Assessment of Soil Quality Indicators under Different Land Use Pattern of West Bengal

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Declaration

I do hereby declare that the present Master thesis entitled '***Assessment of Soil Quality Indicators Under Different Land Use Pattern of West Bengal***' embodies the original research work carried out by me in the Department of Agriculture, Midnapore City College, Paschim Medinipur, West Bengal, India under the supervision of Ms. Shreyosi Roy, Asst. Professor, Department of Agriculture, Midnapore City College, Paschim Medinipur, West Bengal, India. No part thereof has been submitted for any degree or diploma in any University.

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Abstract

The present research study aims to evaluate and compare soil quality indicators, including soil pH, soil texture, and soil organic carbon (SOC) content, across different land use patterns in West Bengal, India. The assessment of soil quality indicators is crucial for sustainable land management practices, as they provide valuable insights into soil health and fertility, influencing agricultural productivity and environmental sustainability. This study adopted a systematic approach to collect soil samples from various land use Pattern. Five major land use patterns were selected using Landsat imagery (Forest Land, Cultivated Land, Fallow land, Barren Land, Pasture lands) across six districts (Purulia, Malda, Nadia, Paschim Medinipur, Bankura, Purba Medinipur) of West Bengal. In this study the change in pre-kharif cropping and land use had been analyzed using NDVI of 2003 and 2023 of every selected districts. Based on false color composite of pre-kharif season sample collection site was selected from each land use pattern. Soil samples were collected from six districts of West Bengal. Samples were obtained, each accompanied by latitude and longitude data at depth of 15 cm from each land use category. The collected soil samples underwent comprehensive laboratory testing, focusing on crucial soil properties such as soil organic carbon (O.C%), soil pH, and soil texture. A thorough statistical analysis was conducted, computing the mean, standard deviation (SD), and coefficient of variation (CV) for each land use pattern. Upon analyzing the data, a noteworthy trend emerged: the forest land exhibited a neutral pH, indicating a balanced soil condition, while its organic carbon content was found to be at a moderate level. The pre-kharif crop lands, where crops are sown before the monsoon season, showed slightly higher organic carbon levels compared to other land use patterns. Fallow land displayed low organic carbon content and barren land had low organic carbon content as well. The laboratory analysis and statistical evaluation of soil samples unveiled significant differences in soil properties across various land use patterns. This information serves as a valuable resource for formulating appropriate land management strategies and sustainable agricultural practices, with the ultimate goal of preserving soil health, productivity, and ecosystem balance in the region.

Keywords: Soil pH, Soil Texture, Soil Organic Carbon, Land Use Patterns, Soil Quality.

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Chapter 1: Introduction

1. Introduction

Soil is a complex and dynamic mixture of minerals, organic matter, water, air, and various microorganisms that covers the Earth's surface. It is formed through the weathering and decomposition of rocks, combined with the accumulation of organic materials over long periods of time and provides a medium for plants to grow by supplying them with essential nutrients, anchoring their roots, and allowing for the circulation of water and air. The formation of just one inch of soil takes thousands of years, making it an invaluable resource. Thus, it is crucial to conserve and effectively manage soil to meet the needs of future generations. The pressing issue of land degradation primarily stems from the mounting population pressure. Over time, the availability of cultivable land per person has significantly dwindled, declining from 0.32 hectares in the 1950s to 0.14 hectares at the turn of the century, and finally falling below 0.1 hectares by 2020. Consequently, the challenge we face is not only to enhance productivity sustainably but also to safeguard and preserve the quality of our soil resources for the benefit of future cohorts. It is important to recognize that the land's capacity for production is inherently limited and determined by a combination of soil, climate, and landform conditions.

To achieve successful agriculture, it is imperative to employ the sustainable utilization of soil resources. This is because soils can rapidly deteriorate in quality and quantity for various reasons within a short span of time (Kiflu and Beyen, 2013). Consequently, agricultural practices necessitate a fundamental understanding of sustainable land use. Furthermore, the effectiveness of soil management in preserving soil quality relies on comprehending how soils respond to agricultural methods over time (Tufa et al., 2019). Recent attention has been drawn to evaluating the quality of our soil resources due to the growing awareness that soil plays a critically significant role in the earth's biosphere. Not only does it contribute to the production of food and fiber, but it also maintains environmental quality on local, regional, and global scales (Doran and Parkin, 1994).

Conversely, feeding the ever-expanding human population poses a major challenge in developing countries due to soil degradation. In Asian countries, for instance, declining per capita food production is primarily attributed to the depletion of soil fertility. As population pressure intensifies and soil resources continue to degrade, this challenge will persist. Reversing this trend hinges upon bolstering the sustainable development of the agricultural sector. However, the foundation for sustainable agricultural development lies in the presence of good soil quality, as maintaining soil quality is an integral component of sustainable agriculture (Liu et al., 2010).

The degradation rate of soil quality is influenced by a combination of factors including land use systems, soil types, topography, and climatic conditions. Among these factors, inappropriate land use practices exacerbate the deterioration of soil physicochemical and biological properties (Singh et al., 1995; Saikhe et al., 1998). The chosen Land Use Patterns significantly impact crucial processes such as erosion, soil structure, aggregate stability, nutrient cycling, leaching, carbon sequestration, and other related physical and biochemical processes (Maddonni et al., 1999).

In India, the livelihoods of millions of people are under threat due to soil degradation resulting from inappropriate Land Use Patterns. The conversion of forest and pasture areas into cultivated land has led to the removal of permanent vegetation, loss of organic matter (OM), and a decrease in water-stable aggregates (WSA) and mean weight diameter (MWD), which contribute to increased soil erodibility. Land-use change has a significant influence on various soil properties, primarily through its impact on soil organic matter. The structural stability of soils, which is positively correlated with the total organic carbon content, is affected by land use (Caravaca et al., 2004). Unscientific cultivation practices have caused a reduction in soil carbon content and altered the distribution and stability of soil aggregates (Six et al., 2000).

The properties of soil are influenced by climate and geological history, particularly on regional and continental scales (Wang et al., 2001). However, at smaller catchment scales, land use emerges as the predominant factor impacting soil properties. Land use practices and soil management techniques have a direct influence on soil nutrients and related processes, including erosion, oxidation, mineralization, leaching, and more (Celik, 2005; Liu et al., 2010). Consequently, they can significantly alter the transport and redistribution of nutrients. In non-cultivated land, the type of vegetative cover plays a crucial role in determining the soil's organic carbon content (Liu et al., 2010).

Furthermore, when land-use change occurs, significant alterations take place in soils, often resulting in diminished soil quality after the cultivation of previously untilled soils (Neris et al., 2012). Therefore, both land use and vegetation type must be considered when examining the relationship between soil nutrients and environmental conditions

(Liu et al., 2010). While it is widely recognized that soil organic carbon is a critical element for improving soil quality, there is an urgent need to explore soil carbon sequestration in different Land Use Patterns as a means to alleviate soil degradation in agricultural systems.

Comprehending the effects and mechanisms associated with changes in land-use patterns is a crucial concern for policy development, particularly in the formulation of strategies for land restoration and reclamation. An illustration of this is the utilization of soil quality indicators, tailored to specific sites and climatic conditions, as a decision-making tool to guide policies aimed at land restoration and enhancing soil productivity in respective regions (Jha and Mohapatra, 2012). This approach facilitates informed decision-making and enables the implementation of targeted measures to restore and improve the productivity of land in accordance with specific environmental contexts.

Typically, agricultural research institutes and universities recommend various Land Use Patterns based on different objectives. These recommendations are then put into practice by farmers in their respective regions. However, there is a lack of sufficient information regarding the impact of these adopted Land Use Patterns on soil properties in West Bengal. This scarcity of information makes it challenging to recommend ideal and sustainable uses of land resources in the area. Therefore, it is crucial to evaluate the effects of these Land Use Patterns on soil properties and quality indicators, taking into account the regional conditions. This evaluation can provide valuable insights for developing strategies to restore soil quality and promote potential Land Use Patterns in the specific region.

In order to make informed decisions regarding Land Use Patterns, it is important to understand the dominant Land Use Patterns and their consequent impacts on soil quality indicators. This knowledge can help identify highly potential and beneficial Land Use Patterns that not only maintain higher soil quality but also contribute to the improvement of degraded lands and sustainable agriculture in the region. With this objective in mind, a study titled "Assessment of soil quality indicators under different land-use patterns of West Bengal" was conducted. This study hypothesized that pH, soil organic carbon, soil texture, and overall soil quality indices are influenced by the specific land-use practices in West Bengal. To test this hypothesis, the study aimed to achieve the following objectives:

- To assess the current status of land use pattern or area occupied by different land use pattern from every district of West Bengal.
- Evaluate variations in soil pH and soil texture across different land-use patterns.
- Quantify the levels of soil organic carbon in relation to different land-use patterns.
- Develop soil quality indicators tailored to specific Land Use Patterns.

By addressing these objectives, the study aimed to provide valuable insights into the relationship between land-use patterns and soil quality indicators, enabling the identification of appropriate Land Use Patterns in West Bengal.

Chapter 2: Literature Review

2. Literature Review

In order to devise successful strategies for the restoration of soil quality and the promotion of sustainable agricultural practices, it is imperative to possess a comprehensive understanding of the impact of land-use pattern on soil properties, as well as the distribution and quantities of carbon and nitrogen. Furthermore, such knowledge is crucial for planning and implementing effective measures aimed at achieving sustainable Land Use Patterns. The fundamental processes affected by Land Use Patterns encompass erosion, soil structure, aggregate stability, nutrient cycling, leaching, carbon sequestration, and various other interrelated physical and biochemical processes (Maddonni et al., 2005). Gaining insights into these intricate relationships enables the formulation of informed decisions pertaining to land-use planning, facilitating the adoption of practices that optimize soil fertility, minimize adverse environmental consequences, and foster long-term sustainability in agriculture. Given the present critical circumstances, the preservation of soil resources for the future has emerged as a significant concern, necessitating the implementation of suitable management practices within Land Use Patterns. Presently, researchers are directing their efforts towards comprehending the impacts of various land-use system types with the aim of augmenting soil organic carbon levels and enhancing overall soil quality.

2.1. The Impact of Land-Use Pattern on Soil Organic Carbon, Soil PH and Soil Texture

Soil organic carbon (SOC) plays a crucial role in soil quality, fertility, and productivity, as a decrease in SOC levels can have various negative impacts on crop yields. SOC is a fundamental attribute of soil quality and sustainability as it influences the physical, chemical, and biological properties and processes of the soil. It serves as a source of energy and nutrients for soil organisms, thereby impacting the nutrient availability and supplying capacity of the soil through mineralization. Moreover, SOC also affects important soil characteristics such as aggregate stability, water retention, and hydraulic properties (Haynes, 2005).

Furthermore, SOC not only directly contributes to plant nutrient availability but also indirectly influences nutrient availability within the soil. Additionally, SOC plays a significant role in maintaining the overall quality of the environment, as soil serves as a substantial reservoir for global carbon stocks (Lal et al., 1998; Verma et al., 2010).

Numerous studies, including those by Cambardella and Elliott (1992), Chan (1997), and Bhattacharyya et al. (2011), suggest that specific fractions of soil organic matter play a more significant role in maintaining soil quality and serve as sensitive indicators for assessing the impact of land-use management. Martin et al. (2010) and Singh et al. (2011) observed a decrease in soil organic carbon stocks under agricultural land-use compared to forestry and horticulture land-uses. However, it is important to recognize that both the quantity and quality of soil organic carbon sequestered can vary under different land-use systems, and these variations can have diverse yet significant effects on soil quality, such as soil structural stability and chemical fertility. This understanding is crucial for selecting appropriate land-use systems, either individually or in combination, to mitigate the impact of changing land-use patterns on global climate change. Cropping systems and management practices that promote the return of a greater amount of crop residues to the soil are expected to contribute to a net increase in soil organic carbon stocks (Kaur et al., 2008).

In the past decade, there has been growing concern about the greenhouse effect, leading to numerous studies focused on understanding the quality, type, distribution, and behavior of soil organic carbon (SOC). The impact of global warming and its implications for SOC management have prompted quantitative estimates of the global carbon content in soil. The current estimate for global SOC stock is approximately 1,500-1,550 Pg (Eswaran et al., 1993). The initial estimation of organic carbon stock in Indian soils, based on 48 soil samples, was 24.3 pg. (1 Pg = 1015 g) (Gupta and Rao, 1994). Forest soils, due to their high organic matter content, play a significant role as carbon sinks, accounting for about 40% of the total SOC stock in global soils. Buringh (1984) reported that the global agricultural soil organic carbon stock is approximately 142 Pg. C, which represents 8-10% of the total soil carbon.

Soils can function as either sinks or sources of carbon in the atmosphere, depending on changes occurring in soil organic matter. The equilibrium between the decomposition rate and the supply rate of organic matter is disrupted when land-use is altered (Lal, 1999). Soil organic matter can increase or decrease depending on various factors, including climate, vegetation type, nutrient availability, disturbances, and land-use and management practices (Leifeld and Kogel-Knabner, 2005). Physical soil properties, such as soil structure, particle size, and composition, have a significant impact on soil carbon. Soil particle size influences the decomposition rate of soil organic carbon. The decomposition of litter plays a crucial role in the internal biogeochemical cycle of an ecosystem, as decomposers release a substantial amount of carbon previously stored in plants or trees back into the atmosphere while recycling nutrients.

Kumar et al. (2003) conducted a study on different agroforestry systems and found that the soil organic carbon stock was highest in the silvi-pasture system (74.82 Mg ha^{-1}), followed by natural grassland (44.33 Mg ha^{-1}), agri-horti-silviculture (43.97 Mg ha^{-1}), horti-pastoral (42.97 Mg ha^{-1}), Agri-horticulture (27.81 Mg ha-1), and lowest in Agri-silviculture (27.33 Mg ha-1).

In a long-term investigation by Kundu et al. (2007) on the impact of manure and fertilizer application in the soybean-wheat cropping system, it was observed that plots treated with NPK + FYM contained 40-70% higher soil organic carbon (SOC) stocks (60.3 Mg C ha-1) compared to NPK-treated (43.1 Mg C ha-1) and control plots (35.5 Mg C ha-1) in the soil section from 0-45 cm depth. The soybean-wheat cropping system contributed a total yearly carbon addition of 890 kg ha-1 yr-1 in the unfertilized control plots, with 19% directly contributing to the increase in soil organic carbon content. The rise in SOC content in the long-term cropping system was attributed to the yearly carbon addition exceeding the required amount to sustain equilibrium soil organic matter content.

Singh et al. (2007) estimated carbon stocks in different soils of Rajasthan and found that the surface soil horizon (0-25 cm) was the major sink for carbon sequestration, accounting for 31% of the total soil carbon stocks (2.13 Pg). The highest carbon stocks were observed in Entisols (0.72 Pg.), followed by Aridisols (0.70 Pg), Inceptisols (0.61 Pg), Alfisols (0.015 Pg.), and lowest in Verisols (0.105 Pg.). The land-use pattern also influenced SOC stocks, with the arid region showing higher average SOC stocks in single and double-cropping systems compared to scrublands, while in the semiarid region, scrublands exhibited higher SOC stocks compared to cropping lands.

