SOIL GEOGRAPHY

# Soil Transition and Spatial Variability of Soil Properties Across the Birbhum–Murshidabad District Transition Zone in West Bengal, India: A Scientific Analysis

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**Abstract**

Soil transition zones exhibit considerable spatial variation in physical and chemical properties, reflecting differences in parent material, geomorphology, and land-use conditions. This study examines the spatial variation of soil properties across the Birbhum–Murshidabad district boundary in West Bengal, focusing on Bishnupur Gram Panchayat in Birbhum and Padamkandi Gram Panchayat in Murshidabad. A total of 18 soil samples were collected from agricultural fields, riverbanks, and representative soil profiles and analysed for texture, pH, organic carbon, available nitrogen, phosphorus, and potassium. The results reveal a distinct textural transition, with relatively higher fine-sand content in Bishnupur and higher coarse-sand and silt–clay fractions in Padamkandi. are recommended to support sustainable soil quality and agricultural productivity. Soil pH shows greater variability in Bishnupur (6.0–8.0), whereas Padamkandi exhibits a narrower range of 6.5–7.0. Organic carbon varies from 0.45–1.00% across the study area, while available nitrogen remains relatively stable at most sampling sites, except for a lower value at Padamkandi Sample 06. Available phosphorus is comparatively higher in Padamkandi, whereas potassium shows greater variability in Bishnupur and consistently lower values in Padamkandi. The results illustrate the spatial variation of the soil transition process around the district border. The need for site-specific management of soils is stressed by the results. It is important to test the soils on a regular basis, use organic matter, maintain balanced fertilization, and manage water properly.

**Keywords:** soil transition; soil properties; soil texture; soil pH; organic carbon; nitrogen; phosphorus; potassium; Birbhum; Murshidabad; West Bengal

## 1 Introduction

The soil is an active constituent of the terrestrial environment that is developed and transformed by the combined effects of climate, organisms, topography, parent material, time, water regime, and anthropogenic factors (Jenny, 1941). Soil transition, thus, means the differentiation and change of soil properties along environmental and landscape gradients. These changes can be manifested by differences in texture, structure, color, pH, organic carbon content, nutrients availability, and other physicochemical properties.

According to the classical state-factor model developed by Jenny (1941), climate, organisms, relief, parent material, and time are considered to be the primary factors controlling soil formation processes. These factors define the intensity and direction of pedogenetic processes, which lead to the differences in soil properties. The parent material is an important factor, which is the mineral

basis of soils, and climate is responsible for weathering, decomposition, leaching, and biological processes. Another example of the impact of the parent material factor on the development of soil morphology and physicochemical properties can be found in the case of northern transitional agro-climatic zone of Karnataka (Pulakeshi et al., 2014). Relief and geomorphology affect erosion, accumulation, drainage, infiltration, depth, and moisture of soils.

Other biological and anthropogenic processes influence soil formation. Vegetation and soil biota control organic matter inputs, decomposition, nutrient cycling, and soil structure while cultivation, irrigation, fertilization, tillage, deforestation, and land use change may affect these processes in a shorter period. As a result, LULC change is one of the factors that affect the transformation of soils today. In the case of Murshidabad district, large changes in LULC from 1991 to 2021 were linked to population increase and land use change (Mustaquim & Islam, 2023). Another study has indicated that there were significant changes in crop composition in the Murshidabad-Jiaganj region from 1990 to 2021 due, among other things, to irrigation and agroclimatic factors (Mohammad et al., 2025).

The process of soil transition also includes changes in the chemical properties of the soil, such as pH, organic carbon, and the nutrient content of the soil. These properties are related to each other, and they are influenced by environmental factors and human activities. As stated by Kundu et al. (2019), the available sulphur, soil organic carbon, and pH were found to be significantly related to each other in the soils of the districts of Murshidabad and Purulia. The above information clearly demonstrates that soil properties need to be studied as a complex of interrelated characteristics.

Recent advancements in remote sensing technology, GIS technology, digital soil mapping, and geostatistics have improved the evaluation of the spatial variability of soils. Remote sensing helps monitor LULC and crop system changes over time, and GIS and statistical methods help integrate and interpret soil, topography, hydrology, and land-use data (Mohammad et al., 2025). Thus, analysis of field samples of soils and the use of such technologies may help evaluate the soil variability and transitions better.

The Birbhum–Murshidabad border provides an appropriate setting for examining such soil transitions because it represents a geographical interface between contrasting physiographic and alluvial environments. Variations in geomorphology, sedimentary conditions, drainage, agricultural land use, and human interventions may produce differences in soil properties over relatively short distances. However, localized empirical assessment of these soil transitions, particularly through the combined analysis of physical and chemical properties, remains limited. Therefore, the present study examines the spatial and vertical variation of soil texture, pH, organic carbon, available nitrogen, phosphorus, and potassium across Bishnupur Gram Panchayat in Birbhum and Padamkandi Gram Panchayat in Murshidabad. The study aims to identify the principal characteristics and spatial patterns of soil transition and to assess their implications for soil fertility and sustainable agricultural management.

## 2 Literature review

Soil fertility and soil quality are very important components when it comes to agricultural production and proper soil management. Soil fertility depends on the relationship between physical, chemical, and biological characteristics and not on any one characteristic alone. The common indicators of soil quality and fertility include soil texture, structure, pH, EC, SOC, CEC, and availability of nutrients such as N, P, K, and S. This variation in both spatial and vertical soil fertility is an important component in understanding differences in soil fertility.

The physico-chemical properties of soil in the agro-ecological zones of West Bengal differ largely due to variation in factors like parent material, geomorphology, drainage system, cropping pattern, and land use practices. The difference between the old red and laterite soil of western West Bengal and the alluvial soils of eastern parts of the state holds a significant position. Some investigations conducted on lateritic soils of West Bengal reveal the existence of variations in fertility status and phosphorus fractions in various agro-ecological zones (Chakraborty et al., 2014).

