34 | 13.3 | 12.6 | 53.1 | 52.64 | 51.37 | Clay Loam |
| S11 | Bolidum | 31.16 | 34.18 | 34.88 | 24.33 | 20.1 | 18.11 | 44.51 | 45.72 | 47.01 | Clay Loam |
| S12 | Gwalpara | 24.63 | 26.06 | 28.04 | 20.11 | 18.13 | 19.25 | 55.26 | 55.81 | 52.71 | Sandy Clay Loam |
| S13 | Vidyadarpur | 22.46 | 24.44 | 25.16 | 15.72 | 13.01 | 12.03 | 61.82 | 62.55 | 62.81 | Sandy Clay Loam |
| S14 | Khejudanga | 26.88 | 27.16 | 29.84 | 18.12 | 16.13 | 15.04 | 55 | 56.71 | 55.12 | Sandy Clay Loam |
| S15 | Sarpungadanga | 23.18 | 25.33 | 27.22 | 19.42 | 17.03 | 15.91 | 57.4 | 57.64 | 56.87 | Sandy Clay Loam |
| S16 | Kashba | 30.16 | 32.06 | 33.93 | 15.34 | 13.73 | 11.44 | 54.5 | 54.21 | 54.63 | Clay Loam |
| S17 | Kamal kandapur | 44.12 | 42.88 | 42.92 | 26.72 | 26.11 | 24.72 | 29.16 | 31.01 | 32.36 | Clay |
| S18 | Seala | 35.88 | 36.18 | 38.11 | 24.16 | 22.12 | 20.08 | 39.96 | 41.7 | 41.81 | Clay Loam |
| S19 | Khanjanpur | 37.22 | 38.31 | 39.01 | 26.03 | 24.88 | 21.22 | 36.75 | 36.81 | 39.77 | Clay Loam |
| S20 | Samaida | 40.16 | 42.28 | 44.88 | 26.21 | 24.02 | 20.63 | 33.63 | 33.7 | 34.49 | Clay |
| S21 | Kolapukurdanga | 30.33 | 32.11 | 34.08 | 25.11 | 23.1 | 20.11 | 44.56 | 44.79 | 45.81 | Clay Loam |
| S22 | Thalthod | 31.77 | 33.21 | 34.03 | 15.04 | 14.03 | 12.16 | 53.19 | 52.76 | 53.81 | Clay Loam |
| S23 | Maheshdal/ musdal | 51.32 | 53.46 | 55.11 | 28.12 | 26.71 | 28.14 | 20.56 | 19.83 | 16.75 | Clay |
| S24 | Bandanga | 41.16 | 42.18 | 44.88 | 24.33 | 26.1 | 22 | 34.51 | 31.72 | 33.12 | Clay Loam |
| S25 | Fuldanga | 54.13 | 56.34 | 58.88 | 23.42 | 22.82 | 20.72 | 22.45 | 20.84 | 20.4 | Clay |
| Range | | 14.16–54.13 | 16.88–56.34 | 19.60–58.88 | 10.72–28.12 | 8.72–26.71 | 8.72–28.14 | 20.56–75.12 | 19.83–72.40 | 16.75–68.40 | |
| Mean | | 33.81 | 35.34 | 36.89 | 20.34 | 18.74 | 17.37 | 45.85 | 45.92 | 45.74 | |
| SD | | 11.39 | 11.25 | 11.26 | 5.33 | 5.49 | 5.12 | 15.03 | 14.87 | 14.55 | |