In a long-term study conducted by Mandal et al. (2008) in alluvial soils of the Indo-Gangetic plain with a rice-based cropping system, the highest carbon sequestration was observed in the rice-wheat-jute system (535 kg ha-1 yr-1) at Barrackpore, followed by

Rice-mustard-sesame (414 kg ha-1 yr-1) and rice-fallow-rice (402 kg ha-1 yr-1) systems at the Central Rice Research Institute (CRRI), Cuttack.

Kishwan et al. (2009) assessed carbon sequestration in various forest types in India and found that from 1995 to 2005, soil carbon in forest land increased from 3552.30 to 3755.81 mt, with a decadal increment of 203.50 mt. Tropical moist deciduous forests exhibited the highest net increment, followed by tropical dry deciduous forests, while Himalayan dry temperate forests showed the least increase due to smaller area and lower soil organic carbon content. The soil component sequestered a larger amount of carbon compared to plant biomass under different forest types.

Guang-Lu and Xiao-Ming (2010) investigated the effect of land-use changes from grassland to cropland and cropland to forest (after 23 years) and orchard (after 7 years) on carbon and nitrogenstocks. They found that cropland soil experienced carbon and nitrogen losses of 31% and 26% compared to grassland soil. However, the conversion of cropland into forest and orchard lands resulted in a 76% and 66% increase in carbon stocks and a 40% and 63% increase in nitrogen stocks, respectively. The increase in carbon and nitrogen stocks was primarily observed in coarse soil aggregate fractions under forest and grassland-use systems.

Dinakaran et al. (2011) studied the influence of grass and herbaceous aerial cover on soil organic carbon (SOC) sequestration in Vadodara, India. They found that herbaceous land cover had a higher SOC content (15.6-23.2 g kg-1) compared to grassland cover (7.8-9.8 g kg-1). Both land cover types showed higher values of SOC, microbial biomass carbon, and dissolved organic carbon during the monsoon season and comparatively lower values during the summer season.

Tesfahunegn and Gebru (2020) conducted a study to assess soil organic carbon and nitrogen stocks in different cropping and land-use systems. The results showed that the highest levels of soil organic carbon (175.3 Mg C ha-1) and total nitrogen (13.6 Mg N ha-1) stocks were observed in natural forest land-use systems. On the other hand, untreated gully lands had the lowest levels of soil organic carbon (14.5 Mg C ha-1) and total nitrogen (1.20 Mg N ha-1). There was a significant reduction in soil organic carbon stocks under untreated gully (UTG) and teff mono-cropping (TM), with reductions of 91.7% and 87.1%, respectively, compared to the natural forest land-use system. Similarly, total nitrogen stocks decreased by 91.2% and 82.7% in UTG and TM, respectively.

The study also found that mean total nitrogen stocks (TN-stock) decreased by 71.9%, 69.6%, 65.1%, and 33.5% in land-uses of crop rotation, intercropping, maize mono-cropping, and treated gully, respectively, compared to the natural forest system.

In their research conducted in 1997, Gilley and Doran investigated the influence of various land-use systems on the soil texture in the top layer of soil. The results showed that the undisturbed system exhibited a higher percentage of very fine silt and clay (34%) compared to the system that underwent cultivation for nine months (24%). The sand content, on the other hand, was recorded at 14% and 16% in the undisturbed and cultivated systems after nine months of tillage, respectively. The study further revealed that the distribution of clay content was altered due to the cultivation practices. Noelle Meyer et al. conducted a study in 2008 to investigate the short-term and long-term effects of converting permanent pasture (PAS) into arable cultivated lands on soil organic carbon and soil aggregation. The findings indicated that in the short-term study sites (with more than three years of cultivation), there was a 29% reduction in the content of large-size aggregates (>4mm) and a 37% increase in the content of very small-size soil aggregates (<1mm). Additionally, there was a 16% decrease in soil organic carbon compared to PAS soils, while the content of intermediate-size soil aggregates (1-4mm) remained unchanged. In contrast, in the long-term study site (with 14 years of cultivation), there was a 30% decrease in the content of intermediate-size soil aggregates and a 32% decrease in organic carbon compared to PAS land. The overall results of the study indicated that soil organic carbon and aggregation underwent rapid changes, but water infiltration, water retention (soil hydraulic properties), and bulk density were primarily affected in the long term due to cultivation when compared to PAS lands.

2.2. Effect of Land Use Pattern on Soil quality Indicators

Periodic evaluation of soil resources is imperative for the purpose of sustainable land management, as well as for the maintenance or enhancement of soil quality, in order to meet the escalating demands for food, feed, fiber, and fuels (Cherubin et al., 2016). Soil quality refers to the inherent capability of a specific type of soil to function effectively within the boundaries of natural or managed ecosystems, thereby ensuring the sustained productivity of biological organisms, the preservation or improvement of water and air quality, and the support of human health and habitation (Karlen et al., 1997). The assessment of soil quality plays a vital role in identifying both detrimental and beneficial alterations in the physicochemical and biological attributes caused by diverse Land Use Patterns. It also guides agricultural land users towards the implementation of sustainable land management practices (McGrath and Zhang, 2003) and aids in the analysis of soil nutrient requirements (Chen et al., 2013). Soil quality indices serve as valuable decision-making tools, efficiently integrating a variety of information for the purpose of making decisions that encompass multiple objectives (Karlen and Stott, 1994). Scientists and researchers have developed diverse equations and assessment frameworks to determine soil quality indices, enabling the detection of the impact of changes in land use on soil quality.

Soil quality research primarily focused on the soil's capacity to supply nutrients and its impact on agricultural productivity. However, more recently, researchers have emphasized that soil quality cannot be directly measured. Instead, it is inferred from various soil quality attributes or indicators, as it is influenced by external factors such as soil management, land-use practices, environmental and ecosystem interactions, as well as political and socioeconomic priorities (Doran et al., 1996). These soil quality indicators, also referred to as soil attributes, monitor the effects that soil has on outcomes such as increased biomass, improved water use efficiency, and enhanced aeration. They also play a crucial role in providing a suitable medium for plant growth, regulating water storage and flow, and acting as a protective buffer against harmful substances in the soil and environment (Larson and Pierce, 1991). Shukla et al. (2006) further reported that these soil quality indicators can be used to evaluate soil management practices and assess the sustainability of land-use in agro-ecosystems.

Brejda and Moorman (2001) have reported that the performance of soil quality indicators is influenced by various factors such as nutrient management practices, land-use, and conservation practices. These indicators are used to determine whether soil quality is stable, improving, or declining. Assessing soil quality involves the use of multiple indicators, but interpreting their results can often be challenging (Karlen et al., 1997). Nortcliff (2002) has emphasized the need for research to identify the most suitable soil quality indicators from the wide range available. Additionally, it is important to establish well-defined methods for measuring these indicators, as inconsistent data sets may provide limited value for comparison. Therefore, the use of numerical indices as synthetic tools is crucial for integrating information on soil quality functions derived from individual parameters. Dalal and Molony (2000) have categorized soil quality indicators into four groups: visual, physical, chemical, and biological. Combining soil properties to develop integrated soil quality indices provides a more comprehensive understanding of soil quality compared to considering individual parameters alone (Sharma et al., 2008).

Certain indicators have been identified as effective measures of soil quality. Parr et al. (1992) reported that higher infiltration, macro-pores, aeration, aggregate stability and distribution, high soil organic carbon (SOC), low bulk density, soil resistance, resilience, erosion, and nutrient runoff are indicators associated with better soil quality. Chaudhury et al. (2005) suggested that for Alluvial soils, total soil nitrogen (N), available phosphorus (P), dehydrogenase activity, and mean weight diameter are key indicators. Karlen et al. (1992) emphasized the importance of biological parameters such as microbial biomass carbon and respiration as indicators of soil quality under long-term soil and land-use management. It should be noted that the selection of indicators for soil quality measurement is specific to the purpose and location of the assessment (Shukla et al., 2006).

Andrews et al. (2002) evaluated various methods of soil quality indexing to determine the best management system for vegetable production in Northern California. They compared methods such as expert opinion, principal component analysis, linear and non-linear scoring, additive index, weighted additive index, and decision support systems. The study found that the organic system consistently achieved higher soil quality index scores compared to low input or conventional treatments in all indexing combinations. Guang-Lu and Xiao-Ming (2010) reported that converting cropland to forest or orchard land significantly improved soil quality, as evidenced by increased soil macro-aggregates and their stability. Mandal et al. (2010) assessed soil quality in a Himalayan watershed and observed changes in soil functions under terraced croplands compared to a reference site. Changes in soil functions varied by landscape position, with habitat for flora and fauna, conservation of soil moisture, organic matter supply and nutrient cycling, infiltration of air and water, and resistance to erosion showing proportional changes.

In a long-term dryland agriculture experiment in Akola (Maharashtra), Sharma et al. (2011) derived soil quality indices under different soil and nutrient management practices. The study found that applying 25 kg P2O5 ha-1 + 50 kg N ha-1 through Leucaena green biomass resulted in a significantly higher soil quality index compared to other practices. Among the different indicators, soil organic carbon, microbial biomass carbon, and available potassium made substantial contributions to the soil quality index. Fernandes et al. (2011) evaluated the effect of different management systems on soil functions using soil quality indexing. Reduced tillage showed the highest soil quality index, followed by conventional tillage and no-tillage with a double-disk planter, while no-tillage with a hoe planter had the lowest index. Macro-porosity and soil capacity for root development played crucial roles in achieving higher soil quality indices under reduced tillage and conventional tillage systems.

Mandal et al. (2013) assessed soil quality indices to evaluate the impact of different Land Use Patterns on soil sustainability in the northwest Himalayas. Significant differences in soil quality parameters were observed among various land-use types, with sal forest soils exhibiting the highest soil quality index and rainfed cropland soils showing the lowest. Lima et al. (2013) compared different indicator sets to determine soil quality indices for rice management systems with various textural classes. The study found that using the entire set of 29 indicators provided the best estimation of soil quality index. However, even a minimum data set of indicators yielded similar results, providing useful information about soil quality for land users.

Gelaw et al. (2015) investigated soil quality indices (SQIs) under various cultivated Land Use Patterns and found that the agroforestry land-use system had the highest SQI score, followed by irrigated crop production and rainfed cultivation systems. Soil organic carbon, water-stable aggregates, total soil porosity, total nitrogen, microbial biomass carbon, and cation exchange capacity were the key indicators influencing the integrated SQI values.

Rahmanipour et al. (2014) conducted a comparative evaluation of two soil quality indexing methods: one considering a total data set of analyzed soil parameters (TDS) and the other using a minimum data set (MDS) derived through principal component analysis (PCA). The integrated quality index (IQI) based on the MDS approach yielded better estimations of soil quality compared to the nemoro quality index (NQI). This suggests that using a minimum number of carefully selected soil quality indicators in a simple, non-linearly scored index can effectively identify the best management practices while reducing the cost of soil analysis.

Ngo-Mbogba et al. (2015) assessed soil quality and properties under different land covers in South Cameroon. Soil organic matter, available phosphorus, calcium, and soil pH were identified as the most appropriate soil quality indicators, accounting for a significant proportion of the soil quality variation. Different sets of soil quality indicators, including SQI13 (thirteen indicators), SQI4 (four indicators), and SQI2 (two indicators), produced similar trends, although absolute changes were observed. The highest soil quality index scores were obtained for bare soils with burned vegetation biomass, while the lowest scores were observed for bush ligneous fallow land cover.

Nakajima et al. (2015) utilized a scoring function analysis to assess soil quality indices and determine the impact of different tillage and drainage systems on soil quality. The study found that saturated hydraulic conductivity, among soil physical properties, and soil organic carbon, among chemical properties, were the most significant indicators for soil quality assessment. The soil quality index ranged from 0.69 to 0.71 under conventional tillage and no-till systems, and from 0.69 to 0.70 in drainage and no-drainage systems, with no statistically significant difference between the treatments. However, the soil quality indices exhibited a significant correlation with corn yield ($R = 0.62$), suggesting that the soil quality index is an effective tool for evaluating agronomic efficiency.

Kalu et al. (2015) determined soil quality indices (SQIs) for different Land Use Patterns in the Panchase region of Nepal. The study revealed that the protected forest system had the highest SQI (0.95), followed by the community forest (0.91), pasture (0.88), and khet (0.81), with the lowest SQI observed in the bari land-use system (0.79). Available phosphorus and soil organic carbon were identified as the most effective soil quality indicators, contributing significantly to the differences in SQIs among the various Land Use Patterns. The presence of protected forests with minimal human impact and abundant vegetation resulted in better soil quality, while the agricultural land-use system, characterized by higher anthropogenic activity, led to soil quality deterioration.

Cherubin et al. (2016) evaluated soil quality indices under different land-use change sequences in southern Brazil using the Soil Management Assessment Framework (SMAF). The study found that native vegetation land-use exhibited a higher soil quality index (0.87) compared to sugarcane (0.74) and pasture (0.70) Land Use Patterns. The soil quality index determined through SMAF showed significant correlations with soil organic carbon stocks and visual evaluation of soil structure scores, which were also used to assess soil quality changes in the study.

Kaushal et al. (2016) assessed soil quality under agroforestry systems dominated by Grewia optiva. The study revealed that the highest soil quality index was observed in the sole Grewia system (0.50), followed by Grewia + Finger millet (0.47) and Grewia + Barn yard millet (0.47), while the fallow land-use system had the lowest index (0.32).

Vasu et al. (2016) developed soil quality indices (SQIs) using soil profile data of recognized soil series in the Deccan plateau, India. The study found that the SQIs derived by both the weighted method using principal component analysis (PCA) and expert opinion (EO) were well correlated with crop yields. However, the EO weighted index method showed comparable performance for both surface (0-15 cm soil depth) and control sections (0-100 cm soil depth), demonstrating its superior relationship with crop yield compared to PCA. Considering subsurface soil properties along with surface properties to assess SQI contributes to a better understanding of the relationship between SQI and distinct soil functions, as well as management objectives.

Cherubin et al. (2017) evaluated the soil quality of Brazilian oxisols using the Soil Management Assessment Framework (SMAF). The study highlighted that the conversion of natural vegetation to agricultural Land Use Patterns leads to soil quality depletion due to deterioration in physical and biological soil properties. Results demonstrated that SMAF was the most effective tool for detecting soil quality changes under different Land Use Patterns. The SMAF soil quality index combines individual soil indicator scores into a comprehensive value, facilitating the evaluation of overall soil functioning within a specific land-use system.

Chapter 3: Aims and Objective

3. Aims and Objectives

This study aims to address the following key aspects related to soil quality indicators and land use patterns in West Bengal and it will enhance our understanding of the relationship between land use patterns and soil quality indicators in West Bengal. The findings will contribute to the scientific knowledge base and provide valuable insights for land planners involved in sustainable land management and agricultural practices in the region. The study will compare and assess the soil quality indicators, such as soil organic carbon, soil pH, soil texture among different land use patterns prevalent in West Bengal. These land use patterns may include agricultural lands, forested areas, urban areas, and industrial zones. By analyzing the soil quality indicators across different land use patterns, the research will identify variations and differences in soil quality. It will aim to determine which land use patterns contribute positively or negatively to soil health and quality.