The soil pH is one of the most important factors affecting the nutrient availability, as it affects nutrient solubility, microbe action, and soil chemical composition. According to Mandal and Ghosh (2021), in some soil profiles in Birbhum District, the pH values varied from 5.01 to 7.07, meaning that soil was quite acidic up to neutral. Moreover, Mandal and Ghosh (2021) mentioned low electrical conductivity of the soil and correlation between pH, organic carbon content, and macronutrient availability.

Organic carbon in soil is also an essential soil quality indicator because it plays an essential role in nutrient recycling, aggregation, moisture retention, microbial activity, and structure development. In the selected soil profiles of Birbhum, higher organic carbon content was recorded in surface horizons compared to subsurface horizons by Mandal and Ghosh (2021). Higher contents of available nitrogen, phosphorus, potassium, and sulfur were found in the upper layers, but the concentration of available nutrients declined with increasing soil depth, and there existed positive correlations between organic carbon and available macronutrients.

The availability of nutrients is dependent on the combined effect of soil reaction, organic matter, soil texture, mineral content, moisture status, and farming practices. In the case of Birbhum, as found by Mandal and Ghosh (2021), the available amounts of N and P nutrients were low to moderate, sulphur was low, while potassium was from moderate to high in the surface soil layers with variability across the soil profile. The same has been found by Kundu et al. (2019) in the study of Murshidabad and Purulia, where available sulphur had shown a large variation and significant negative correlation between soil pH and available sulphur, but positive correlation with soil organic carbon.

The area comprising Birbhum-Murshidabad is one such place where it becomes suitable to conduct a study on spatial soil variability since the area consists of varied geomorphological and depositional settings. While the west consists of old and high landscapes, the eastern and central areas comprise vast alluvium landscapes. As mentioned by Brahma (2022) in an aquifer mapping study on some areas in Murshidabad and surrounding Birbhum areas, the presence of Quaternary alluvium and spatial variability in terms of geological and geomorphological conditions could be seen in the area.

Soil texture is especially significant due to the fact that the ratio between sand, silt, and clay affects the process of drainage, infiltration, aeration, water retention, and nutrient holding capability. The soil containing more sand usually allows for quick drainage while having less capability to retain water and nutrients, while soils containing more silt and clay tend to retain more water and nutrients, but at the same time, they could be less permeable when there is too much clay present.

The other factor that contributes to altering soil characteristics is through modifications brought about by land use and cropping practices in terms of variations in organic matter supply, nutrient loss, irrigation practices, and cultivation intensity. In a recent study conducted in Murshidabad-Jiaganj, there have been considerable shifts in cropping practices and cultivated lands during the last few decades through the use of multi-temporal remote sensing and GIS approaches. This implies that agricultural landscapes are dynamic and that the study of soil characteristics needs to take into

account both environmental and land use characteristics. Nevertheless, shifting cropping intensities are not due to soil fertility alone.

## 3 Research gap

The studies that have been conducted before have significantly enhanced knowledge regarding soil fertility, nutrient distribution, soil profile, and agricultural-land dynamics in Birbhum and Murshidabad. But many of these studies have dealt either with individual soil characteristics, nutrient status, soil profile, or agricultural and land dynamics. Relatively less attention has been paid to the spatial study of different soil characteristics in a transition area between Birbhum and Murshidabad. This is important due to the fact that transition areas may show significant changes in texture, soil reaction, organic carbon content, and nutrients over a small distance.

Hence, in the current study, an attempt has been made to examine the spatial variations of certain physical and chemical attributes of soils in the Birbhum-Murshidabad transitional belt, with special reference to soil texture, pH, organic carbon, and available nutrients such as N, P, and K. The purpose of this comparative study of soils in Bishnupur Gram Panchayat, Birbhum and Padamkandi Gram Panchayat, Murshidabad is to examine the spatial differentiation of soils.

## 4 Significance of the study

This boundary area is very important from the pedological viewpoint since it indicates the transition between red and lateritic soils in the older Rarh region and the younger alluvial soils in the Bagri region. Such a difference in physical conditions makes it possible to conduct an appropriate investigation of variability in soil characteristics both in terms of their horizontal and vertical profiles. Unfortunately, despite the significance of this area in the agronomic sense, very little has been done so far to evaluate the variability of soil properties.

This study carries both scientific and practical importance. The study is important scientifically in that it utilizes field observation, laboratory determination of soil, vertical profiling, land use data and spatial interpretation to determine the patterns of soil transition under different environmental conditions. The vertical soil profiling, on the other hand, allows the determination of changes in the nutrient status of soils and other soil properties with depth, which would not be effectively determined with just surface-soil analysis. On the practical side, the findings from the study can be used to evaluate the spatial variations in soil fertility and plan specific soil and nutrient management. This will help in managing agricultural inputs such as organic amendments, fertilizers and irrigation, among others, depending on soil conditions and not using a universal approach. Lastly, the study can serve as a base for future monitoring of soil-fertility change, land use effects and soil degradation in the Birbhum-Murshidabad transition zone.

## 5 Research objectives

The study aims to:

1. Characterize the major physical and chemical properties of soils across the Birbhum–Murshidabad transition zone.
2. Analyse the spatial and vertical variation of selected soil properties.
3. Assess the spatial pattern of soil fertility using selected soil and nutrient indicators.

4. Examine variations in soil properties and fertility across major land-use and land-cover categories.
5. Delineate the soil transition pattern and suggest appropriate strategies for sustainable soil and agricultural management.

## 6 Research questions

1. What are the major physical and chemical characteristics of soils across the transition zone?
2. How do soil properties vary spatially and vertically across the study area?
3. How does soil fertility vary spatially based on the selected indicators?
4. How do soil properties and fertility differ among major land-use and land-cover categories?
5. What soil-transition patterns emerge, and how can they inform sustainable soil and agricultural management?