*S.L.No. = Sampling Location Number

**Table 2. Depth-wise variation of few soil chemical properties and water soluble boron content in soils of Bolpur block**

| S.L. No. | pH at depth (cm) | | | OC (%) content at depth (cm) | | | CEC (c mol $kg^{-1}$) content at depth (cm) | | | Amorphous Fe (g $kg^{-1}$) content at depth (cm) | | | Amorphous Al (g $kg^{-1}$) content at depth (cm) | | | Water soluble B (mg $kg^{-1}$) content at depth (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** |
| **S1** | 4.33 | 4.48 | 5.13 | 0.32 | 0.27 | 0.11 | 7.8 | 9.37 | 11.55 | 3.74 | 3.05 | 2.80 | 2.75 | 1.53 | 1.27 | 0.18 | 0.11 | 0.09 |
| **S2** | 4.5 | 4.58 | 4.68 | 0.53 | 0.44 | 0.24 | 24.31 | 26.31 | 27.12 | 7.90 | 4.42 | 2.09 | 3.82 | 3.13 | 2.08 | 0.22 | 0.15 | 0.10 |
| **S3** | 5.41 | 5.48 | 5.82 | 0.52 | 0.37 | 0.17 | 26.34 | 28.41 | 26.31 | 8.22 | 5.87 | 5.76 | 5.12 | 3.48 | 3.18 | 0.33 | 0.17 | 0.11 |
| **S4** | 5.31 | 5.71 | 6.01 | 0.45 | 0.29 | 0.16 | 20.12 | 21.25 | 22.97 | 7.40 | 5.20 | 2.90 | 4.99 | 3.71 | 3.36 | 0.27 | 0.16 | 0.11 |
| **S5** | 6.05 | 6.3 | 6.58 | 0.32 | 0.21 | 0.13 | 11.24 | 13.28 | 14.27 | 5.41 | 4.95 | 3.26 | 5.76 | 2.80 | 2.07 | 0.20 | 0.13 | 0.07 |
| **S6** | 5.29 | 5.61 | 6.05 | 0.54 | 0.41 | 0.27 | 10.38 | 11.85 | 13.14 | 5.29 | 5.24 | 4.57 | 2.62 | 2.33 | 1.86 | 0.16 | 0.11 | 0.06 |
| **S7** | 5.58 | 6.11 | 6.59 | 0.45 | 0.29 | 0.17 | 11.98 | 14.25 | 10.14 | 5.62 | 5.37 | 3.69 | 5.33 | 2.65 | 2.31 | 0.25 | 0.15 | 0.11 |
| **S8** | 5.42 | 5.48 | 5.57 | 0.42 | 0.22 | 0.14 | 10.09 | 12.13 | 13.02 | 6.09 | 4.74 | 2.80 | 3.00 | 1.67 | 1.17 | 0.23 | 0.09 | 0.05 |
| **S9** | 4.39 | 6.08 | 6.18 | 0.43 | 0.31 | 0.15 | 18.34 | 20.01 | 23.43 | 5.57 | 6.84 | 5.16 | 2.32 | 1.26 | 1.13 | 0.19 | 0.20 | 0.15 |
| **S10** | 5.57 | 5.47 | 5.95 | 0.51 | 0.28 | 0.21 | 16.28 | 14.22 | 18.27 | 8.14 | 7.57 | 5.15 | 5.49 | 2.65 | 3.55 | 0.31 | 0.11 | 0.08 |
| **S11** | 4.99 | 5.08 | 5.43 | 0.43 | 0.38 | 0.26 | 9.47 | 10.99 | 12.22 | 7.79 | 7.60 | 5.98 | 3.46 | 3.08 | 2.22 | 0.23 | 0.15 | 0.13 |
| **S12** | 4.48 | 4.76 | 6.07 | 0.58 | 0.31 | 0.23 | 12.85 | 14.25 | 15.72 | 6.16 | 5.79 | 4.01 | 2.73 | 2.50 | 1.73 | 0.27 | 0.17 | 0.12 |
| **S13** | 6.12 | 6.77 | 6.91 | 0.42 | 0.29 | 0.25 | 10.33 | 12.28 | 14.06 | 5.62 | 6.04 | 2.59 | 2.99 | 1.58 | 1.15 | 0.21 | 0.13 | 0.10 |