By achieving following objectives, a comprehensive understanding of the soil quality indicators under different land use patterns in West Bengal. The outcomes of the study will support evidence-based decision-making, land management strategies, and sustainable agricultural practices in the region.

Objectives:

1. To assess the current status of land use pattern or area occupied by different land use pattern from every district of West Bengal.
2. To determine of soil quality under different land use patter.
3. To represent the analyzed data in spatial map.
4. To study the correlation between land use pattern and soil quality status.

Chapter 4: Materials and Methods

4.1. Study Area

The current study focuses on evaluating soil quality indicators across various land use patterns in the state of West Bengal, India. The study area encompasses six selected districts, which have been chosen to represent the diverse land use patterns prevalent in West Bengal.

The six districts chosen for the study are (1) Purulia (2) Malda (3) Nadia (4) Paschim Medinipur (5) Bankura (6) Purba Medinipur. Each district represents a different land use pattern, providing a comprehensive understanding of the variation in soil quality indicators across different types of land use.

The selection of these diverse districts allows for a comprehensive analysis of soil quality indicators across different land use patterns, including agricultural, forested, fallow land and barren land. By encompassing these varied districts, the study aims to capture the range of soil types and land management practices that influence soil quality in West Bengal.

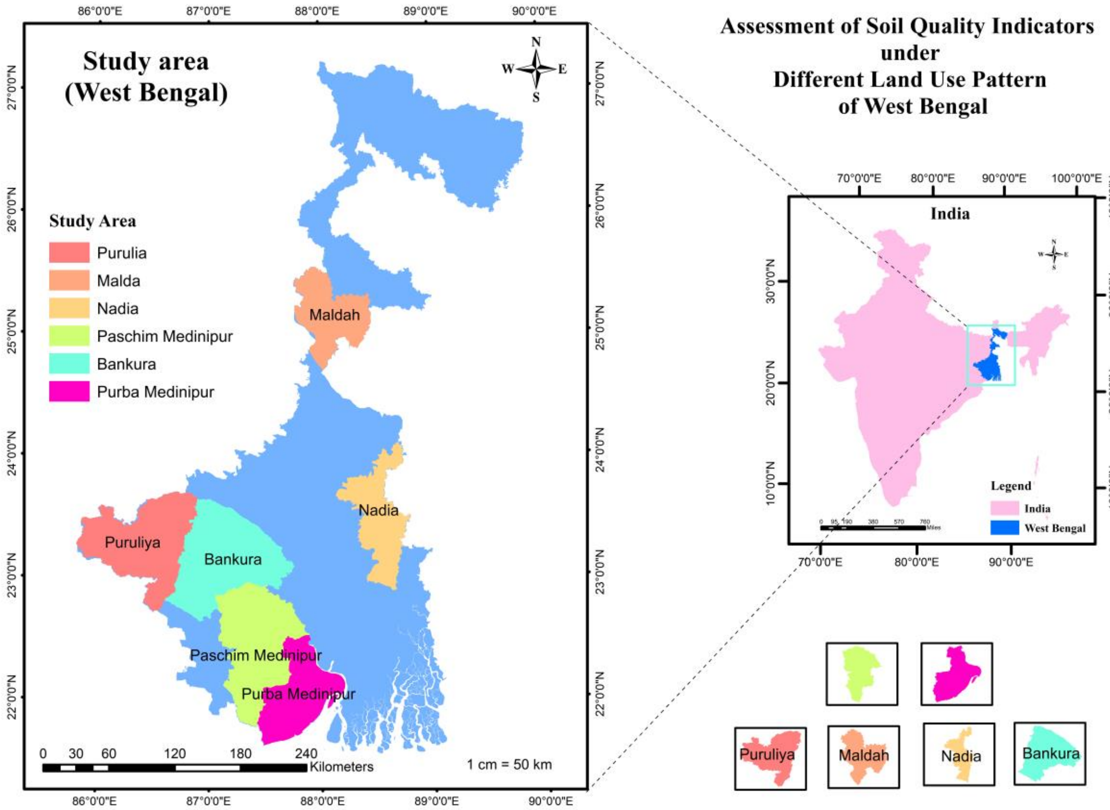

Figure 1. Study Area, Purulia, Malda, Nadia, Bankura, Paschim & Purba Medinipur.

Purulia District: Purulia, district of West Bengal, India is situated between 22.60 degrees and 23.50 degrees north latitudes and 85.75 degrees and 86.65 degrees east latitudes. Covering area of district is 6259 km2 with a population of 2,930,115. Purulia experience sub-tropical climate and owing to this it is one of the most drought prone districts of West Bengal. Purulia district is the eastern part of chotongpur plateau. It is characterized by gently sloping to plateau, hills, residual hill rocks, narrow vallies, etc. The main three rivers passing through the district are Kansabati, Darakeswar and Kumari, which are at present nearly-seasonal in nature. The major portions are classified under net are sown (53.0%), land under non-agriculture uses (16.1%), current fallow (15.9%) and forest (12.0%); while lands for other purposes are very meagre. The forest area which declined to 75.05 thousand ha mainly due to deforestation, urbanization. Although the population of district has been increased but there is a little increase net sown area.

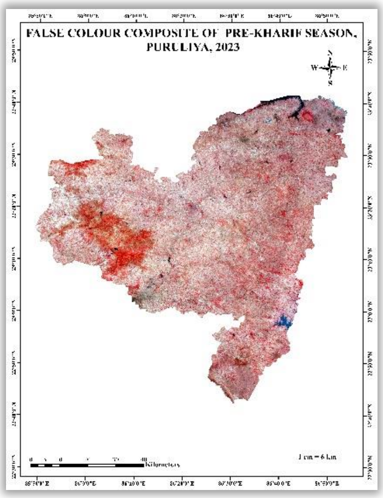

Figure 2. False color composite of Purulia district

Malda District: Malda, district of West Bengal, India is situated between the latitude and longitude of 24°40′20″N to 25°32′08″N and 88°28′10″E to 87°45′50″E respectively with a total geographical area of 3455.66 sq km. The region is covered with plentiful natural vegetation, which makes it verdant. River beds, ponds, marshy land etc. are good habitats for the wetland undergrowth. Most of the remote villages are covered by jungles, which consist chiefly of thorny scrub bush and large trees showing wide distribution of flora. The soil of the western region of the district is particularly suited to the growth of mulberry and mango, for which Malda has become famous. Malda district encompasses a vast expanse of low-lying plains, traversed by several meandering rivers. When considering its topography and drainage pattern, the district can be divided into three distinct regions, Tal, Diara, Barind.

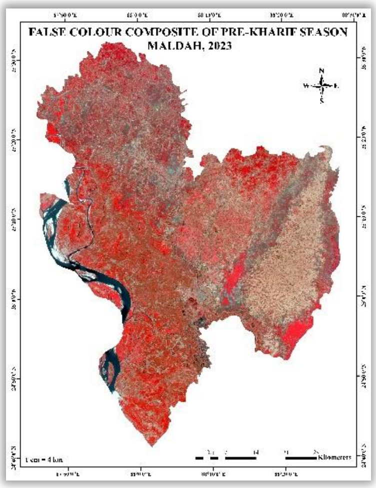

Figure 3. False color composite of Malda District 2023, Pre-kharif Season

Nadia District: Nadia is a district located in the state of West Bengal, India, situated between the geographic coordinates of 22°53" and 24°11" N latitude and 88°09" and 88°48" E longitude. Covering of area of 390,027 km 2 with a population of 46,03, 756.The region is covered with plentiful natural vegetation, which makes it verdant. River beds, ponds, marshy land etc., are good habitats for the wetland undergrowth. Wetlands are generally highly productive ecosystems, providing various important benefits to the environment. Most of the remote villages are covered by forest and jungles, which consist chiefly of thorny scrub bush and large trees sowing wide distribution of flora. Nadia district is home to the Bethuadahari Wild life Sanctuary, which has an area of 0.7 km2. Nadia district under fluvial landscape, out which 78.35% under alluvial plain, 9.64% under flood plain and 6.44% under marshy land.

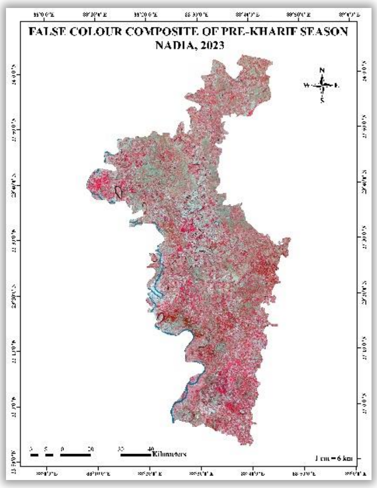

Figure 4. False color composite of Nadia District, 2023, Pre-kharif season.

Paschim Medinipur: The targeted study area includes Paschim Medinipur district situated in south-west part of West Bengal state, India (coordinated of 22°15′N 87°39′E). It is having very vast and diverse geography and rich sociocultural status. That ranked second largest of total area consist 9295.28 km² after the South 24-Parganas which have 9960 km². It stands third and fourth so far, the rural population (4.58 million) and tribal population percentage (14.87) is concerned among West Bengal districts. National Highway (NH) namely NH-14 and NH-16 cuts the district into two natural divisions. Flat, fertile, alluvial soils reside on the east side of the road and undulating, infertile laterite soil is on the west. Dry deciduous forest persists in the west region while marshy wetlands are in the east part. The alluvial portion is also divisible into two vital parts. One near to Hooghly and Rupnarayan river, intersected by many rivers and associated watercourses. Remaining of the eastern half is water logged filled with rice culture plain and intersected

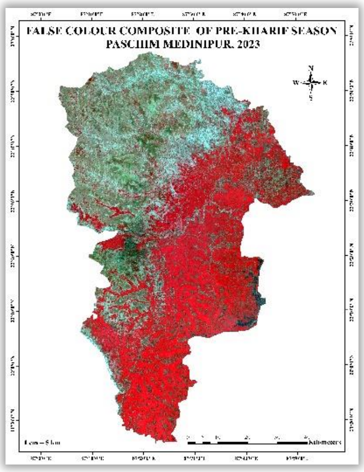

Figure 5. False color composite of Paschim Medinipur District, 2023, Prekharif season.

by various waterways and tidal creeks. Both flood and drought are observed in selected part of Paschim Medinipur. Flood prone zone includes Ghatal and portion of Kharagpur subdivision with a total area of 1426.47 km² and destroys crops of Pingla, Sabang. Narayangarh Community Development Blocks etc. and drought prone areas include Jhargram and Medinipur sub-division with an area of 3352.48 km².

Bankura: Bankura, district of West Bengal, India is situated between 23.165°N, 87. 0624°E.coverning of area of 3882 km square with a population of 3296, 901.The region is covered with plentiful natural vegetation, which makes it verdant. River beds, ponds, marshy land etc., are good habitats for the wetland undergrowth. Agricultural and allied sectors contribute nearly 17.8 and 17% of GDP of India. Bankura district is a part of red lateritic 'Rarh plain' of Paschim Banga and it contains a significant portion of thick sal forest. Forest land of Bankura district is 148177 ha which constitutes 21.5% total geographically area of the district coverage. A vast area of Bankura is not cultivable due to undulation of land and morum soil. Still the rest of the land (about 60-65%) is fertile and due to availability of sufficient water supplied by either by canal or deep tube wells. Soil of Bankura district can be broadly grouped into three principal types (Groundwater resources assessment and management of the Bankura district. Viz- (1) Red soil (2) Alluvial soil and (3) Laterite soil

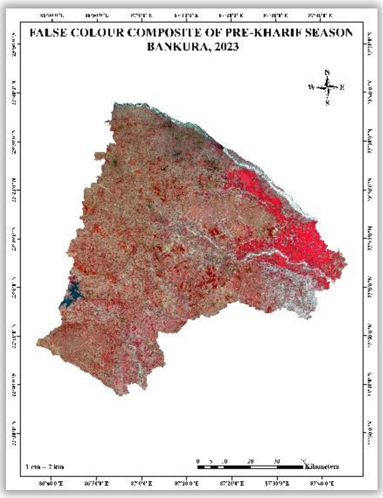

Figure 6. False color composite of Bankura District, 2023, Pre-kharif season.

Purba Medinipur: Purba Medinipur district in West Bengal, India, is a significant study area in the research titled "Assessment of Soil Quality Indicators under Different Land Use Patterns of West Bengal." Located in the eastern part of the state. Purba Medinipur offers a distinct land use pattern and represents specific soil characteristics within the region. The district is geographically situated between approximately 21.8945° N latitude and 87.5788° E longitude. The district lies nestled between the Bay of Bengal to the south and Balasore District of Orissa State to its southern border. To the west lies

Paschim Medinipur, while the northern boundary is shared with Howrah district and its eastern flank is bordered by South 24 Parganas. This district spans across 4,30,140 hectares, constituting 4.7% of the total geographically area of the state. It accommodates approximately 5.58% of the state's population. The district's net cultivated area is 3,04,800 hectares, which accounts for 58% of the district's total land area, amounting to 1,79,025 hectares. The predominant irrigation method employed in this cultivated land is tidal water, resulting in a cropping intensity of about 170%. It encompasses a diverse range of land use patterns, including agricultural areas, urban centers, and coastal regions. This variety allows for the investigation of soil quality indicators across different land uses, providing valuable insights into the impact of these patterns on soil health. In Purba Medinipur, agricultural practices play a vital role in the district's economy, with crops such as rice, jute, pulses, groundnut and vegetables being cultivated extensively. The region's soil characteristics, including texture, nutrient content, and organic matter, are influenced by agricultural activities, water availability, and land management practices. Moreover, Purba Medinipur's coastal regions add another dimension to the study area. These coastal areas are characterized by distinct soil profiles influenced by tidal effects, saltwater intrusion, and coastal vegetation. The unique combination of marine influence and land use practices in these regions contributes to the complexity of soil quality indicators. Understanding the soil quality indicators in Purba Medinipur is essential for sustainable land use planning, agricultural productivity, and environmental management. The research aims to evaluate parameters such as soil pH, organic matter content, nutrient levels, compaction, and microbial activity in this specific district, considering the variations in land use patterns and their effects on soil health.

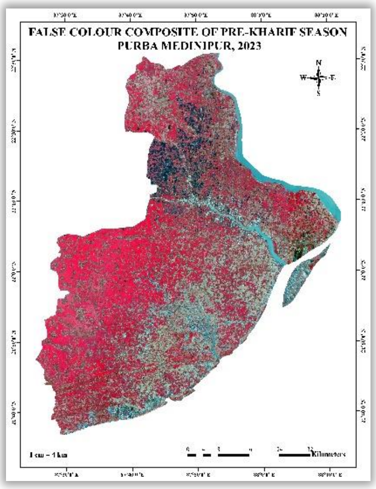

Figure 7. False color composite of Purba Medinipur District, 2023, Pre-kharif season.

In conclusion, the selection of these six districts in West Bengal as the study area will enable a comprehensive assessment of soil quality indicators under different land use patterns. The research aims to contribute to the scientific knowledge base and inform evidence-based decision-making for sustainable land management practices in the region.