## 7 Study area

The study area is located along the **Birbhum–Murshidabad district boundary of West Bengal, India**, representing a transitional landscape between the Rarh region of Birbhum and the Bagri region of Murshidabad. The study was conducted in **Bishnupur and Padamkandi Gram Panchayats**, which extend approximately from **24°07′12″ N to 24°09′36″ N latitude and 87°52′48″ E to 87°57′36″ E longitude** and comprise predominantly rural and agricultural landscapes (Figure 1). The area exhibits contrasting geological and geomorphological characteristics, with relatively older lateritic and alluvial formations towards the western side and younger fluvial alluvial deposits towards the eastern side, resulting in spatial variation in soil texture, drainage, moisture conditions, and nutrient status (Brahma, 2022). The terrain is predominantly level to gently undulating, with agricultural fields, seasonal drainage channels, ponds, marshes, and settlements distributed across the landscape, while the **Dwarka River and associated fluvial processes** contribute to local erosion, sediment deposition, and seasonal waterlogging. The region experiences a tropical monsoon climate, with hot summers, relatively cool winters, and approximately **1,400 mm of annual rainfall**, concentrated mainly during the southwest monsoon from June to September. The major LULC categories include paddy and other agricultural fields, vegetable cultivation, current and permanent fallow land, vegetation, settlements, ponds, marshes, and barren or sparsely vegetated areas (Figure 1.2). Common vegetation includes mango (*Mangifera indica*), bamboo (*Bambusa* spp.), jackfruit (*Artocarpus heterophyllus*), babla (*Vachellia nilotica*), arjun (*Terminalia arjuna*), simul (*Bombax ceiba*), and sissoo (*Dalbergia sissoo*) (Pradhan & Rahaman, 2014; Das & Bardhan, 2023). The study area has a predominantly agrarian economy, with approximately **17,849 and 15,034 inhabitants** in Padamkandi and Bishnupur Gram Panchayats, respectively, and agriculture based mainly on paddy, wheat, mustard, pulses, jute, and seasonal vegetables, supplemented by livestock rearing, dairy farming, sericulture, and small-scale trade (Chakraborty, 2012; Chakraborty & Ghosh, 2016). The combination of contrasting physiographic settings, fluvial processes, diverse LULC patterns, and agricultural dependence makes the area particularly suitable for investigating the **spatial and depth-wise variation of physicochemical soil properties and the characteristics of soil transition across the Birbhum–Murshidabad border region**.

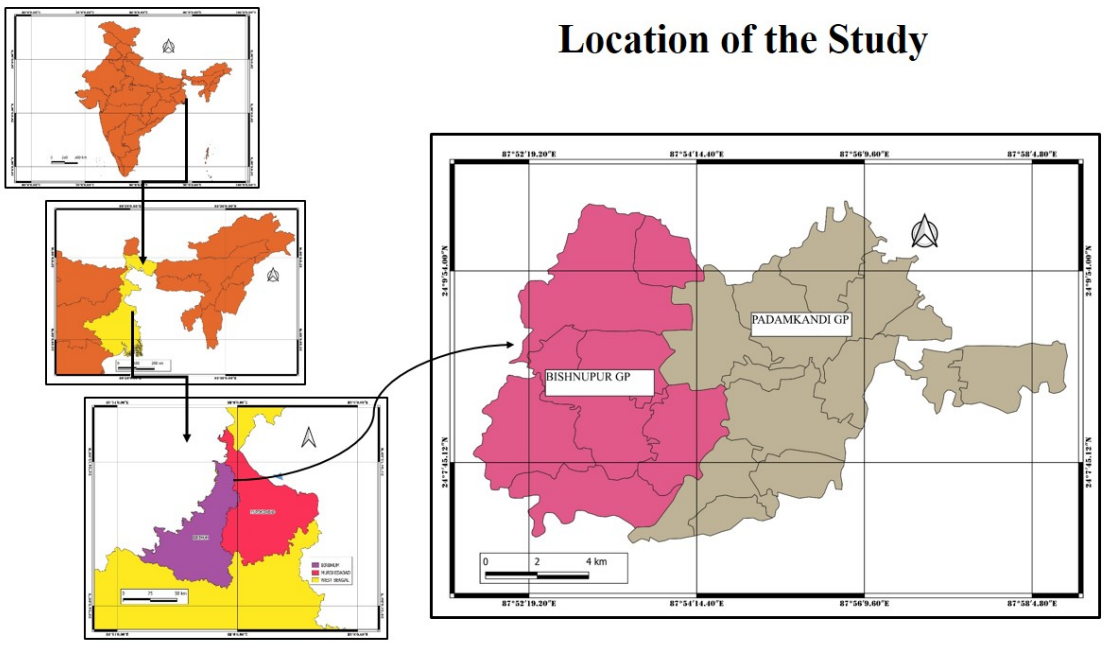



**Figure 1.** Location map of the study area

## 8 Methodology

The research used an integrated field, laboratory and geospatial methodology to study the spatial and vertical variations of soil properties in the Birbhum-Murshidabad transition zone. The methodology used for the research entailed field observations, soil sampling, laboratory analyses and the use of geospatial and remote sensing data. Parameters such as soil texture, soil color, soil bulk density, soil pH, electrical conductivity (EC), soil organic carbon (OC) and soil nutrients were considered to characterize soil conditions and study their spatial and fertility variations. Vertical variations of soil properties and characteristics were studied using soil profile analysis and soil sampling. GIS and remote sensing data was used to study the spatial interactions of soil properties, terrain and transitional zone characteristics.

### 8.1 Data sources and site selection

The primary data were collected through systematic field surveys and soil sampling in Bishnupur Gram Panchayat, Birbhum District and Padamkandi Gram Panchayat, Murshidabad District. Both study sites were chosen because they belong to the Birbhum-Murshidabad transition zone with varied physiographic conditions. Initial field surveys were carried out to select suitable sites for sampling on the basis of physiographic, drainage, soil types and predominant land use practices. Paddy fields and riverbanks were chosen as representative environments. The geographic co-ordinates of the sampling sites are provided in Table 1.