| **S14** | 6.1 | 6.3 | 6.58 | 0.32 | 0.23 | 0.12 | 14.68 | 16.05 | 12.24 | 6.72 | 4.04 | 2.26 | 3.51 | 2.74 | 2.16 | 0.18 | 0.12 | 0.09 |
| **S15** | 5.34 | 5.5 | 5.82 | 0.53 | 0.42 | 0.18 | 18.53 | 19.11 | 20.47 | 5.80 | 6.63 | 3.89 | 5.15 | 2.09 | 1.30 | 0.30 | 0.09 | 0.04 |
| **S16** | 5.05 | 5.8 | 6.5 | 0.44 | 0.38 | 0.24 | 11.26 | 13.65 | 15.02 | 7.54 | 5.12 | 2.85 | 3.70 | 1.76 | 1.96 | 0.19 | 0.10 | 0.05 |
| **S17** | 4.9 | 5.56 | 5.86 | 0.55 | 0.37 | 0.22 | 17.21 | 18.89 | 20.21 | 8.03 | 6.53 | 5.13 | 2.11 | 2.15 | 1.50 | 0.27 | 0.12 | 0.08 |
| **S18** | 6.26 | 6.41 | 6.51 | 0.34 | 0.26 | 0.11 | 10.82 | 12.64 | 13.24 | 6.97 | 6.04 | 5.44 | 3.46 | 4.78 | 2.44 | 0.24 | 0.11 | 0.09 |
| **S19** | 5.16 | 6.34 | 6.74 | 0.37 | 0.2 | 0.17 | 12.25 | 14.25 | 16.34 | 7.31 | 4.51 | 3.57 | 3.79 | 3.41 | 1.22 | 0.25 | 0.14 | 0.11 |
| **S20** | 5.43 | 6.08 | 6.68 | 0.55 | 0.33 | 0.16 | 17.24 | 18.97 | 20.45 | 8.04 | 7.40 | 6.41 | 6.22 | 4.76 | 2.95 | 0.23 | 0.20 | 0.15 |
| **S21** | 5.9 | 6.05 | 6.59 | 0.45 | 0.31 | 0.1 | 16.98 | 14.22 | 18.74 | 6.58 | 5.14 | 4.87 | 4.05 | 3.45 | 1.86 | 0.21 | 0.11 | 0.09 |
| **S22** | 5.73 | 6.3 | 6.52 | 0.42 | 0.21 | 0.15 | 10.78 | 13.1 | 14.71 | 7.94 | 5.38 | 2.86 | 2.15 | 2.42 | 2.35 | 0.20 | 0.15 | 0.10 |
| **S23** | 5.62 | 5.98 | 6.01 | 0.41 | 0.39 | 0.29 | 24.31 | 25.14 | 23.02 | 5.83 | 4.88 | 3.87 | 2.55 | 2.14 | 1.94 | 0.31 | 0.17 | 0.13 |
| **S24** | 5.15 | 6.28 | 6.54 | 0.56 | 0.47 | 0.11 | 20.76 | 22.21 | 26.17 | 7.29 | 5.37 | 4.41 | 5.68 | 3.24 | 2.67 | 0.29 | 0.15 | 0.07 |
| **S25** | 5.45 | 6.19 | 6.42 | 0.53 | 0.42 | 0.27 | 19.76 | 21.03 | 22.28 | 8.53 | 7.52 | 6.41 | 5.15 | 3.76 | 2.92 | 0.28 | 0.13 | 0.11 |
| **Range** | 4.33–6.26 | 4.48–6.77 | 4.68–6.91 | 0.32–0.58 | 0.20–0.47 | 0.10–0.29 | 7.80–26.34 | 9.37–28.41 | 10.14–27.12 | 3.74–8.53 | 3.05–7.60 | 2.09–6.41 | 2.11–6.22 | 1.26–4.78 | 1.13–3.55 | 0.16–0.33 | 0.08–0.20 | 0.04–0.15 |
| **Mean** | 5.34 | 5.79 | 6.15 | 0.46 | 0.32 | 0.18 | 15.36 | 16.71 | 17.80 | 6.78 | 5.65 | 4.11 | 3.92 | 2.76 | 2.09 | 0.24 | 0.14 | 0.10 |
| **SD** | 0.54 | 0.59 | 0.54 | 0.08 | 0.08 | 0.06 | 5.22 | 5.12 | 5.13 | 1.22 | 1.17 | 1.32 | 1.28 | 0.93 | 0.72 | 0.046 | 0.030 | 0.029 |