4.2. Materials Used

Table 1. List of chemicals and instruments used in this study:

List of Chemical	List of Instruments
Potassium dichromate 60 gram	pH Meter
Sulfuric acid 2.5 liters	Spade
Phosphoric acid 1.5 liter	Khurpi
Ferrous sulfate	Sample Containers
Diphenylamine	Tray
Distilled water 25 liters	Glass wares
Sodium hexametaphosphate	GPS

4.3. Sample Collection Methods

For this study, firstly the land use and land cover of each block of Purba Medinipur district is analyzed. False color composite imagery was acquired from satellite imagery datasets, such as Landsat or Sentinel, covering the study area during an appropriate time period. The false color composites were generated using bands that emphasize specific features like vegetation, water bodies, and built-up areas. This technique enabled us to visually differentiate the various land use patterns for selecting representative sampling sites. Then the soil sample site according to the land use pattern or land class, like cultivated area, current fallow area, forest area is selected and it is found that there is very few amounts of grazing land, fallow land and barren land. Field visits were conducted to collect soil samples from the pre-identified sample sites. At each location, soil samples were collected using an auger or soil corer at a depth of 0-15 cm, taking care to avoid any visible contamination or disturbance. Each sample was carefully labeled, and GPS coordinates were recorded for accurate geolocation. The soil samples were collected across different land use pattern form the six districts during the pre-kharif season, specifically from 5th march to 10th April 2023. The collected soil samples were carefully stored in airtight polythene bags for subsequent laboratory investigations. Before analysis, the samples were air-dried, initially crushed using a pestle and mortar, and then passed through a 2mm sieve.

Table 2. Soil Samples of Purulia District

Land use pattern	Sample No	Block Name	Latitude	Longitude
Barren	1	Manbazar-II	22.935	86.657
	2	Hura	23.310	86.649
	3	Bagmundi	23.194	86.050
	4	Raghunathpur-II	23.623	86.544
Cultivated	5	Manbazar-II	22.934	86.657
	6	Hura	23.310	86.649
	7	Bagmundi	23.194	86.051
	8	Raghunathpur-II	23.623	86.542
Cultivated waste	9	Manbazar-II	22.934	86.657
	10	Hura	23.310	86.648
	11	Bagmundi	23.195	86.050
	12	Raghunathpur-II	23.623	86.543
Non cultivated	13	Hura	23.310	86.649
	14	Manbazar-II	22.934	86.657
	15	Bagmundi	23.195	86.051
	16	Raghunathpur-II	23.624	86.544
Pasture	17	Manbazar-II	22.935	86.657
	18	Hura	23.310	86.649
	19	Bagmundi	23.194	86.051
	20	Raghunathpur-II	23.623	86.543

Table 3. Soil Samples of Malda District

Land use pattern	Sample No	Block Name	Latitude	Longitude
Cultivated	1	Bamongola	25.164	88.379
	2	Chanchal-I	25.367	88.081
	3	Chanchal-II	25.328	88.048
	4	Kaliachak-II	24.933	88.046
	5	Gazol	25.211	88.188
	6	Manikchak	25.076	87.900
Cultivated waste	7	Kaliachak-I	24.888	88.026
	8	Kaliachak-II	24.920	88.045
Fallow	9	Bamongola	25.211	88.396
	10	Chanchal-II	25.323	88.033
	11	Gazol	25.203	88.182
	12	Manikchak	25.089	87.887
Non cultivated	13	Bamongola	25.138	88.445
	14	Chanchal-I	25.393	88.010
	15	Kaliachak-I	24.879	88.029
	16	Kaliachak-II	24.925	88.053
	17	Manikchak	25.070	87.899
Pasture	18	Chanchal-I	25.381	88.075
	19	Chanchal-II	25.334	88.056
	20	Gazol	25.202	88.171

Table 4. Soil Samples of Nadia District

Land use pattern	Sample No	Block Name	Latitude	Longitude
Barren	1	Kaliganj	23.209	88.573
	2	Krishnanagar-I	23.275	88.442
Cultivated	3	Nakashipara	23.617	88.381
	4	Kaliganj	23.209	88.573
	5	Krishnanagar-I	23.276	88.442
	6	Krishnanagar-II	23.276	88.442
	7	Ranaghat-I	23.209	88.573
	8	Ranaghat-II	23.168	88.528
Cultivated waste	9	Ranaghat-I	23.208	88.574
	10	Ranaghat-II	23.167	88.528
Fallow	11	Ranaghat-I	23.209	88.572
	12	Tehatta-II	23.811	88.459
Forest	13	Nakashipara	23.619	88.383
Non cultivated	14	Kaliganj	23.209	88.572
	15	Krishnanagar-I	23.275	88.442
	16	Krishnanagar-II	23.276	88.442
	17	Tehatta-II	23.812	88.471
Pasture	18	Nakashipara	23.691	88.386
	19	Krishnanagar-II	23.275	88.442
	20	Ranaghat-II	23.169	88.511

Table 5. Soil Samples of Paschim Medinipur District

Land use pattern	Sample No	Block name	Latitude	Longitude
Cultivated	1	Sabong	22.150	87.703
	2	Kharagpur-I	22.319	87.459
	3	Daspur-I	22.566	87.692
	4	Daspur-II	22.616	87.747
	5	Midnapore	22.449	87.323
	6	Garbeta-I	22.877	87.275
Fallow	7	Sabong	22.147	87.703
	8	Kharagpur-I	22.317	87.459
	9	Daspur-I	22.616	87.747
Non cultivated	10	Sabong	22.150	87.702
	11	Kharagpur-I	22.319	87.452
	12	Daspur-I	22.565	87.692
	13	Daspur-II	22.616	87.747
	14	Keshpur	22.561	87.396
	15	Midnapore	22.452	87.326
	16	Garbeta-I	22.876	87.275
Pasture	17	Daspur-II	22.563	87.395
	18	Keshpur	22.561	87.396
	19	Midnapore	22.449	87.326
	20	Garbeta-I	22.878	87.275

Table 6. Soil Samples of Bankura District

Land use pattern	Sample No	Block name	Latitude	Longitude
Barren	1	Gangajal ghati	23.457	87.048
	2	Saltora	23.529	87.933
	3	Sonamukhi	23.291	87.406
	4	Onda	23.129	87.211
Cultivated	5	Gangajal ghati	23.455	87.055
	6	Saltora	23.527	87.934
	7	Bishnupur	23.053	87.313
	8	Sonamukhi	23.300	87.418
	9	Megia	23.557	87.110
	10	Indus	23.150	87.631
	11	Onda	23.137	87.212
Non cultivated	12	Saltora	23.524	87.935
	13	Bishnupur	23.300	87.412
	14	Sonamukhi	23.292	87.405
	15	Megia	23.501	87.107
	16	Indus	23.151	87.632
	17	Onda	23.132	87.210
Pasture	18	Bishnupur	23.054	87.312
	19	Megia	23.561	87.104
	20	Indus	23.150	87.631

Table 7. Soil Samples of Purba Medinipur District

Land use pattern	Sample No	Block name	Latitude	Longitude
Forest Area	1	Ramnagar 1	21.615	87.492
	2	Contai 1	21.697	87.793
	3	Haldia	22.067	88.027
	4	Ramnagar1	21.621	87.512
	5	Haldia	22.058	88.033
Crop Land (Pre Kharif)	6	Khejuri 2	21.918	87.922
	7	Ramnagar 2	21.69	87.684
	8	Contai 2	21.785	87.848
	9	Pataspur 2	21.986	87.541
	10	Egra 1	21.860	87.523
Barren Land	11	Ramnagar 2	21.677	87.709
Current Fallow (6 Months)	12	Contai 1	21.728	87.750
	13	Haldia	22.118	88.005
	14	Nandigram 2	22.036	87.931
	15	Chandipur	22.086	87.837
	16	Nandigram1	21.972	87.977
Fallow Land	17	Ramnagar 1	21.667	87.507
	18	Nandigram1	22.018	87.976
	19	Sutahata	22.140	88.089
	20	Egra 2	21.879	87.662

4.4. Soil Test Methods

Determination of Organic Carbon: The estimation of soil organic carbon followed the method proposed by Walkley and Black in 1934. In this procedure, 1 grams of soil were mixed with a solution comprising 10 ml of 1N $K_2Cr_2O_7$ and 20 ml of concentrated H_2SO_4 (96% pure). The mixture was allowed to react for 30 minutes. Subsequently, 200 ml of water and 10 ml of orthophosphoric acid were added and stirred into the mixture. Then, 1 ml of diphenylamine was added and stirred as well. The titration process involved using 0.5N Ferrous ammonium sulphatic [Fe $(NH_4)_2$ $(SO_4)_2$] solution until the blue color just changed to green color. To account for any potential background interference, a blank reading was also taken.

Determination Soil pH: Soil pH is measured by pH meter containing glass and reference electrode and marked pH scale from 0-14. The mid-point 7.0 of this scale is neutral, below this denotes acidity and above this denotes alkalinity, pH meter is standardized with the help of buffer solutions of known pH and then the pH of the solution is determined.

Soil Texture Analysis "The Jar Test": The soil texture test method, commonly known as the jar test, is a simple yet effective technique used to determine the relative proportions of sand, silt, and clay in a soil sample. In this method, a soil-water mixture is prepared in a clear glass jar, allowing the particles to settle according to their size and weight. After filling the jar with soil and water, the mixture is vigorously shaken to ensure thorough dispersion. Once shaken, the jar is set aside, allowing the soil particles to settle over time. Due to their different settling rates, the sand settles first, followed by silt, and then clay. By observing the distinct layers formed after a sufficient resting period, the soil texture can be determined by measuring the depth of each layer relative to the total depth.

Chapter 5: Results

5. Results

Following are the test results of 6 districts: Purulia, Malda, Nadia, Paschim Medinipur, Bankura, and Purba Medinipur. The NDVI values for the past 20 years have been calculated using Landsat and Sentinel satellite data for each district in 2023 and 2003. Soil samples were also collected from various land use patterns in each district and analyzed in the laboratory to determine soil characteristics, including soil texture, soil pH, and soil organic carbon content. Additionally, statistical measures such as mean, standard deviation, and coefficient of variation (CV) were calculated to assess the variability of these soil parameters across different land use patterns.

5.1. Results of Purulia District

NDVI of Purulia 2003 and 2023 (Pre-Kharif Season):

Over the span of two decades, the examination of the Normalized Difference Vegetation Index (NDVI) has provided valuable insights into the vegetation dynamics of Purulia district. In 2003, the NDVI analysis showcased the dense and sprawling forests of Ayodhya Hills and the enchanting Bamni Falls Forest were prominent areas displaying high NDVI values, indicative of flourishing forest cover and thriving biodiversity. the fertile agricultural lands of Adra and the terraced fields of Barabazar exhibited a different NDVI pattern, representing cultivated lands with moderate to high vegetation activity, typical of the agricultural landscape. In 2023, and the updated NDVI results offer valuable information about the changes in vegetation over the years. While Ayodhya Hills and Bamni Falls Forest have managed to maintain their green canopy, certain forested areas have encountered challenges due to anthropogenic activities and urban expansion. Particularly, some outskirts of Adra have witnessed infrastructural development and residential expansion, causing the transformation of previously forested regions into urban

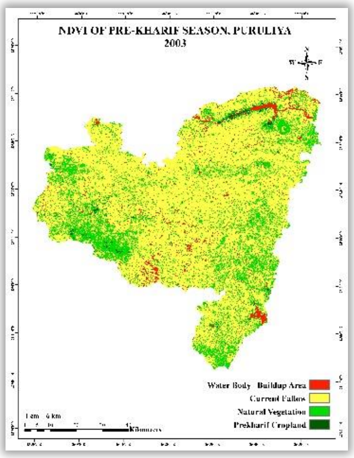

Figure 9. NDVI of Purulia, 2003

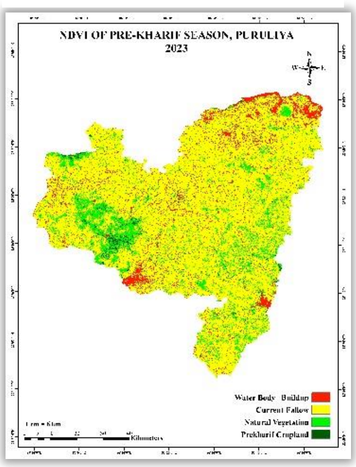

Figure 8. NDVI of Purulia, 2023

settlements, impacting their NDVI values. Similarly, the once predominantly agricultural lands around Barabazar have experienced changes, with certain areas being converted into industrial zones or other non-vegetated land uses, leading to alterations in the overall NDVI landscape.

Table 8. Soil Test Results of Purulia District

Land use pattern	Sample No	pH	O.C	Soil texture
Barren	1	6	0.51	Silt
	2	7.4	0.61	Sandy loam
	3	5.5	0.46	Silt
	4	5.4	0.48	Silty loam
Cultivated	5	6.1	0.59	Loam
	6	5	0.66	Loam
	7	4.7	0.47	Loam
	8	5.3	0.49	Silty loam
Cultivated waste	9	5.9	0.53	Silty loam
	10	6.6	0.63	Silty loam
	11	5.4	0.42	Loam
	12	5.6	0.43	Silty loam
Non cultivated	13	6.7	0.56	Silt
	14	7.8	0.65	Silt
	15	5.8	0.45	Silty loam
	16	5.3	0.47	Silt
Pasture	17	6.7	0.54	Silty loam
	18	5.7	0.64	Silty loam
	19	6	0.44	Silty loam
	20	5.5	0.45	Silty clay

Table 9. Statistical analysis of Purulia District

Land Use Pattern	pH			O.C %		
	Mean	**SD**	**CV**	**Mean**	**SD**	**CV**
Barren	6.075	0.758	12.47	0.515	0.0655	12.73
Cultivated	5.775	0.636	11.01	0.5775	0.0844	14.61
Cultivated waste	5.875	0.566	9.64	0.5275	0.0932	17.66
Non cultivated	6.65	1.245	18.71	0.5575	0.0882	15.82
Pasture	5.975	0.599	10.02	0.5175	0.0927	17.92

Barren Land: Barren land samples exhibit a pH range of 6.0 to 7.4, with a mean pH of 6.075. The organic carbon (O.C.) content ranges from 0.46% to 0.61%, with a mean value of 0.515%. The predominant soil textures observed in barren land are silt and sandy loam. The coefficient of variation (CV) indicates moderate variation in both pH (12.47%) and O.C. (12.73%) within the barren land samples.

Cultivated Land: Cultivated land samples display a pH range of 4.7 to 6.1, with a mean pH of 5.775. The O.C. content ranges from 0.47% to 0.66%, with a mean value of 0.5775%. The dominant soil texture observed in cultivated land is loam, with some samples displaying silty loam. The CV values indicate moderate variation in both pH (11.01%) and O.C. (14.61%) within the cultivated land samples.