**Table 1.** Soil sample sites

| Soil sample no. | Place | Location | Land use |
|---|---|---|---|
| 1 | Purapara | 24°07′42.5″N 87°54′49.0″E | Paddy field |
| 2 | Deshalpur | 24°07′47.3″N 87°54′44.5″E | Paddy field |
| 3 | Deshalpur | 24°07′49.4″N 87°54′33.3″E | Paddy field |

| Soil sample no. | Place | Location | Land use |
|---|---|---|---|
| 4 | Sabaldaha | 24°08′16.9″N 87°54′52.2″E | Paddy field |
| 5 | Sabaldaha | 24°08′23.6″N 87°54′46.2″E | Paddy field |
| 6 | Purapara | 24°07′29.9″N 87°55′05.2″E | Paddy field |
| 7 | Ganful | 24°07′16.6″N 87°54′55.7″E | Paddy field |
| 8 | Purapara | 24°07′26.7″N 87°55′17.6″E | Paddy field |
| 9 | Purapara | 24°07′34.5″N 87°55′37.7″E | Paddy field |
| 10 | Kalidaha | 24°07′42.8″N 87°54′07.6″E | Paddy field |
| 11 | Durgapur | 24°08′51.2″N 87°52′56.5″E | Paddy field |
| 12 | Podda | 24°09′52.3″N 87°53′01.6″E | Paddy field |
| 13 | Patdanga | 24°08′25.5″N 87°57′25.9″E | River bank |
| 14 | Patdanga | 24°08′25.5″N 87°57′25.9″E | River bank |
| 15 | Patdanga | 24°08′25.5″N 87°57′25.9″E | River bank |
| 16 | Baswa | 24°07′57.8″N 87°52′02.2″E | River bank |
| 17 | Baswa | 24°07′57.8″N 87°52′02.2″E | River bank |
| 18 | Baswa | 24°07′57.8″N 87°52′02.2″E | River bank |

### 8.2 Soil sample collection

Soil samples were collected totalling 18, 12 from Padamkandi Gram Panchayat and 6 from Bishnupur Gram Panchayat. Soil samples were taken from chosen paddy fields and along the river banks to determine the spatial variation of soil properties. Moreover, soil profiles were studied at Baswa village in Bishnupur and Patdanga village in Padamkandi to know vertical variations and transitional features. The soil profile was stratified into three layers depending on the change in colour and morphology of the soil and samples were collected from each individual layer. Around 70 to 80 grams of soil was collected from each sampling site using clean sampling tools.

### 8.3 Soil sample preparation

The samples collected were dried in air, manually disaggregated with mortar and pestle, and sieved with a 2-mm sieve to exclude gravel, roots, and other coarse particles. The sieved samples were kept in clean and labeled air-tight polyethylene bags before analyses. Laboratory analyses were carried out to measure the chosen physical and chemical properties of the soil samples. A picture of the prepared soil samples is given in Figure 1.3.

All collected soil samples were analysed in the Soil and Geomorphology Laboratory, Department of Geography, Visva-Bharati, following standard procedures for the determination of selected physical and chemical properties.

### 8.4 Data processing and analysis

The laboratory results for pH, OC, N, P, and K were entered into Microsoft Excel and subjected to calculations, tabulation, comparative analysis, and interpretation. The processed data were subsequently used to examine the spatial and depth-wise variation of soil chemical properties across the study area




**Figure 2.** Soil sample collection (field photographs)

## 9 Results and discussion

### 9.1 Soil texture

The soil texture was assessed through the determination of the amount of sand, silt, and clay within each sample. Around 50 g of soil collected from each sampling site was used for laboratory testing. The soil samples were prepared to obtain the different particle-size components, and the amounts of sand, silt, and clay were measured and recorded. These measurements were then fed into Microsoft Excel for the calculation of the percentage content of each component. The textural composition obtained was used to describe the physical characteristics of soils in the study area.




**Figure 3.** Proportion of coarse sand, fine sand and silt + clay

### 9.2 Chemical analysis

The physical properties of the soil samples obtained from the selected locations were studied in order to ascertain soil reactions and nutrients in the context of soil quality and suitability for agriculture. Parameters such as pH, organic carbon (OC), available nitrogen (N), phosphorus (P) and potassium (K) were analyzed as per the procedures followed in soil fertility and characterization in the past studies (Kekane et al., 2019; Pulakeshi et al., 2014). The laboratory experiment was done in the Soil and Geomorphology Laboratory, Department of Geography, Visva-Bharati using A/O Model Soil Testing Kit.

### 9.3 Soil properties of Bishnupur Gram Panchayat, Birbhum

The first aim of this study was to develop a pedological benchmark for the western section of the study area, which belongs to Bishnupur Gram Panchayat (GP) in Birbhum District. This region is a

part of Rarh, where topography consists of gentle undulations and soils that are under the influence of laterite and old alluvium. To evaluate the variability of soil