*S.L.No. = Sampling Location Number

**Table 3. Depth-wise variation of clay, silt, sand content and textural classes of soils collected from different sampling sites of Illambazar block**

| S.L. No. | Name of the samplng village | Clay (%) content at depth (cm) | | | Silt (%) content at depth (cm) | | | Sand (%) content at depth (cm) | | | Textural Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0–20 | 20–40 | 40–60 | 0–20 | 20–40 | 40–60 | 0–20 | 20–40 | 40–60 | |
| **S1** | Phalasdanga | 35.28 | 37.28 | 43.28 | 24.72 | 24.72 | 20.72 | 40.00 | 38.00 | 36.00 | Clay Loam |
| **S2** | BansidangaBarpara | 28.16 | 28.72 | 34.88 | 30.16 | 31.44 | 20.72 | 41.68 | 39.84 | 44.40 | Clay Loam |
| **S3** | Nachansaha | 36.32 | 42.16 | 46.72 | 28.00 | 24.88 | 17.44 | 35.68 | 32.96 | 35.84 | Clay Loam |
| **S4** | Kulungdanga | 41.60 | 40.88 | 40.88 | 26.00 | 26.00 | 22.00 | 32.40 | 33.12 | 37.12 | Clay |
| **S5** | Narayan pur | 43.28 | 42.72 | 44.72 | 20.72 | 24.72 | 26.72 | 36.00 | 32.56 | 28.56 | Clay |
| **S6** | Mitikona | 22.88 | 26.16 | 28.16 | 8.72 | 8.16 | 9.44 | 68.40 | 65.68 | 62.40 | Sandy Clay Loam |
| **S7** | Katna | 27.44 | 26.72 | 33.44 | 28.72 | 32.72 | 26.72 | 43.84 | 40.56 | 39.84 | Clay Loam |
| **S8** | Konda | 47.60 | 49.60 | 51.60 | 22.00 | 26.00 | 22.72 | 30.40 | 24.40 | 25.68 | Clay |
| **S9** | Chunpolasi | 32.16 | 36.88 | 39.44 | 28.16 | 29.44 | 29.44 | 39.68 | 33.68 | 31.12 | Clay Loam |
| **S10** | Joypur | 51.28 | 55.28 | 61.44 | 17.44 | 16.72 | 16.72 | 31.28 | 28.00 | 21.84 | Clay |
| **S11** | Nanasol | 52.88 | 63.60 | 58.88 | 16.72 | 16.00 | 16.00 | 30.40 | 20.40 | 25.12 | Clay |
| **S12** | Navagram | 38.16 | 36.00 | 35.44 | 28.72 | 30.72 | 34.00 | 33.12 | 33.28 | 30.56 | Clay Loam |
| **S13** | Payer | 21.60 | 25.60 | 28.96 | 12.72 | 12.00 | 14.16 | 65.68 | 62.40 | 58.96 | Sandy Clay Loam |
| **S14** | Balai | 22.56 | 24.36 | 26.84 | 10.02 | 13.30 | 12.34 | 67.42 | 62.34 | 60.82 | Sandy Clay Loam |
| **S15** | Nohana | 24.40 | 22.81 | 22.62 | 20.16 | 14.03 | 10.51 | 55.44 | 63.16 | 66.87 | Sandy Clay Loam |
| **S16** | Machpara | 41.60 | 42.88 | 46.16 | 32.72 | 26.72 | 24.72 | 25.68 | 30.40 | 29.12 | Clay |
| **S17** | Akomba | 33.44 | 37.44 | 39.28 | 28.72 | 26.00 | 24.72 | 37.84 | 36.56 | 36.00 | Clay Loam |
| **S18** | ChotachalkDungapara | 20.56 | 22.77 | 26.64 | 10.43 | 10.20 | 10.46 | 69.01 | 67.03 | 62.90 | Sandy Clay Loam |
| **S19** | Arambag | 33.44 | 36.16 | 39.60 | 22.72 | 25.44 | 24.72 | 43.84 | 38.40 | 35.68 | Sandy Clay Loam |
| **S20** | Gudisha | 52.88 | 58.88 | 61.60 | 14.72 | 12.72 | 12.72 | 32.40 | 28.40 | 25.68 | Clay |
| **S21** | Gudisha school | 32.88 | 34.16 | 36.16 | 30.72 | 31.44 | 30.72 | 36.40 | 34.40 | 33.12 | Clay Loam |
| **S22** | Mehandipur | 21.56 | 24.56 | 26.81 | 23.10 | 12.30 | 12.31 | 55.34 | 63.14 | 60.88 | Sandy Clay Loam |
| **S23** | Sinut | 22.10 | 23.56 | 28.56 | 12.46 | 9.01 | 14.34 | 65.44 | 67.43 | 57.10 | Sandy Clay Loam |
| **S24** | Kamr para | 31.44 | 37.60 | 38.16 | 30.72 | 28.00 | 30.16 | 37.84 | 34.40 | 31.68 | Clay Loam |
| **S25** | Gopalnagar | 22.88 | 23.44 | 24.16 | 5.28 | 8.72 | 12.72 | 71.84 | 67.84 | 63.12 | Sandy Clay Loam |
| **Range** | | 20.56–52.88 | 22.77–63.60 | 22.62–61.60 | 5.28–32.72 | 8.16–32.72 | 9.44–34.0 | 25.68–71.84 | 20.40–67.84 | 21.84–66.87 | |
| **Mean** | | 33.54 | 36.01 | 38.58 | 21.38 | 20.86 | 19.89 | 45.08 | 43.14 | 41.62 | |
| **SD** | | 10.42 | 11.69 | 11.30 | 8.10 | 8.40 | 7.33 | 14.81 | 15.89 | 14.90 | |