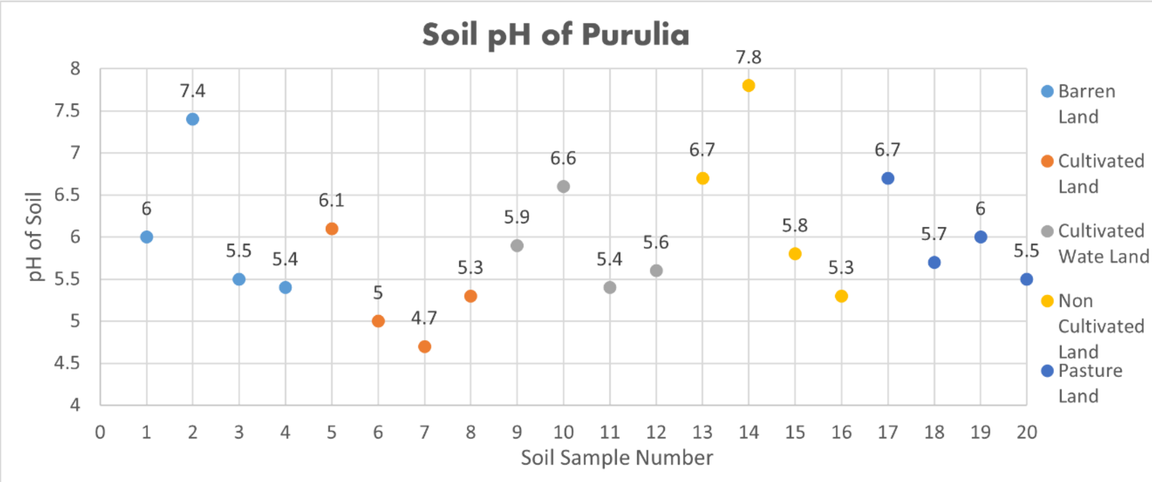

Figure 10. Soil pH of Purulia

Cultivated Waste Land: Cultivated waste land samples exhibit a pH range of 5.4 to 6.6, with a mean pH of 5.875. The O.C. content ranges from 0.42% to 0.63%, with a mean value of 0.5275%. The predominant soil texture observed in cultivated waste land is silty loam. The CV values indicate relatively low variation in pH (9.64%) and moderate variation in O.C. (17.66%) within the cultivated waste land samples.

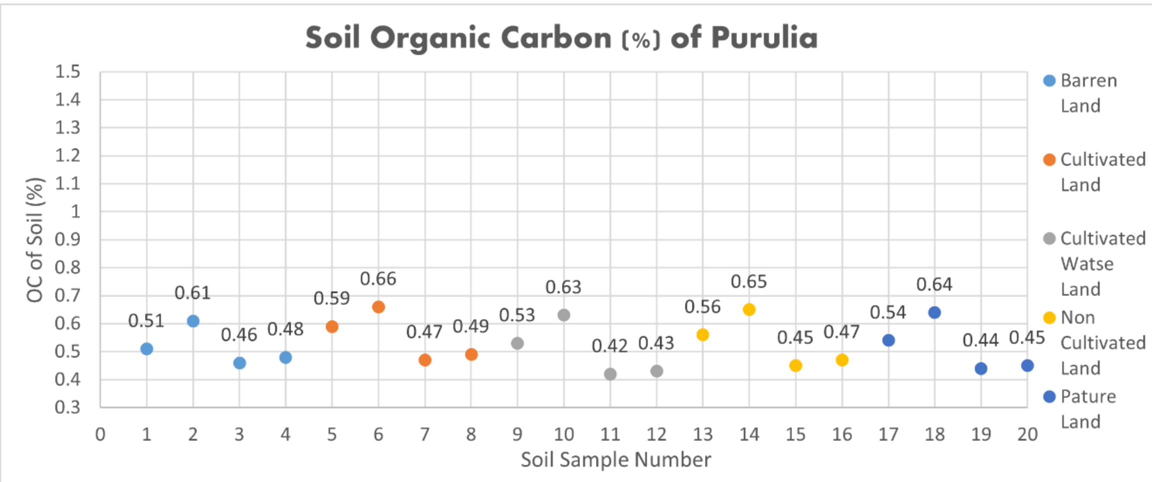

Figure 11. Soil Organic Carbon of Purulia

Non-cultivated Land: Non-cultivated land samples display a pH range of 5.8 to 7.8, with a mean pH of 6.65. The O.C. content ranges from 0.45% to 0.65%, with a mean value of 0.5575%. The predominant soil texture observed in non-cultivated land is silt. The CV values indicate moderate variation in pH (18.71%) and O.C. (15.82%) within the non-cultivated land samples.

Pasture Land: Pasture land samples exhibit a pH range of 5.5 to 6.7, with a mean pH of 5.975. The O.C. content ranges from 0.44% to 0.64%, with a mean value of 0.5175%. The predominant soil texture observed in pasture land is silty loam, with one sample displaying silty clay. The CV values indicate moderate variation in both pH (10.02%) and O.C. (17.92%) within the pasture land samples.

5.2. Results of Malda District

NDVI of Malda 2003 and 2023 (Pre-Kharif Season): Malda district has experienced notable changes in its land use pattern, primarily influenced by factors like population growth, agricultural practices, and industrialization. In 2003, the NDVI analysis revealed distinct patterns across various locations within the district. The expansive and verdant forests of Gour and the picturesque Chanchal Forests were notable areas with dense vegetation cover, reflecting high NDVI values indicative of healthy forest ecosystems. The fertile agricultural lands of Harish Chandrapur and the green fields of Bamangola displayed a different NDVI pattern, signifying cultivated areas with moderate to high vegetation activity, characteristic of the region's agricultural landscape. By 2023, some regions around Harish Chandrapur have witnessed urban expansion and agricultural intensification, leading to the conversion of forested lands into residential areas or farmlands, resulting in alterations to their NDVI values. Additionally, the once extensive agricultural lands of

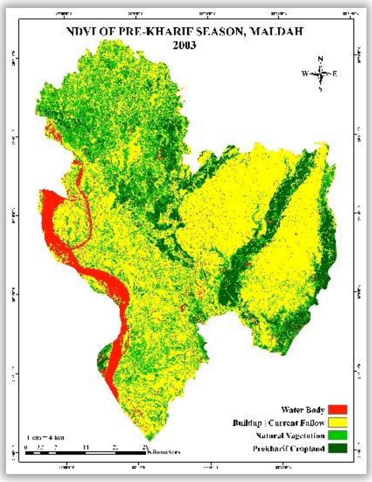

Figure 13. NDVI of Malda, 2003

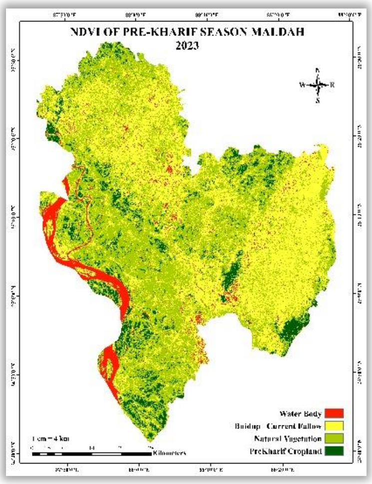

Figure 12. NDVI of Malda, 2023

Bamangola have experienced changes, with certain areas being transformed into industrial zones or other non-vegetated land uses, impacting the overall NDVI landscape. The expansion of agricultural land, there has been a rise in the establishment of agro-industries and food processing units in the region. The fertile land and abundant produce of Malda have attracted investors to set up agro-based businesses, leading to the transformation of rural areas into semi-urban zones. Over the past 20 years, Malda district has experienced a decrease in natural vegetation, particularly forests and trees. Additionally, the practice of pre-kharif cultivation has also witnessed a decline during this period.

Table 10. Soil Test Results of Malda District

Land use pattern	Sample No	pH	O.C	Soil texture
Cultivated	1	5.4	0.45	Clay loam
	2	6.1	0.55	Clay loam
	3	6.2	0.52	Clay loam
	4	6.6	0.48	Loam
	5	6.6	0.47	Loam
	6	5.5	0.47	Clay loam
Cultivated waste	7	6.3	0.5	Sandy loam
	8	6.2	0.49	Sandy loam
Fallow	9	5.3	0.5	Sandy clay
	10	6.4	0.53	Sand
	11	5.6	0.49	Sandy clay
	12	5	0.67	Sandy loam
Non cultivated	13	5.8	0.49	Sand
	14	6.3	0.57	Sandy loam
	15	6.7	0.49	Sand
	16	6.9	0.48	Sand
	17	5.7	0.65	Sand
Pasture	18	6	0.59	Sandy clay
	19	6.1	0.54	Sandy clay
	20	5.1	0.5	Sandy loam

Table 11. Statistical analysis of Malda District

Land Use Pattern	pH			O.C %		
	Mean	**SD**	**CV**	**Mean**	**SD**	**CV**
Cultivated	5.8	0.482	8.31	0.495	0.041	8.28
Cultivated waste	6.25	0.0566	0.906	0.495	0.007	1.414
Fallow	5.575	0.6041	10.85	0.5475	0.0862	15.75
Non cultivated	6.28	0.678	10.8	0.536	0.0801	14.93
Pasture	5.733	0.553	9.654	0.543	0.0453	8.345

Cultivated Land: Cultivated land samples exhibit a pH range of 5.4 to 6.6, with a mean pH of 5.8. The organic carbon (O.C.) content ranges from 0.45% to 0.55%, with a mean

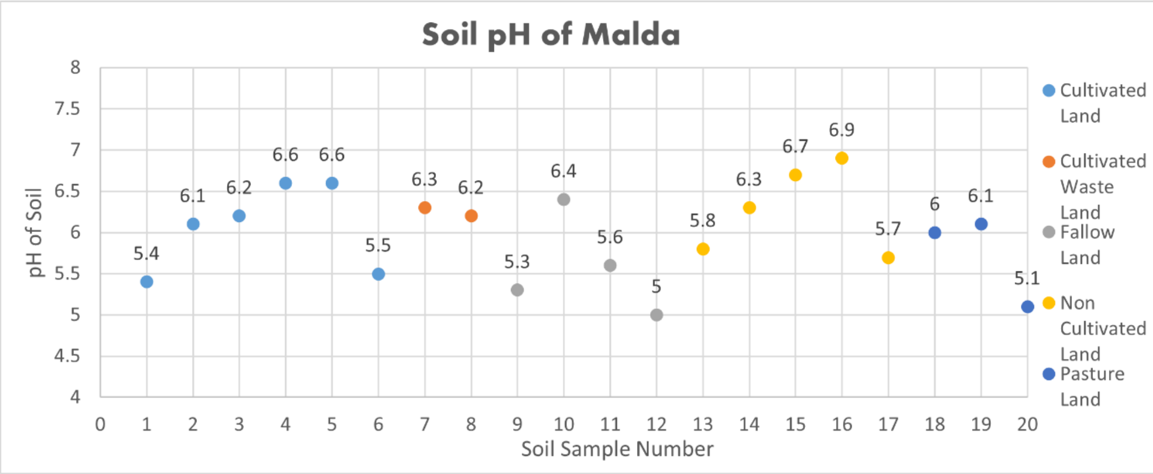

Figure 14. Soil pH of Malda

value of 0.495%. The predominant soil texture observed in cultivated land is clay loam and loam. The coefficient of variation (CV) indicates moderate variation in both pH (8.31%) and O.C. (8.28%) within the cultivated land samples.

Cultivated Waste Land: Cultivated waste land samples display a relatively narrow pH range of 6.2 to 6.3, with a mean pH of 6.25. The O.C. content ranges from 0.49% to 0.5%, with a mean value of 0.495%. The dominant soil texture observed in cultivated waste land is sandy loam. The CV values indicate low variation in pH (0.906%) and very low variation in O.C. (1.414%) within the cultivated waste land samples.

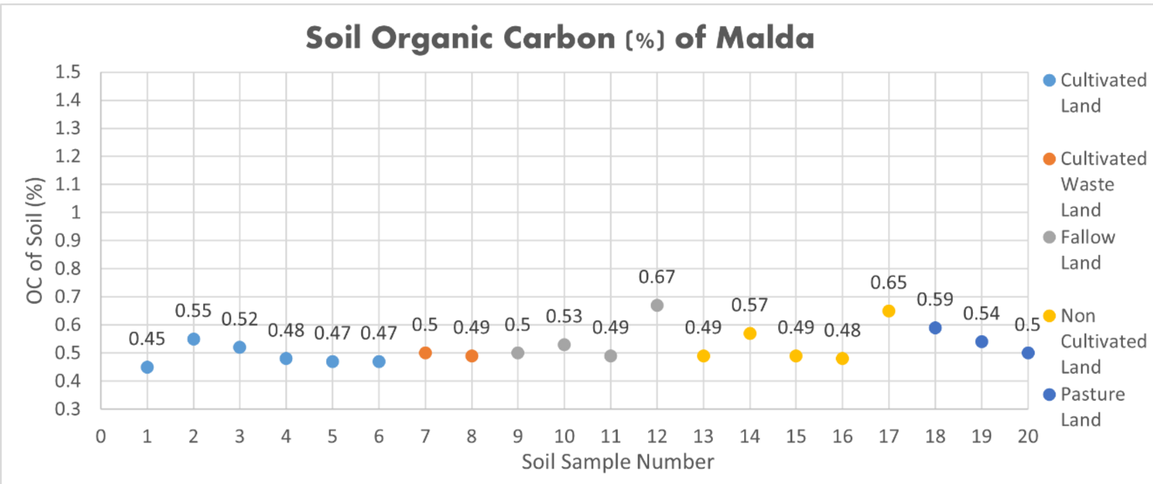

Figure 15. Soil Organic Carbon of Malda

Fallow Land: Fallow land samples exhibit a pH range of 5 to 6.4, with a mean pH of 5.575. The O.C. content ranges from 0.49% to 0.67%, with a mean value of 0.5475%. The predominant soil textures observed in fallow land are sandy clay and sandy loam. The CV values indicate moderate variation in both pH (10.85%) and O.C. (15.75%) within the fallow land samples.

Non-cultivated Land: Non-cultivated land samples display a pH range of 5.7 to 6.9, with a mean pH of 6.28. The O.C. content ranges from 0.48% to 0.678%, with a mean value of 0.536%. The dominant soil texture observed in non-cultivated land is sand. The CV values indicate moderate variation in both pH (10.8%) and O.C. (14.93%) within the non-cultivated land samples.

Pasture Land: Pasture land samples exhibit a pH range of 5.1 to 6.1, with a mean pH of 5.733. The O.C. content ranges from 0.54% to 0.59%, with a mean value of 0.543%. The dominant soil texture observed in pasture land is sandy clay. The CV values indicate moderate variation in both pH (9.654%) and O.C. (8.345%) within the pasture land samples

5.3. Results of Nadia District

NDVI of Nadia 2003 and 2023 (Pre-Kharif Season): The analysis of NDVI (Normalized Difference Vegetation Index) results for Nadia district in 2003 and 2023 reveals significant changes in the region's vegetation over the past two decades.