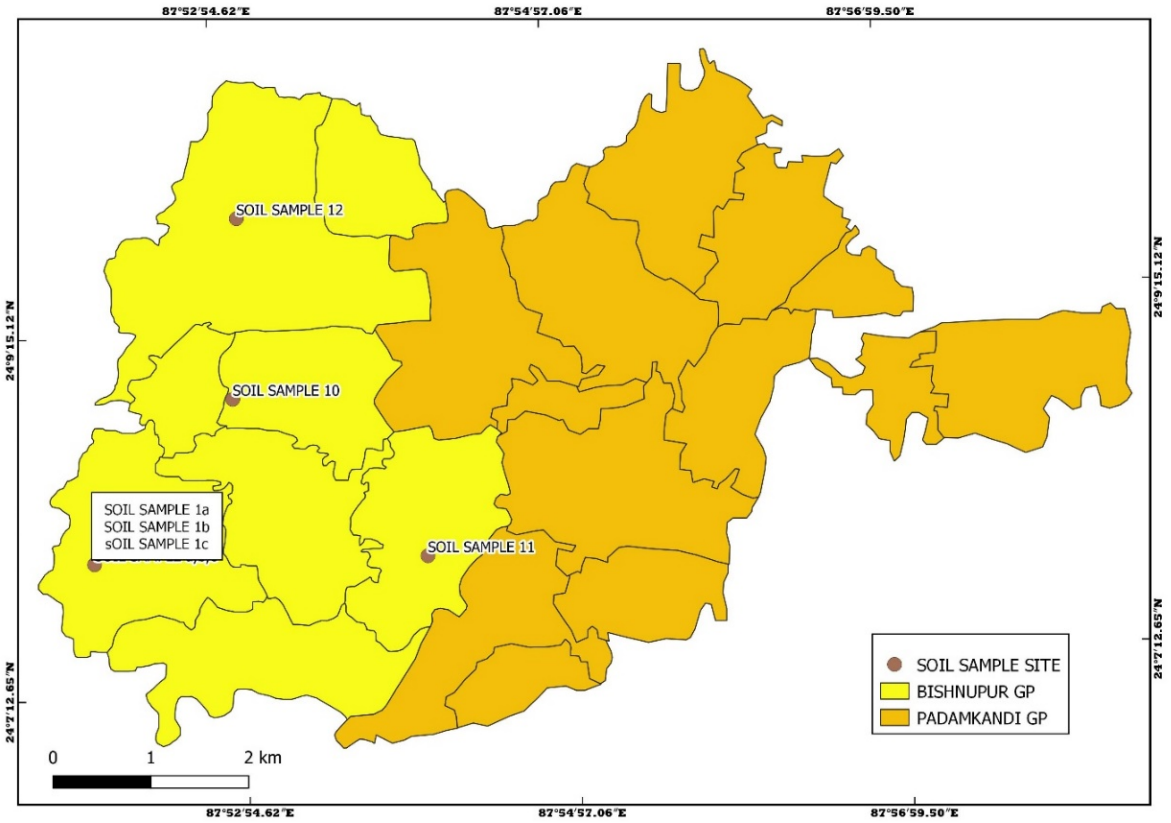



**Figure 4.** Soil sample collection sites in Birbhum District

To investigate these properties, six soil samples were collected from the paddy field and riverbank soils from Durgapur, Podda, Baswa, and Kalidaha villages (Figure 4). Soil samples 10, 11, and 12 were collected from the paddy fields from Kalidaha, Durgapur, and Podda villages, whereas other samples were collected from the riverbank soils (Table 2). The physical and chemical properties of the samples were studied in order to identify the spatial variations of soils in Bishnupur GP.

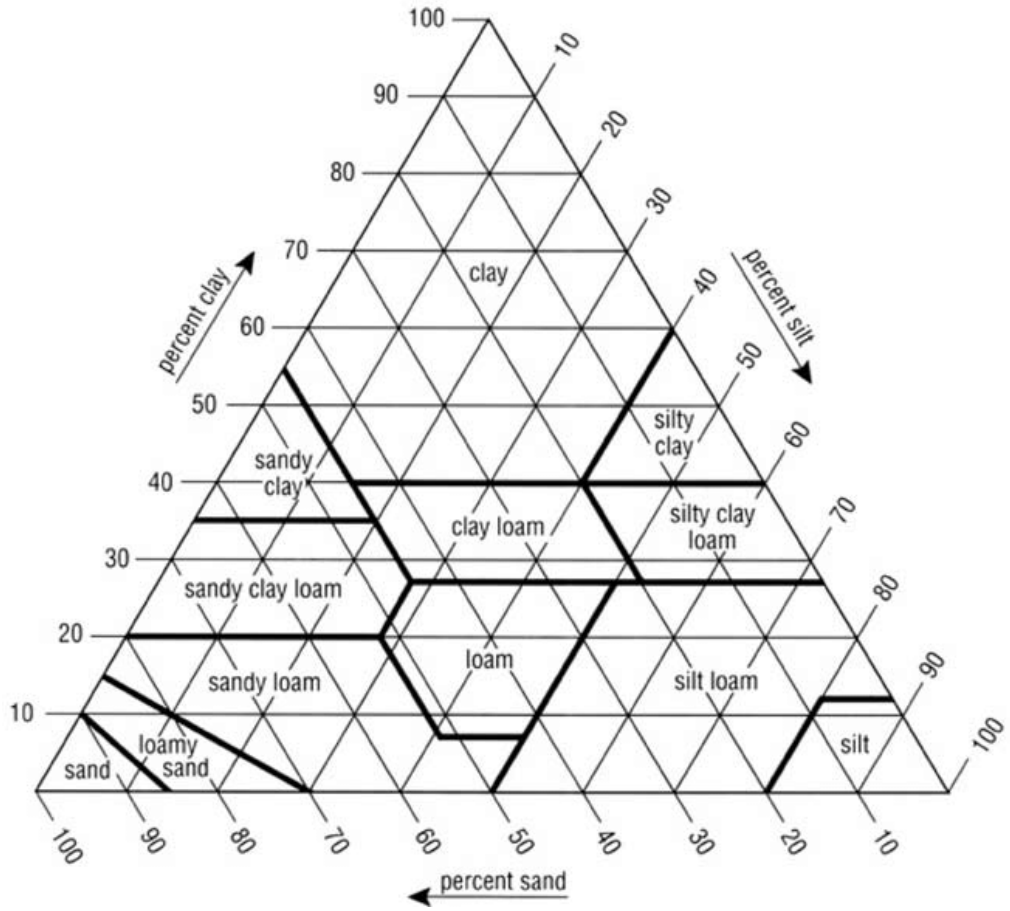



**Figure 5.** Soil texture triangle (source: Twarakavi et al., 2010)

### *9.3.1 Analysis of physical properties of soil in Bishnupur GP (Birbhum)*

#### *9.3.1.1 Soil texture*

Textural analysis shows that there is a considerable difference in the percentages of coarse sand, fine sand, and silt plus clay in the soil samples taken from Bishnupur Gram Panchayat (Table 2). The most predominant type is fine sand in the percentage range of 37.82% - 53.82%, followed by coarse sand (23.23%-40.53%) and silt plus clay (14.56%-21.79%). Using Samples 10-12, it has been estimated that the average percentages of coarse sand, fine sand, and silt plus clay are 34.53%, 45.01%, and 18.79%, respectively. The predominance of sands shows that the soils are mainly sandy loam in texture, but there is some spatial difference among the samples collected. The high presence of sand is an indicator of good drainage and aeration in the soil, while the silt and clay improve water and nutrient retention in the soil.