*S.L.No. = Sampling Location Number

**Table 4. Depth-wise variation of few soil chemical properties and water soluble boron content in soils of Illambazar block**

| S.L. No. | pH at depth (cm) | | | OC (%) content at depth (cm) | | | CEC (c mol $kg^{-1}$) content at depth (cm) | | | Amorphous Fe (g $kg^{-1}$) content at depth (cm) | | | Amorphous Al (g $kg^{-1}$) content at depth (cm) | | | Water soluble B (mg $kg^{-1}$) content at depth (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** | **0–20** | **20–40** | **40–60** |
| **S1** | 5.93 | 6.22 | 6.35 | 0.63 | 0.44 | 0.31 | 11.21 | 13.98 | 14.27 | 5.06 | 4.78 | 2.56 | 4.57 | 3.31 | 1.45 | 0.25 | 0.17 | 0.08 |
| **S2** | 5.14 | 6.45 | 6.66 | 0.39 | 0.29 | 0.18 | 7.02 | 8.14 | 8.78 | 4.63 | 4.22 | 3.67 | 4.38 | 3.47 | 2.19 | 0.29 | 0.22 | 0.12 |
| **S3** | 6.50 | 5.81 | 6.14 | 0.76 | 0.54 | 0.23 | 13.54 | 15.27 | 17.42 | 7.26 | 3.67 | 2.92 | 3.12 | 2.88 | 1.51 | 0.32 | 0.14 | 0.10 |
| **S4** | 5.44 | 6.14 | 6.52 | 0.49 | 0.26 | 0.21 | 18.99 | 21.12 | 22.24 | 8.32 | 4.43 | 3.30 | 4.90 | 3.92 | 2.22 | 0.22 | 0.14 | 0.07 |
| **S5** | 6.35 | 6.64 | 6.70 | 0.92 | 0.52 | 0.32 | 24.64 | 23.78 | 26.71 | 7.66 | 6.77 | 4.71 | 6.53 | 4.74 | 3.41 | 0.26 | 0.22 | 0.13 |
| **S6** | 6.08 | 6.38 | 6.83 | 0.68 | 0.32 | 0.27 | 11.12 | 13.65 | 14.27 | 8.98 | 4.76 | 3.96 | 2.81 | 1.39 | 1.54 | 0.32 | 0.19 | 0.08 |
| **S7** | 6.13 | 6.68 | 6.85 | 0.66 | 0.23 | 0.17 | 9.24 | 11.21 | 10.24 | 5.49 | 4.86 | 3.52 | 5.22 | 3.04 | 1.39 | 0.20 | 0.07 | 0.05 |
| **S8** | 6.51 | 6.72 | 6.83 | 0.39 | 0.17 | 0.11 | 18.90 | 19.68 | 20.47 | 8.52 | 6.02 | 2.43 | 3.56 | 2.51 | 1.46 | 0.22 | 0.16 | 0.12 |
| **S9** | 6.37 | 6.48 | 6.74 | 0.62 | 0.52 | 0.46 | 13.14 | 15.36 | 17.28 | 6.43 | 3.71 | 4.15 | 4.67 | 4.58 | 1.80 | 0.27 | 0.11 | 0.07 |
| **S10** | 6.38 | 6.71 | 6.80 | 0.62 | 0.48 | 0.28 | 21.00 | 25.33 | 23.54 | 8.26 | 5.05 | 4.47 | 5.67 | 2.01 | 1.57 | 0.25 | 0.21 | 0.12 |
| **S11** | 6.69 | 6.77 | 6.82 | 0.57 | 0.35 | 0.15 | 26.11 | 27.31 | 24.20 | 8.58 | 6.96 | 5.20 | 5.15 | 3.42 | 2.94 | 0.29 | 0.14 | 0.10 |
| **S12** | 6.56 | 6.45 | 6.81 | 0.56 | 0.35 | 0.19 | 6.54 | 8.24 | 7.00 | 7.63 | 6.55 | 4.73 | 2.46 | 1.30 | 1.17 | 0.30 | 0.19 | 0.11 |