In 2003, the NDVI analysis showcased distinct patterns across various locations within the district. The lush and expansive Krishnagar Forest, along with the enchanting woodlands of Bethuadahari Wildlife Sanctuary, were prominent areas displaying high NDVI values, indicating dense forest cover and thriving biodiversity. Conversely, the fertile plains of Tehatta and the agricultural fields of Chapra exhibited a different NDVI pattern, representing cultivated lands with moderate to

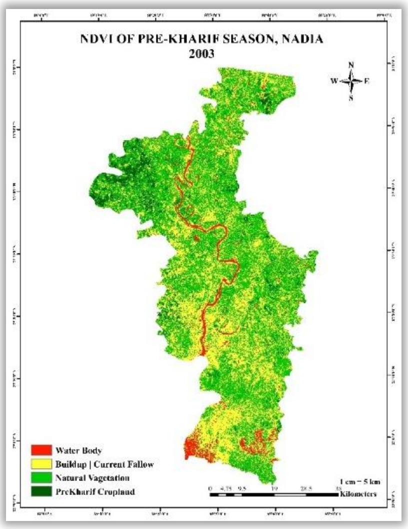

Figure 16. NDVI of Nadia, 2003

high vegetation activity, typical of the agricultural landscape.

In 2023, the updated NDVI results provide critical information about the changes in vegetation cover over the years. While Krishnagar Forest and Bethuadahari Wildlife Sanctuary have managed to maintain their greenery, certain forested areas have faced challenges due to urbanization and developmental activities. Notably, the outskirts of Krishnagar have experienced expansion as suburban settlements, causing the transformation of some forested regions into residential areas. Similarly, the once predominantly agricultural lands of Tehatta have undergone changes, with some areas converted into commercial zones or industrial establishments, altering their NDVI values.

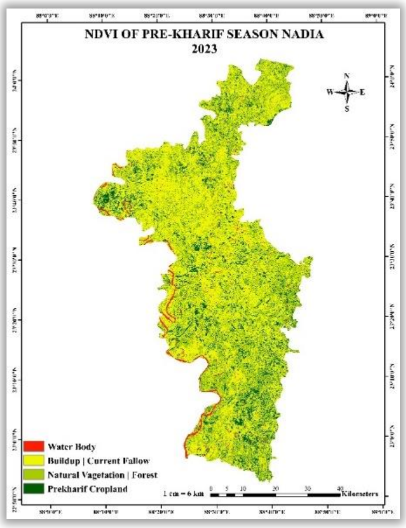

Figure 17. NDVI of Nadia, 2023

Table 12. Soil Test Results of Nadia District

Land use pattern	Sample No	pH	O.C %	Soil Texture
Barren	1	5.6	0.39	Silty clay
	2	6.3	0.46	Sandy loam
Cultivated	3	5.2	0.66	Clay loam
	4	5.5	0.58	Sandy clay
	5	5.7	0.42	Clay
	6	6.2	0.57	Silty loam
	7	6.5	0.58	Sandy loam
	8	6.6	0.45	Sandy loam
Cultivated waste	9	6.3	0.57	Silty clay
	10	6.9	0.55	Clay
Fallow	11	6.2	0.62	Loam
	12	5.9	0.62	Clay loam
Forest	13	5.4	0.68	Clay
Non cultivated	14	5.8	0.38	Sandy loam
	15	6.1	0.45	Loam
	16	6.8	0.42	Sandy clay
	17	5.9	0.48	Silty clay
Pasture	18	5.6	0.69	Loam
	19	6.5	0.48	Clay loam
	20	5.3	0.59	Sandy loam

Table 13. Statistical analysis of Nadia District

Land Use Pattern	pH			O.C%		
	Mean	**SD**	**CV**	**Mean**	**SD**	**CV**
Barren	5.95	0.57	9.51	0.43	0.06	13.30
Cultivated	5.78	0.49	8.50	0.55	0.08	14.67
Cultivated waste	6.60	0.42	6.44	0.56	0.01	1.27
Fallow	6.05	0.21	3.50	0.62	0.00	0.00
Forest	5.40	0.00	0.00	0.68	0.00	0.00
Non cultivated	6.15	0.45	7.36	0.43	0.04	9.64
Pasture	5.80	0.58	9.96	0.59	0.10	17.68

Barren Land: The pH of barren land ranges from 5.6 to 6.3, with a mean pH of 5.95. The organic carbon content (O.C.) ranges from 0.39% to 0.46%, with a mean value of 0.43%. The soil texture predominantly observed in barren land is silty clay. The coefficient of variation (CV) indicates moderate variation in both pH (9.51%) and O.C. (13.30%) within barren land samples.

Cultivated Land: Cultivated land displays a pH range from 5.2 to 6.6, with a mean pH of 5.78. The O.C. content ranges from 0.42% to 0.66%, with a mean value of 0.55%. The

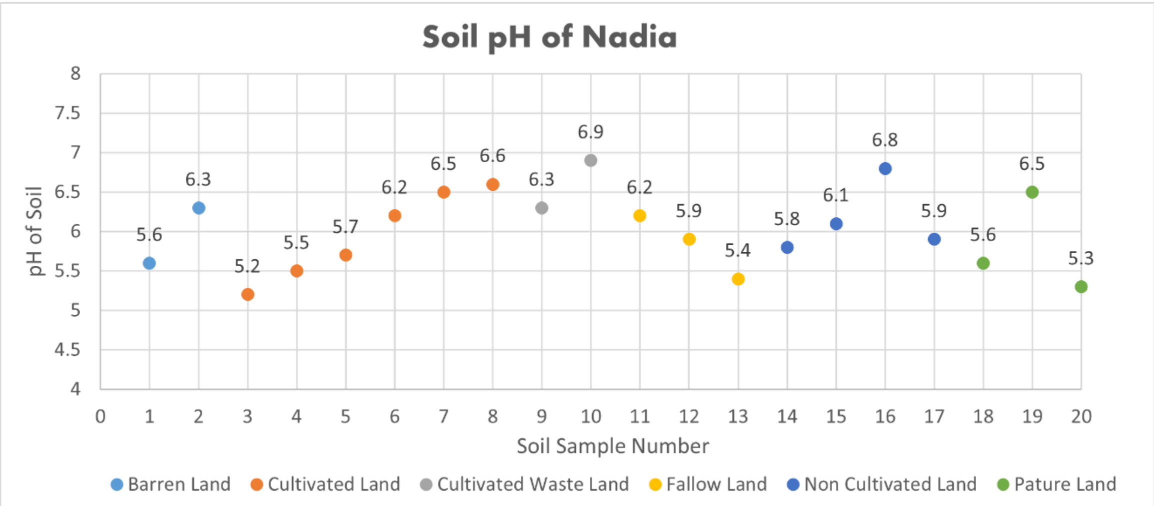

Figure 18. Soil pH of Nadia

soil texture varies across the cultivated land samples, including clay loam, sandy clay, clay, and silty loam. The CV values indicate moderate variation in both pH (8.50%) and O.C. (14.67%) within cultivated land samples.

Cultivated Waste Land: The cultivated waste land exhibits a relatively narrow pH range of 6.3 to 6.9, with a mean pH of 6.60. The O.C. content ranges from 0.42% to 0.57%, with a mean value of 0.56%. The dominant soil textures observed in cultivated waste land are silty clay and clay. The CV values indicate relatively low variation in both pH (6.44%) and O.C. (1.27%) within cultivated waste land samples.

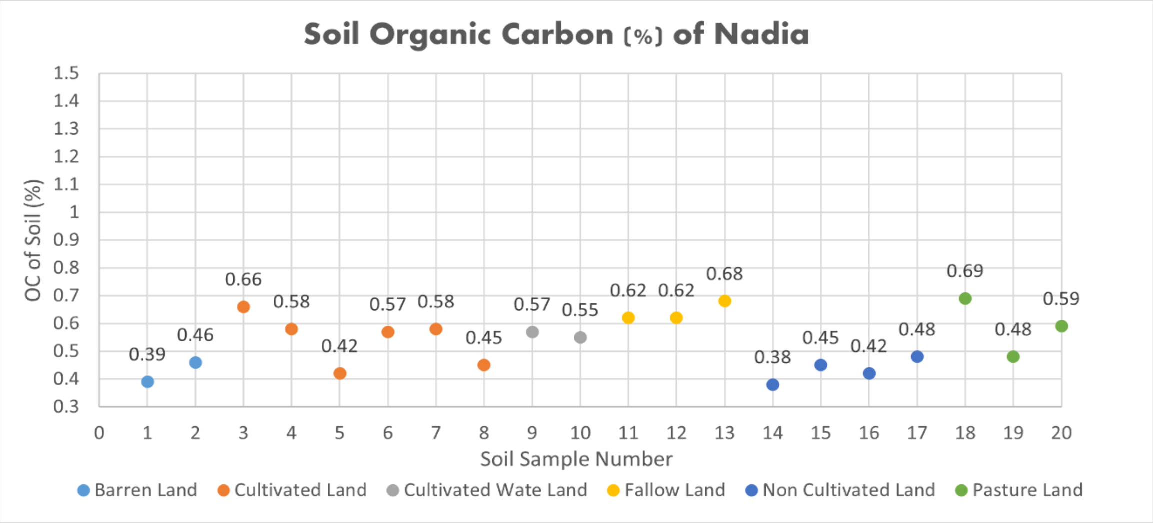

Figure 19. Soil Organic Carbon of Nadia

Fallow Land: Fallow land shows a pH range of 5.9 to 6.2, with a mean pH of 6.05. The O.C. content is relatively consistent, ranging from 0.62%. The soil texture of fallow land is predominantly loam and clay loam. The CV values indicate low variation in both pH (3.50%) and O.C. (0.00%) within fallow land samples.

Forest Land: The forest land data displays a pH value of 5.4, indicating slightly acidic conditions. The O.C. content is constant at 0.68%. The soil texture observed in forest land is clay. The CV values indicate low variation in both pH (0.00%) and O.C. (0.00%) within forest land samples.

Non-cultivated Land: Non-cultivated land exhibits a pH range from 5.8 to 6.8, with a mean pH of 6.15. The O.C. content ranges from 0.38% to 0.48%, with a mean value of 0.43%. The dominant soil textures observed in non-cultivated land are sandy loam and silty clay. The CV values indicate moderate variation in both pH (7.36%) and O.C. (9.64%) within non-cultivated land samples.

Pasture Land: Pasture land displays a pH range from 5.3 to 6.5, with a mean pH of 5.80. The O.C. content ranges from 0.48% to 0.69%, with a mean value of 0.59%. The soil texture predominantly observed in pasture land is loam. The CV values indicate moderate variation in both pH (9.96%) and O.C. (17.68%) within pasture land samples

5.4. Results of Paschim Medinipur District

NDVI of Paschim Medinipur 2003 and 2023 (Pre-Kharif Season): Over the span of two decades, the analysis of the Normalized Difference Vegetation Index (NDVI) has provided valuable insights into the vegetation dynamics of Pachim Medinipur district, a region known for its diverse landscapes and agricultural significance.

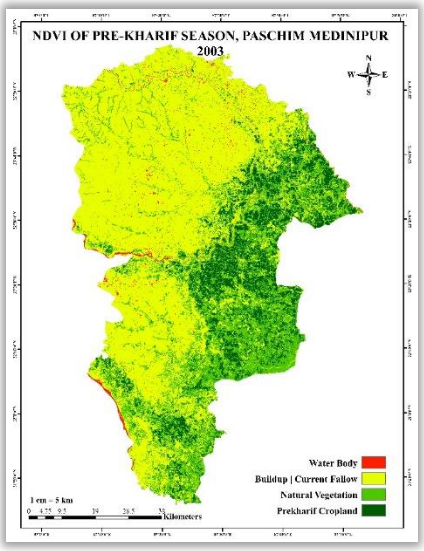

Figure 20. NDVI of Paschim Medinipur, 2003

In 2003, the NDVI assessment revealed distinct patterns across various locations within the district. The dense and biodiverse forests of Jhargram and the picturesque Salboni Forest Reserve were notable areas with high NDVI values, indicative of thriving forest cover and ecological richness. The agricultural heartlands of Kharagpur and the fertile fields of Midnapore displayed a different NDVI pattern, signifying cultivated lands with moderate to high vegetation activity, characteristic of the region's agricultural landscape.

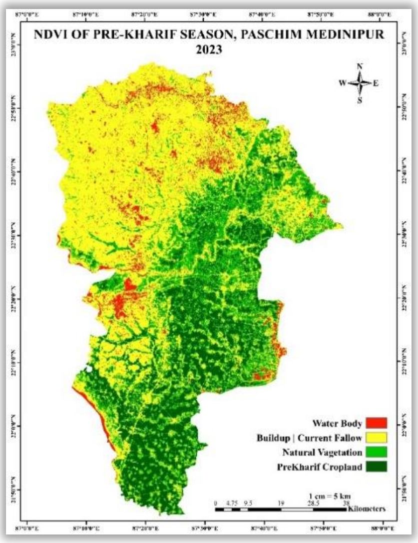

Figure 21. NDVI of Paschim Medinipur, 2023

2023, and the updated NDVI results shed light on the changes in vegetation over the years. While Jhargram and Salboni Forest Reserve have managed to sustain their greenery, certain forested areas have faced challenges due to human encroachment and infrastructural development. Specifically, some outskirts of Kharagpur have witnessed urban expansion, leading to the transformation of previously forested regions into residential or commercial zones, impacting their NDVI values. Additionally, certain agricultural lands around Midnapore have undergone changes, with the conversion of some areas into industrial hubs, altering the overall NDVI landscape.

Table 14. Soil Test Results of Paschim Medinipur District

Land use Pattern	Sample No	pH	O.C	Soil texture
Cultivated	1	6	0.56	Loam
	2	5.6	0.41	Sand
	3	6	0.45	Loam
	4	6	0.4	Loam
	5	6.2	0.41	Loam
	6	5.8	0.59	Sandy loam
Fallow	7	5.8	0.55	Sandy loam
	8	5.2	0.46	Sand
	9	5	0.46	Sandy loam
Non cultivated	10	6.6	0.54	Sand
	11	5.5	0.48	Silt
	12	5.8	0.42	Sand
	13	5.6	0.47	Sand
	14	6.1	0.46	Sand
	15	5.6	0.58	Silt
	16	5.1	0.57	Sand
Pasture	17	5.4	0.45	Sandy loam
	18	6	0.43	Silt
	19	5.7	0.54	Sand
	20	5.2	0.58	Silt

Table 15. Statistical analysis of Paschim Medinipur District

Land Use Pattern	pH			OC %		
	Mean	**SD**	**CV**	**Mean**	**SD**	**CV**
Cultivated	5.93	0.25	4.16	0.48	0.08	16.27
Fallow	5.67	0.42	7.47	0.49	0.05	9.61
Non cultivated	5.73	0.54	9.48	0.51	0.06	11.85
Pasture	5.58	0.36	6.41	0.50	0.06	12.72

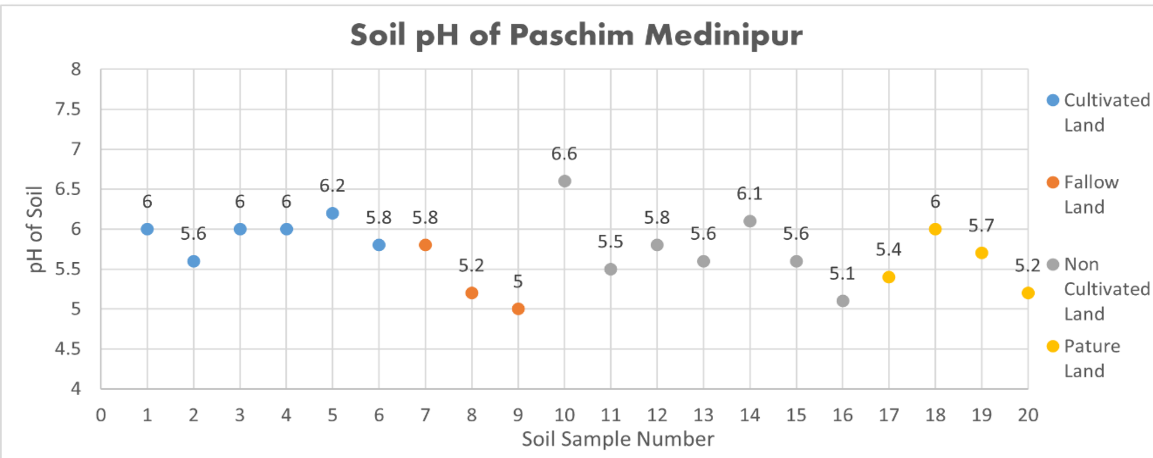

Figure 22. Soil pH of Paschim Medinipur.