**Table 2.** Soil aggregates of soil samples of Bishnupur GP

| Sample no. | Actual weight of sample (g) | Coarse sand (g) | Coarse sand (%) | Fine sand (g) | Fine sand (%) | Silt + clay (g) | Silt + clay (%) |
|---|---|---|---|---|---|---|---|
| 10 | 31.5 | 12.5495 | 39.84 | 13.6688 | 43.39 | 4.5849 | 14.56 |
| 11 | 30.3 | 12.2805 | 40.53 | 11.4605 | 37.82 | 6.0625 | 20.01 |
| 12 | 30.6 | 7.1094 | 23.23 | 16.4702 | 53.82 | 6.6678 | 21.79 |

#### 9.3.1.2 Depth-wise variation in soil properties

The soil profile has the same predominant texture type which is sandy loam in all samples collected. Fine sand forms the majority of the soil composition. Soil pH does not change much; it maintains its level of 6.5 in all samples collected. On the other hand, organic carbon content drops from 1.00% in the surface layer to 0.45% in subsoil samples due to less accumulation of organic content with increasing soil depth. Available phosphorus goes up from 0 kg/acre in L1 to 22.68 kg/acre in L3. Potassium levels go up from 20 mg/L in L1 to 50 mg/L in L2 and stay at the same level of 50 mg/L in L3. Such variations show different nutrient distribution in the soil profile by depth. Nitrogen levels do not vary much from sample to sample.

### 9.3.2 Analysis of chemical properties of soil in Bishnupur GP (Birbhum)

The chemical properties of soil samples from Bishnupur Gram Panchayat have been investigated to determine their fertility status and spatial variations that can be used for better agricultural practices (Table 3). Soil pH, organic carbon (OC), available nitrogen (N), phosphorus (P), and potassium (K) are some of the important parameters taken into consideration to study the chemical status of soil. Results indicate that there is great variability in soil pH, OC, phosphorus, and potassium content, but nitrogen does not vary at all. The value of soil pH varies from 6.0 to 8.0; thus, the soil is neutral to moderately alkaline in nature.

The amount of organic carbon in the three surface soil samples in Table 3 varies between 0.50% and 0.75%, signifying that there is spatial variability in the condition of the organic matter. The higher amounts of organic carbon will help in improving soil structure, nutrient retention, and biological activities while the relatively lower amounts signify that there is an opportunity to incorporate organic amendments and crop residues in the management of the soils. The available nitrogen has been measured to be 20.41 kg/acre in the three surface soil samples, signifying no spatial variability in the condition of the nitrogen.

**Table 3.** Chemical properties of the soil samples of Bishnupur GP

| Sample no. | pH | Organic carbon (%) | Nitrogen (N) (kg/acre) | Phosphorus (P) (kg/acre) | Potassium (K) (mg/L) |
|---|---|---|---|---|---|
| 10 | 8 | 0.75 | 20.41 | 22.68 | 20 |
| 11 | 8 | 0.75 | 20.41 | 9.07 to 22.68 | 50 |
| 12 | 6 | 0.5 | 20.41 | 9.07 to 22.68 | 50 |

Available phosphorus also varies significantly, with available phosphorus having been found to range between 9.07 to 22.68 kg/acre. Such variation in the available phosphorus level might indicate the variations in phosphorus availability at different sampling sites and would have significant implications for managing crop nutrient requirements. Phosphorus is one of the key macronutrients required by plants to transfer energy, promote root growth and perform various physiological functions. Potassium levels were found to be between 20 and 50 mg/L, while Samples 11 and 12 had more potassium than Sample 10. Potassium is responsible for the regulation of water, enzyme activities, and stress resistance in plants; hence, variations in its availability should be accounted for in the development of nutrient management strategies specific to the site.

## 9.4 Soil properties of Padamkandi Gram Panchayat, Murshidabad

The east portion of the study area which is constituted by Padamkandi Gram Panchayat (GP) of Murshidabad District, has been studied to understand the soil properties in the Birbhum-Murshidabad transition zone. This area is a transitional region with difference in geology, physiography, and land use characteristics. Nine soil samples (Samples 01-09) have been taken from the selected areas and analyzed for their physical and chemical properties.