| **S13** | 6.40 | 5.47 | 5.90 | 0.85 | 0.50 | 0.49 | 9.24 | 10.32 | 11.67 | 4.32 | 4.05 | 3.05 | 3.33 | 2.53 | 2.09 | 0.26 | 0.15 | 0.08 |
| **S14** | 5.25 | 5.55 | 5.85 | 0.76 | 0.35 | 0.20 | 14.32 | 16.24 | 11.28 | 4.51 | 4.43 | 2.83 | 2.22 | 1.81 | 1.44 | 0.21 | 0.13 | 0.06 |
| **S15** | 6.21 | 5.56 | 5.72 | 0.96 | 0.55 | 0.49 | 5.90 | 6.47 | 7.85 | 4.88 | 3.15 | 2.38 | 3.44 | 2.77 | 1.15 | 0.33 | 0.16 | 0.08 |
| **S16** | 5.38 | 5.70 | 5.76 | 0.86 | 0.50 | 0.47 | 18.24 | 20.47 | 15.32 | 8.32 | 7.80 | 4.86 | 4.78 | 3.24 | 2.40 | 0.23 | 0.15 | 0.09 |
| **S17** | 5.97 | 5.98 | 6.24 | 0.66 | 0.35 | 0.15 | 14.08 | 17.81 | 14.56 | 6.69 | 5.81 | 4.13 | 4.19 | 3.42 | 3.11 | 0.22 | 0.10 | 0.08 |
| **S18** | 5.16 | 6.26 | 6.35 | 0.53 | 0.41 | 0.37 | 6.34 | 8.27 | 5.34 | 4.81 | 4.14 | 2.80 | 4.41 | 2.65 | 1.87 | 0.18 | 0.15 | 0.11 |
| **S19** | 5.48 | 5.55 | 5.94 | 0.87 | 0.45 | 0.39 | 14.38 | 16.10 | 12.34 | 6.69 | 6.57 | 4.17 | 4.61 | 3.14 | 1.37 | 0.27 | 0.12 | 0.09 |
| **S20** | 5.75 | 5.55 | 5.96 | 0.99 | 0.56 | 0.43 | 26.47 | 27.88 | 29.14 | 8.58 | 5.71 | 4.48 | 5.39 | 4.15 | 1.05 | 0.31 | 0.25 | 0.13 |
| **S21** | 5.26 | 5.58 | 5.62 | 0.96 | 0.55 | 0.39 | 22.31 | 21.25 | 20.34 | 5.58 | 4.21 | 2.81 | 3.17 | 2.38 | 1.19 | 0.26 | 0.14 | 0.10 |
| **S22** | 5.67 | 6.31 | 6.55 | 0.69 | 0.27 | 0.14 | 7.54 | 9.37 | 7.26 | 4.31 | 3.47 | 2.82 | 3.28 | 2.95 | 2.54 | 0.16 | 0.12 | 0.08 |
| **S23** | 5.02 | 6.54 | 6.69 | 0.44 | 0.28 | 0.21 | 10.25 | 12.38 | 8.24 | 4.42 | 4.28 | 3.01 | 2.17 | 2.06 | 1.39 | 0.15 | 0.11 | 0.07 |
| **S24** | 6.36 | 5.71 | 5.91 | 0.87 | 0.69 | 0.58 | 24.36 | 22.34 | 26.37 | 7.29 | 6.84 | 2.02 | 5.46 | 3.46 | 3.50 | 0.22 | 0.17 | 0.10 |
| **S25** | 5.61 | 5.74 | 5.93 | 0.33 | 0.27 | 0.18 | 14.35 | 15.98 | 11.37 | 4.58 | 4.26 | 2.54 | 3.69 | 2.62 | 1.91 | 0.18 | 0.10 | 0.08 |
| **Range** | 5.02–6.69 | 5.47–6.77 | 5.62–6.85 | 0.33–0.99 | 0.17–0.69 | 0.11–0.17 | 5.90–26.47 | 6.47–27.88 | 5.34–29.14 | 4.31–8.98 | 3.15–7.80 | 2.02–5.20 | 2.17–6.53 | 1.30–4.74 | 1.05–3.50 | 0.15–0.33 | 0.07–0.25 | 0.05–0.13 |
| **Mean** | 5.90 | 6.12 | 6.34 | 0.68 | 0.41 | 0.29 | 14.77 | 16.32 | 15.50 | 6.47 | 5.06 | 3.50 | 4.13 | 2.95 | 1.91 | 0.25 | 0.15 | 0.09 |
| **SD** | 0.53 | 0.46 | 0.43 | 0.19 | 0.13 | 0.14 | 6.58 | 6.26 | 6.96 | 1.67 | 1.28 | 0.92 | 1.15 | 0.88 | 0.72 | 0.05 | 0.04 | 0.02 |