Cultivated Land: Cultivated land samples show a pH range of 5.6 to 6.2, with a mean pH of 5.93. The O.C. content ranges from 0.4% to 0.59%, with a mean value of 0.48%. The dominant soil texture observed in cultivated land is loam. The coefficient of variation (CV) indicates moderate variation in both pH (4.16%) and O.C. (16.27%) within the cultivated land samples.

Fallow Land: Fallow land samples exhibit a pH range of 5.2 to 5.8, with a mean pH of 5.67. The O.C. content ranges from 0.46% to 0.55%, with a mean value of 0.49%. The predominant soil texture observed in fallow land is sandy loam. The CV values indicate moderate variation in pH (7.47%) and relatively low variation in O.C. (9.61%) within the fallow land samples.

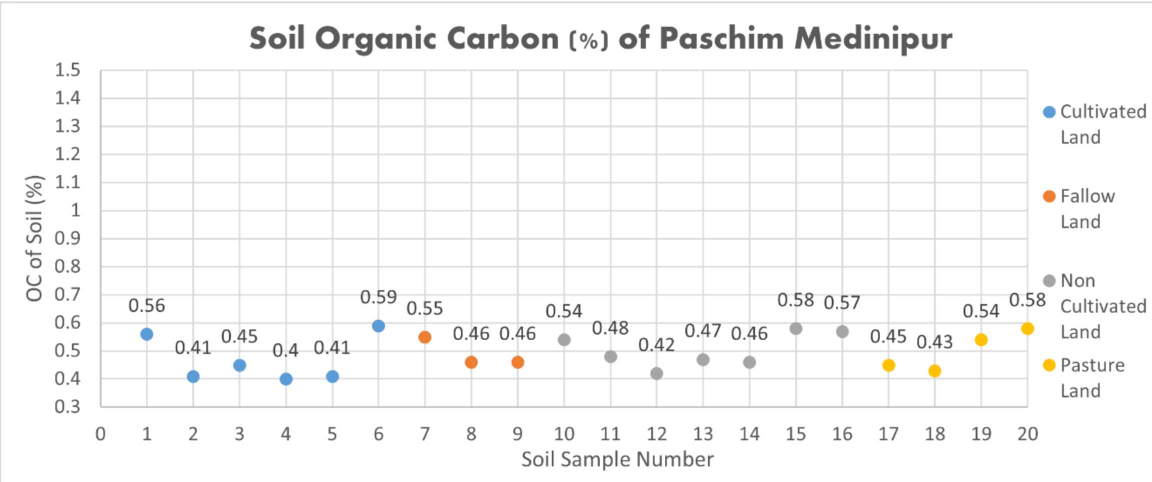

Figure 23. Soil Organic Carbon of Paschim Medinipur

Non-cultivated Land: Non-cultivated land samples display a pH range of 5.1 to 6.6, with a mean pH of 5.73. The O.C. content ranges from 0.42% to 0.58%, with a mean value of 0.51%. The dominant soil texture observed in non-cultivated land is sand. The CV values indicate moderate variation in pH (9.48%) and O.C. (11.85%) within the non-cultivated land samples.

Pasture Land: Pasture land samples exhibit a pH range of 5.2 to 6, with a mean pH of 5.58. The O.C. content ranges from 0.43% to 0.54%, with a mean value of 0.50%. The predominant soil textures observed in pasture land are sandy loam and silt. The CV values indicate moderate variation in both pH (6.41%) and O.C. (12.72%) within the pasture land samples.

5.5. Results of Bankura District

NDVI of Nadia 2003 and 2023 (Pre-Kharif Season): Over the span of two decades, the Normalized Difference Vegetation Index (NDVI) has provided valuable insights into the vegetation dynamics of Bankura district, a region known for its diverse landscapes and ecological significance. Utilizing NDVI data, which indicates the health and density of vegetation, we can observe these changes from 2003 to 2023.

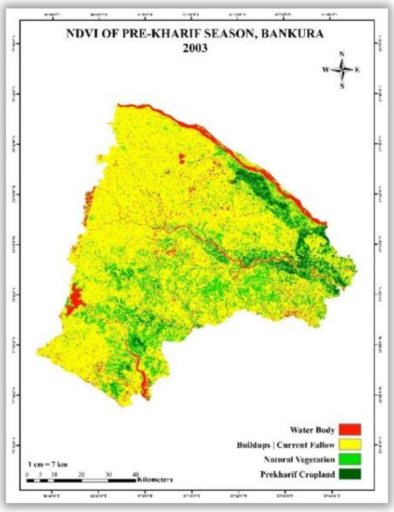

Figure 24. NDVI of Bankura 2003

In 2003, the NDVI analysis revealed a striking contrast between different areas within the district. Lush green forests, such as the enchanting Chhander Hill Forest and the serene Mukutmanipur Forest, stood out as regions with high NDVI values, indicative of dense vegetation cover and thriving biodiversity. Meanwhile, agricultural lands like the fertile plains of Bishnupur and the picturesque terraced fields of Susunia displayed a different NDVI pattern. These cultivated lands exhibited moderate to high NDVI values, reflecting the presence of healthy crops and vegetation typical of an agrarian landscape.

2023, and the NDVI results continue to offer valuable information about the changes in vegetation over the years. While the forests of Chhander Hill and Mukutmanipur have managed to sustain their rich greenery, the ever-increasing human population and developmental activities have taken a toll on some forested regions.

Notably, some previously forested areas have undergone significant changes, giving way to expanding urban centers like Bishnupur and Bankura town itself. Additionally, certain agricultural lands have transformed into industrial zones or other non-vegetated land uses, leading to alterations in their NDVI values.

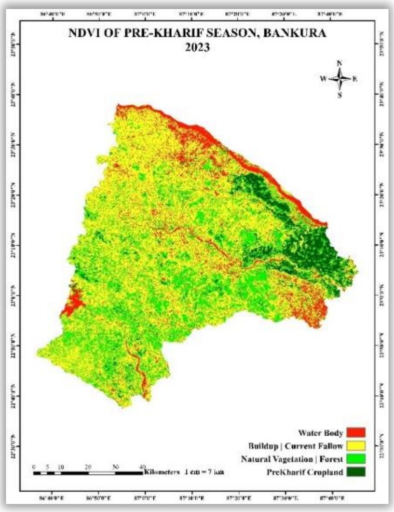

Figure 25. NDVI of Bankura 2023

Table 16. Soil Test Results of Bankura District

Land use pattern	Sample No	pH	O.C	Soil texture
Barren	1	6	0.53	Sandy loam
	2	6	0.66	Clay loam
	3	6.3	0.49	Sandy clay
	4	6.2	0.61	Sand
Cultivated	5	6.2	0.59	Clay loam
	6	7.1	0.51	Sandy clay
	7	6.3	0.65	Sandy clay
	8	5.6	0.46	Clay loam
	9	5.9	0.47	Sandy loam
	10	6.4	0.45	Loam
	11	6.3	0.62	Sandy
Non cultivated	12	6.4	0.56	Clay
	13	7.3	0.54	Clay
	14	5.4	0.63	Clay
	15	7.1	0.43	Clay loam
	16	6.5	0.49	Sandy loam
	17	6.6	0.65	Sandy clay
Pasture	18	5.8	0.42	Sandy clay
	19	7	0.48	clay
	20	6.8	0.47	Clay loam

Table 17. Statistical analysis of Bankura District

Land Use Pattern	pH			O.C %		
	Mean	**SD**	**CV**	**Mean**	**SD**	**CV**
Barren	6.125	0.1414	2.31	0.5725	0.0683	11.93
Cultivated	6.1714	0.4435	7.18	0.5429	0.0756	13.93
Non cultivated	6.45	0.7166	11.11	0.5583	0.0859	15.39
Pasture	6.5333	0.6467	9.9	0.4567	0.0289	6.33

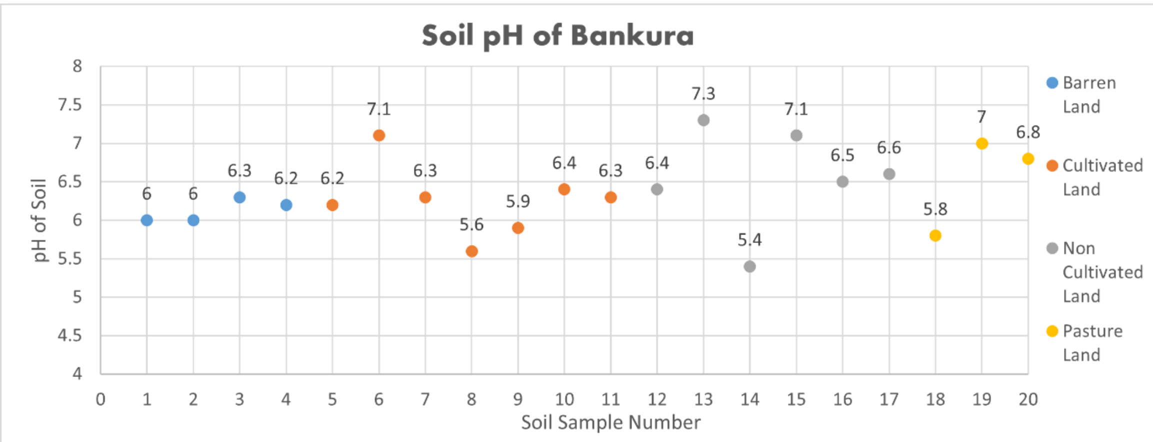

Figure 26. Soil pH of Bankura

Barren Land: Barren land samples exhibit a pH range of 6 to 6.3, with a mean pH of 6.125. The O.C. content ranges from 0.49% to 0.66%, with a mean value of 0.5725%. The dominant soil textures observed in barren land are sandy loam and clay loam. The coefficient of variation (CV) indicates low variation in pH (2.31%) and moderate variation in O.C. (11.93%) within the barren land samples.

Cultivated Land: Cultivated land samples show a pH range of 5.6 to 7.1, with a mean pH of 6.1714. The O.C. content ranges from 0.45% to 0.65%, with a mean value of 0.5429%. The dominant soil textures observed in cultivated land are clay loam, sandy clay, sandy loam, and loam. The CV values indicate moderate variation in both pH (7.18%) and O.C. (13.93%) within the cultivated land samples.

Non-cultivated Land: Non-cultivated land samples display a pH range of 5.4 to 7.3, with a mean pH of 6.45. The O.C. content ranges from 0.43% to 0.7166%, with a mean value of 0.5583%. The dominant soil textures observed in non-cultivated land are clay and clay loam. The CV values indicate moderate variation in both pH (11.11%) and O.C. (15.39%) within the non-cultivated land samples.

Pasture Land: Pasture land samples exhibit a pH range of 5.8 to 7, with a mean pH of 6.5333. The O.C. content ranges from 0.42% to 0.48%, with a mean value of 0.4567%. The dominant soil textures observed in pasture land are sandy clay and clay loam. The CV values indicate low variation in pH (9.9%) and relatively low variation in O.C. (6.33%) within the pasture land samples

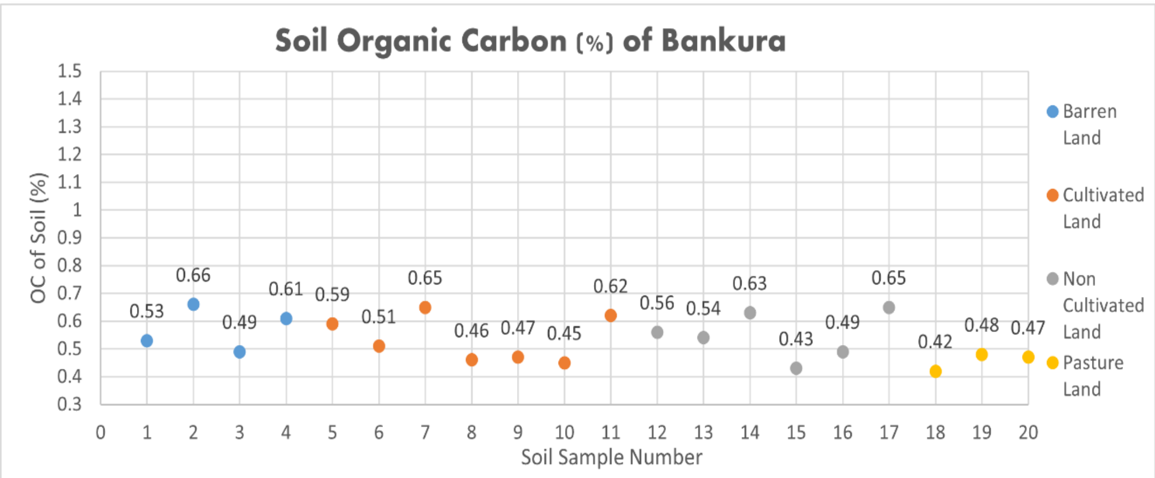

Figure 27. Soil Organic Carbon of Bankura

5.6. Results of Purba Medinipur District

NDVI of Purba Medinipur 2003, 2013 and 2023 (Pre-Kharif Season): The Normalized Difference Vegetation Index (NDVI) is a critical tool used to monitor changes in vegetation over time. The NDVI results for Purba Medinipur district in the years 2003, 2013 and 2023, focusing on pre-kharif cultivation, conversion of cropland to fishing pond, and the decline of natural vegetation is analyzed below. The land use pattern in Purba Medinipur district has undergone significant changes over the past two decades, evident through the analysis of Normalized Difference Vegetation Index (NDVI) data of 2003, 2013 and 2023.