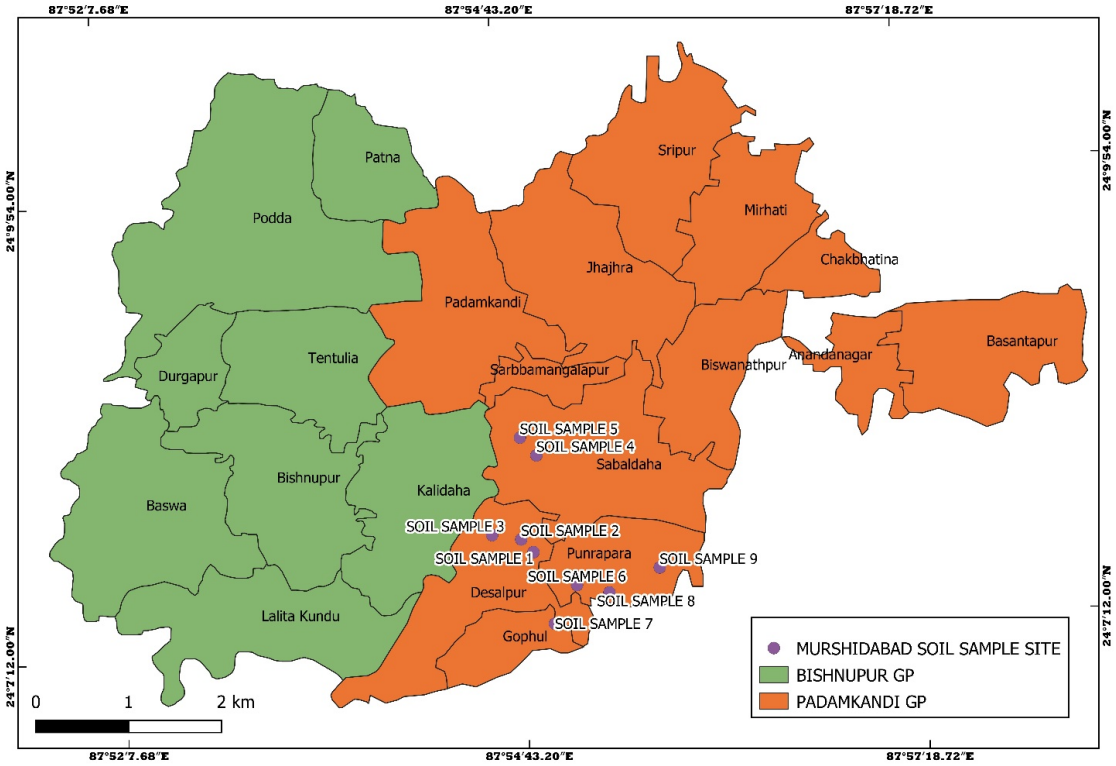



**Figure 6.** Soil sample collection sites in Murshidabad District

### *9.4.1 Analysis of physical properties of soil in Padamkandi GP*

Results of texture analysis reveal wide fluctuations in the relative percentages of coarse sand, fine sand, and silt plus clay in Padamkandi Gram Panchayat (Table 4). Coarse sand is the predominant soil particle in all of the samples, comprising an average of 41.86% of the total weight, while fine sand constitutes 33.71% and silt plus clay 23.12%. The sample 06 has the maximum coarse sand content (52.09%), and Sample 02 stands out due to its high fine sand content (58.66%) and low silt plus clay percentage (5.75%). Sample 04, on the other hand, has the maximum percentage of silt plus clay (30.68%). Thus, prevalence of sand-sized particles makes the soils predominantly sandy loam in texture. High sand content results in increased soil permeability and aeration, while presence of silt and clay improves soil water retention and fertility. Thus, these textural properties are crucial in determining spatial variation of soil behaviour and proper management of soil and water for agricultural purposes in the area under investigation.

**Table 4.** Soil aggregates of soil samples of Padamkandi GP

| Sample no. | Actual weight of sample (g) | Coarse sand (g) | Coarse sand (%) | Fine sand (g) | Fine sand (%) | Silt + clay (g) | Silt + clay (%) |
|---|---|---|---|---|---|---|---|
| 01 | 26.1 | 11.098 | 42.52 | 7.3472 | 28.15 | 7.2821 | 27.90 |
| 02 | 26.5 | 9.296 | 35.08 | 15.5446 | 58.66 | 1.5248 | 5.75 |
| 03 | 18.5 | 7.3527 | 39.74 | 5.323 | 28.77 | 5.4353 | 29.38 |
| 04 | 24.7 | 8.9755 | 36.34 | 7.6588 | 31.01 | 7.5771 | 30.68 |
| 05 | 27.1 | 13.897 | 51.28 | 5.4038 | 19.94 | 7.7992 | 28.78 |
| 06 | 27.4 | 14.2736 | 52.09 | 7.9653 | 29.07 | 4.6146 | 16.84 |
| 07 | 38.2 | 18.5618 | 48.59 | 12.2895 | 32.17 | 6.8006 | 17.80 |
| 08 | 53.3 | 16.7568 | 31.44 | 22.6866 | 42.56 | 13.1298 | 24.63 |
| 09 | 25.3 | 10.04 | 39.68 | 8.361 | 33.05 | 6.6485 | 26.28 |

### *9.4.2 Analysis of chemical properties of soil in Padamkandi GP (Murshidabad)*

**Table 5.** Chemical properties of soil samples of Padamkandi GP

| Sample no. | pH | Organic carbon (%) | Nitrogen (N) (kg/acre) | Phosphorus (P) (kg/acre) | Potassium (K) (mg/L) |
|---|---|---|---|---|---|
| 01 | 6.5 | 0.5 | 20.41 | 9.07 to 22.68 | 20/0 |
| 02 | 7 | 0.5 | 20.41 | 9.07 to 22.69 | 20 |
| 03 | 7 | 0.75 | 20.41 | 9.07 to 22.70 | 20/0 |
| 04 | 7 | 1 | 20.41 | 9.07 | 20/0 |
| 05 | 6.5 | 0.5 | 20.41 | 9.07 | 20 |
| 06 | 7 | 0.5 | 8.16 | 9.07 to 22.68 | 20/0 |
| 07 | 6.5 | 0.5 | 20.41 | 9.07 | 20 |
| 08 | 7 | 0.5 | 20.41 | 9.07 | 20 |
| 09 | 7 | 0.5 | 20.41 | 22.68 to 29.48 | 20 |

Spatial variations are observed in the values of pH, OC, available N, P and K in the soils of Padamkandi Gram Panchayat, which serve as a proxy for assessing the status of the soil in terms of its chemical composition and fertility. The values of soil pH vary from 6.5 to 7.0, with an average of 6.83 and very slightly acidic to neutral condition. This is beneficial for the availability of plant nutrients. The spatial variation in the values of organic carbon varies from 0.50% to 1.00%, where the maximum value is recorded in Sample 04, whereas 0.50% is found at the majority of sampling points. There is less spatial variation observed in the available nitrogen content, which is around 20.41 kg/acre for most of the soil samples, except at Sampling 06, where it goes down to 8.16 kg/acre, which signifies that there is comparatively lesser availability of nitrogen at that point. The available phosphorus content shows a high degree of spatial variation, where the range varies from 9.07 to 29.48 kg/acre, with the highest value at Sampling 09. On the other hand, potassium stays constant at 20 mg/L across all the sampling locations.

The soil profile contains notable variations in its chemistry depending on the depth. For example, soil pH goes from 8.0 in the surface layer (L1) to 7.0 in the lower layers (L2-L3), which means the change

of the soil acidity from the alkaline one in the surface soil to the neutral one in the lower depths. At the same time, the amount of organic carbon only slightly drops from 0.50% in L1 to 0.45% in L2 and L3, which means that the organic matter content becomes lower in the lower soil depth. The available nitrogen also goes through significant changes going from 20.41 kg/acre in L1 to 8.16 kg/acre in L2 and L3. Potassium goes through an increase from 20 mg/L in L1 to 50 mg/L in L2 and L3, while the available phosphorus in the surface soil is at 22.68 kg/acre while it disappears in the lower depths. Therefore, the difference between the distribution of these elements in soil depending on its depth confirms that there is notable vertical heterogeneity in soil properties.