*S.L.No. = Sampling Location Number

**Table 5. Pearson correlation coefficients (r) between water soluble B content and major soil physicochemical properties**

| Sampling block/soil depth | | Soil properties | | | | | |
|---|---|---|---|---|---|---|---|
| Bolpur Block | | pH | Clay | OC | CEC | Amr-Fe | Amr-Al |
| 0-20 cm soil depth | Water soluble B | 0.025 | 0.584** | 0.470* | 0.630** | 0.412* | 0.409* |
| 20-40 cm soil depth | Water soluble B | 0.058 | 0.459* | 0.098 | 0.492* | 0.24 | 0.24 |
| 40-60 cm soil depth | Water soluble B | 0.072 | 0.408* | 0.133 | 0.225 | 0.369 | 0.188 |
| Illambazar Block | | | | | | | |
| 0-20 cm soil depth | Water soluble B | 0.457* | 0.351 | 0.405* | 0.111 | 0.428* | 0.068 |
| 20-40 cm soil depth | Water soluble B | 0.065 | 0.416* | 0.344 | 0.277 | 0.244 | 0.081 |
| 40-60 cm soil depth | Water soluble B | 0.101 | 0.567* | 0.09 | 0.455* | 0.293 | 0.125 |

*, ** Significant at 0.05 and 0.01 probability levels, respectively