## 10 Soil transition

The soil transition between the districts of Birbhum and Murshidabad has been done by examining the physical and chemical attributes of the soil samples collected from Bishnupur Gram Panchayat (Birbhum) and Padamkandi Gram Panchayat (Murshidabad). It can be seen that there is a gradual spatial variation in soil characteristics of the two regions depending on the physiographic setting, parent material, drainage, and soil use conditions. In the case of Bishnupur Gram Panchayat of the Rarh landscape, the texture of soil is generally coarse, mainly comprising sand fraction. However, in the case of Padamkandi, even though there is presence of sand in significant amount, there are variations in particle size distribution. There is difference in pH value, organic carbon, and available nitrogen, phosphorus, and potassium in both the sites.

### 10.1 Physical transition of soil texture

These textural traits show a clear west-east difference in the composition of the soil particles size in spite of the fact that both the areas have been designated sandy loam. While fine sand is the main particle type in Bishnupur GP area, having an average percentage of 46.86, coarse sand is at 30.47%. On the contrary, the Padamkandi GP area shows more percentage of coarse sand than fine, i.e., an average of 41.86% as opposed to 33.71% of fine sand. This implies the variation in the predominant sand particles and hence soil texture between the two areas. It is worth noting that considerable local heterogeneity exists in the Padamkandi area, with Sample 06 having the largest percentage of coarse sand, 52.09% while Sample 02 contains a very high percentage of fine sand, 58.66%. The total silt and clay composition is also seen to increase eastwards from 19.17% of Bishnupur to 23.12% of Padamkandi, with the maximum at 30.68% in Sample 04. The increased sand content in both areas is an indication of relatively better soil water permeability and aeration, while the increased percentage of silt and clay in Padamkandi would lead to better water and nutrients retention.

### 10.2 Chemical transition: soil pH

**Table 6.** Physical and chemical properties of the soil profiles

| Layer | Depth (cm) | Coarse sand (%) | Fine sand (%) | Silt + clay (%) | pH | Organic carbon (%) | Nitrogen (N) (kg/acre) | Phosphorus (P) (kg/acre) | Potassium (K) (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| **Profile 1 (Birbhum)** | | | | | | | | | |
| L1 | 0–15 | 29.72 | 46.69 | 12.61 | 6.5 | 1 | 20.41 | 0 | 20 |
| L2 | 15–50 | 29.03 | 43.88 | 25.17 | 6.5 | 0.45 | 20.41 | 9.07 | 50 |

| Layer | Depth (cm) | Coarse sand (%) | Fine sand (%) | Silt + clay (%) | pH | Organic carbon (%) | Nitrogen (N) (kg/acre) | Phosphorus (P) (kg/acre) | Potassium (K) (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| L3 | 50–100 | 20.5 | 55.54 | 20.85 | 6.5 | 0.45 | 20.41 | 22.68 | 50 |
| **Profile 2 (Murshidabad)** | | | | | | | | | |
| L1 | 0–80 | 47.22 | 32.55 | 13.9 | 8 | 0.5 | 20.41 | 22.68 | 20 |
| L2 | 80–180 | 39.17 | 36.16 | 22.94 | 7 | 0.45 | 8.16 | 0 | 50 |
| L3 | 180–278 | 71.69 | 24.61 | 2.03 | 7 | 0.45 | 8.16 | 0 | 50 |

There is a marked variation in the chemical characteristics of the soils along the Birbhum-Murshidabad boundary line. The pH level of soils in western Bishnupur GP varies between 6.0 and 8.0, implying slight acidity to moderate alkalinity of the soils, with a mean value of 6.9. The broad spectrum of the pH level implies that there is more local variation, and for high pH values, it may affect the bioavailability of some micronutrients. On the other hand, the pH of the soils in eastern Padamkandi GP varies in a narrow band of 6.5-7.0, with an average value of 6.83, implying slight acidity to neutral soils.

### 10.3 Chemical continuities: organic carbon and nitrogen

Although there is spatial variability in the soil texture and soil pH, there is minimal spatial variability in the levels of organic carbon and available nitrogen. The levels of organic carbon range from 0.45–1.00%, with values of 0.50–1.00% noted in most of the sampling areas, which signifies that there are low to moderate levels of organic carbon present in the soils. On the other hand, the level of available nitrogen is 20.41 kg/acre at most of the sampling areas; however, the levels of available nitrogen in Padamkandi Sample 06 are 8.16 kg/acre.

### 10.4 Chemical divergence: the shift in phosphorus and potassium

The most distinct variation in the case of chemicals in the Birbhum-Murshidabad transition zone occurs in terms of available phosphorus and potassium. Available phosphorus in the western Bishnupur GP varies between 0 and 22.68 kg/acre while that in the eastern Padamkandi GP varies between 9.07 and 29.48 kg/acre, which implies a relatively higher phosphorus content in the east than in the west. The variation may possibly be attributed to variations in soil characteristics and nutrients. On the other hand, available potassium displays much variation in Bishnupur where it varies between 20 and 50 mg/L while it displays a consistent value of 20 mg/L in Padamkandi.

## 11 Conclusion and recommendations

There is a clear but spatially heterogeneous transition of the soils between Bishnupur and Padamkandi regions. The soils of Bishnupur are relatively more in fine sand, whereas the soils of Padamkandi are more in coarse sand along with slightly higher silt-clay contents. There is relatively more variability in soil pH in the soils of Bishnupur region as compared to the soils of Padamkandi region, where the pH value varies from 6.5 to 7.0, as compared to the variation of soil pH value in

Bishnupur ranging from 6.0 to 8.0. The organic carbon level in the soil of both the regions is relatively low to moderate, whereas the available nitrogen level is quite stable in most of the soils, with exception at few sites. The level of available phosphorus is relatively more in the soils of Padamkandi, whereas that of potassium is relatively higher in Bishnupur region and lower in Padamkandi. These results suggest that there is a spatial differentiation of soils requiring site-specific management practices. It is recommended that regular soil testing along with organic manure, crop residues, and phosphate/potassium fertiliser application be followed.

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