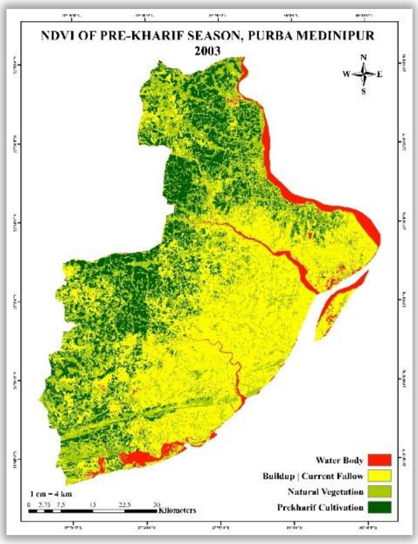

Figure 28. NDVI of Purba Medinipur, 2013

In 2003, NDVI imagery showed vast expanses of lush green vegetation, indicating extensive agricultural land use in the region. Pre-kharif Rice cultivated fields, and other crops dominated the landscape, reflecting the district's agrarian economy. Light green color represents natural vegetation, such as dense forests and trees ware present, indicating a healthy and ecologically diverse environment. Red color representing river and water body.

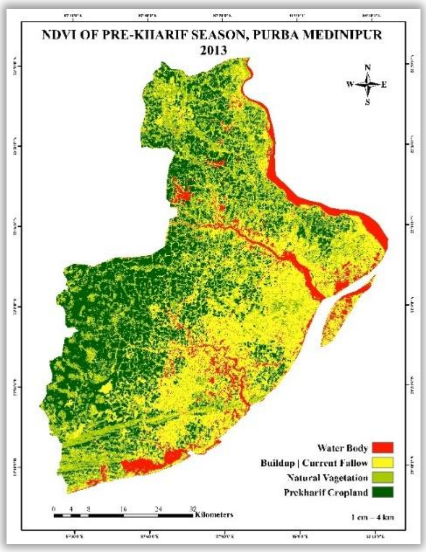

Figure 29. NDVI of Purba Medinipur, 2013

Fast forward to 2013, the NDVI imagery started revealing subtle shifts in the land use pattern. Urban areas and settlements began to encroach upon agricultural land, resulting in a decrease in overall green vegetation but slight increase in pre-kharif cultivation. The expansion of residential and commercial areas was clearly visible, leading to a reduction in the once-dominant agricultural zones. The number of fishing ponds had started to increase. This finding indicated a shift in land use practices, possibly influenced by changing economic and environmental factors. As the region experienced urbanization and alterations in agricultural practices, some farmers might have explored alternative sources of income, leading to the establishment of more fishing ponds.

By the year 2023, the land use pattern in Purba Medinipur district experienced a more profound transformation. The pre-kharif cultivation areas had significantly reduced due to the continued expansion of built-up areas, urban sprawl, and industrial growth. It has been observed that there is a significant decrease in pre-kharif cultivation in Purba Medinipur compared to other districts in West Bengal. Despite this decline, Purba Medinipur remains one of the districts with the highest pre-kharif cultivation. In the south-western part of Purba Medinipur, particularly in Ramnagar 1 and Egra 1 blocks, there has been a significant increase in vegetation over the past 20 years. By ground survey, it has been confirmed that this increase is primarily due to the expansion of cashew nut plantations in the region.

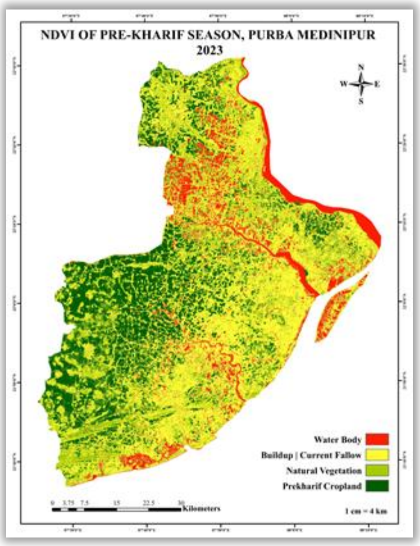

Figure 30. NDVI of Purba Medinipur, 2023

Cashew nut plants have been increasingly cultivated, contributing to the overall rise in vegetation in the area. NDVI images revealed a decline in the density of green areas, indicating the decline of natural vegetation coverage like forests and trees. With a growing population and economic activities, there have been increased pressure on the land, leading to a decrease in fallow lands and their conversion into developed spaces. The data also revealed a gradual rise in the number of fishing ponds from 2013 to 2023. As traditional agricultural practices shifted and land use diversified, farmers have explored alternative sources of income, leading to the development of more fishing ponds for aquaculture.

Additionally, deforestation and the conversion of green areas into non-vegetated land or barren land contributed to the observable changes in NDVI imagery. The district's growth and development have led to a decline in the quality of the environment and ecosystems, warranting a closer examination of sustainable land use practices for future planning.

Overall, the evolution of Purba Medinipur's land use pattern between 2003 and 2023, as depicted by NDVI data, highlights the complex interplay between urbanization, industrialization, and agriculture.

Table 18. Soil Test results of Purba Medinipur District

Land use pattern	Sample No	Soil pH	Organic Carbon (%)	Soil Texture
Forest	1	7.62	0.62	Sand
	2	7.49	0.57	Sand
	3	7.41	0.96	Clay
	4	7.33	0.67	Sand
	5	7.52	0.99	Clay
Cropped Land (Pre Kharif)	6	6.62	1.16	Clay
	7	6.41	1.24	Clay
	8	5.78	1.19	Clay
	9	7.3	1.12	Clay Loam
	10	5.9	1.09	Clay Loam
Barren	11	7.67	0.49	Sandy Clay
Current Fallow (6 months)	12	4.99	0.64	Clay Loam
	13	4.96	0.86	Clay
	14	5.21	0.73	Clay
	15	5.79	0.78	Clay
	16	4.43	0.53	Clay
Fallow Land	17	6.93	0.68	Sandy Loam
	18	6.02	0.93	Clay
	19	6.27	0.85	Clay
	20	6.13	0.66	Clay Loam

Table 19. Statistical results of Purba Medinipur District

Land Use Pattern	pH			O.C%		
	Mean	**SD**	**CV**	**Mean**	**SD**	**CV**
Forest	7.47	0.10	1.32	0.76	0.18	23.23
Cropped Land	6.40	0.55	8.54	1.16	0.05	4.53
Barren	7.67	0.00	0.00	0.49	0.00	0.00
Current Fallow	5.08	0.33	6.57	0.71	0.11	16.11
Fallow	6.34	0.35	5.58	0.78	0.11	2.04

The land use pattern in the study area consists of four different types: Forest, Cropped Land (Pre Kharif), Barren, and Fallow Land. Each land use type has been sampled multiple times to analyze soil properties such as pH, Organic Carbon (O.C%) content, and Soil Texture.

Forest: The soil samples taken from the forest area had a mean pH value of 7.47 with a standard deviation (SD) of 0.10. The coefficient of variation (CV) for pH was relatively low at 1.32%, indicating a relatively stable pH across the forest samples. The mean Organic Carbon content was 0.76%, with an SD of 0.18, resulting in a CV of 23.23%. The soil texture in the forest area was predominantly sandy, indicating the presence of sand particles. The soil samples taken from the sandy soil in coastal forests showed a lower organic carbon content. The forest samples collected from Haldia, characterized by clay soil texture, exhibited a higher organic carbon content

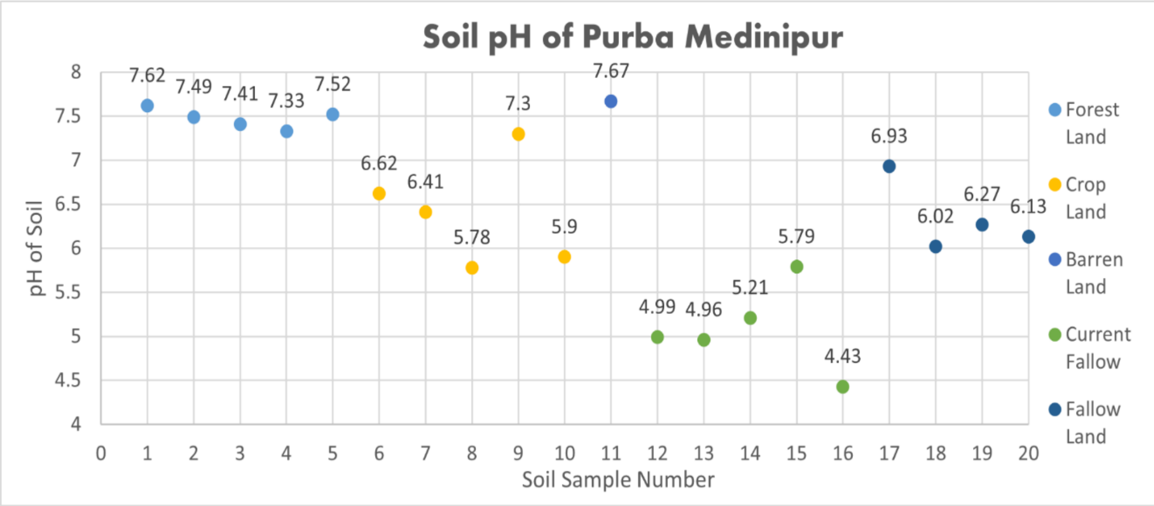

Figure 31. Soil PH of Purba Medinipur District

Cropped Land (Pre Kharif): In the cropped land area, the mean pH value was 6.40, and the SD was 0.55. The CV for pH was 8.54%, The mean Organic Carbon content in the cropped land was 1.16%, with an SD of 0.05 and a CV of 4.53%. The soil texture was mostly clay, suggesting a higher percentage of clay particles in the soil.

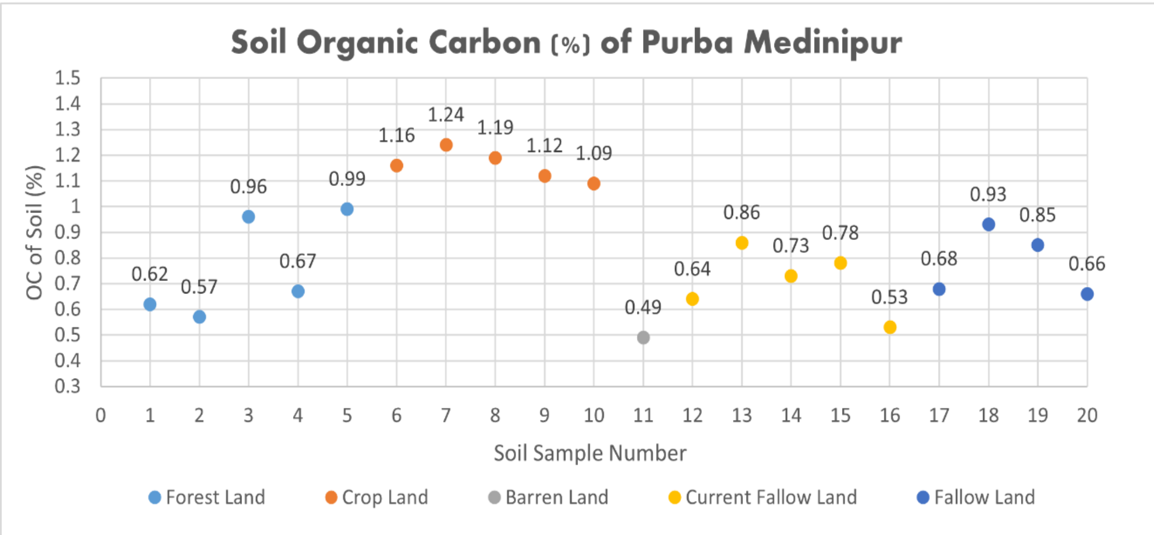

Figure 32. Soil Organic Carbon of Purba Medinipur District

Barren Land: The barren land had a mean pH value of 7.67, The barren area had a very low organic carbon content of 0.49%, indicating poor soil fertility. The soil texture in this area was classified as sandy clay,

Current Fallow (6 months): The current fallow land is the cultivable land which is left fallow after past kharif cultivation. The current fallow land had a mean pH value of 5.08 and an SD of 0.33. The CV for pH was 6.57%, suggesting moderate variability in pH levels. The mean Organic Carbon content in this area was 0.71%, with an SD of 0.11 and a CV of 16.11%. The soil texture in the current fallow area was primarily clay loam.

Fallow Land: The fallow land had a mean pH value of 6.34, with an SD of 0.35. The CV for pH was 5.58%, The mean Organic Carbon content was 0.78%, with an SD of 0.11, resulting in a CV of 2.04%. The soil texture in the fallow land was predominantly clay.

Chapter 6: Discussion

6. Discussion:

The laboratory tests conducted on soil samples collected from different land use patterns in six different districts have provided valuable insights into the various environmental factors and their impact on the respective regions. The results obtained from these tests reveal significant differences in soil texture, soil pH, soil organic carbon among the districts.

Purulia district: The analysis on different land use patterns of soil samples in Purulia district reveals significant variations in pH and organic carbon content, along with the dominant soil types in each land use category. The study shows that barren land in the region generally exhibits moderate variation in both pH and organic carbon content, with a prevalence of silt and sandy loam soils. This indicates that the barren land might have undergone weathering processes, leading to the accumulation of fine particles such as silt and sand. The moderate variation in pH and organic carbon content suggests that these areas may have limited organic matter input, resulting in a relatively stable soil environment.

On the other hand, cultivated land in Purulia district displays moderate variation in both pH and organic carbon content, with a dominance of loam soil. Loam soils are a well-balanced mixture of sand, silt, and clay, making them highly suitable for agriculture. The moderate variation in pH could be attributed to the use of different agricultural practices and fertilizers, while the presence of organic carbon indicates the presence of organic matter from crop residues and other inputs.

Cultivated waste land, in contrast, shows relatively low variation in pH and moderate variation in organic carbon content, predominantly comprising silty loam soil. The lower variation in pH might be due to the continued disturbance and degradation of the land, leading to a more uniform soil condition. The presence of moderate organic carbon content suggests that despite being waste land, there is some level of organic matter input, possibly from previous agricultural activities or natural organic debris.

Non-cultivated land in Purulia district exhibits moderate variation in both pH and organic carbon content, primarily composed of silt soil. The prevalence of silt soil might be related to the specific geological characteristics of the area, such as weathering of rock materials rich in silt. The moderate variation in both pH and organic carbon content suggests that these areas have maintained a relatively stable soil condition with limited anthropogenic disturbance.

Pasture land in the region demonstrates moderate variation in both pH and organic carbon content, with a predominance of silty loam soil and one sample of silty clay soil. Silty loam soils are well-draining and fertile, making them suitable for pasture and grazing activities. The presence of silty clay soil in one sample might be indicative of localized variations in soil types within the pasture land. The moderate variation in pH and organic carbon content suggests that these areas are influenced by both natural processes and human activities, such as grazing and management practices.

The district's geological formations, including laterite soils and red soils, play a crucial role in determining soil properties. Laterite soils, which are common in the region, tend to have low pH levels due to their iron and aluminum-rich nature. Red soils, on the other hand, may have varying pH levels depending on their weathering history. The moderate variation in pH and organic carbon content in cultivated and cultivated waste land may result from different agricultural practices, such as the use of chemical fertilizers and crop residues. These practices can influence soil acidity and organic matter accumulation. The variations in pH and organic carbon content in different land use categories may also be influenced by land management practices, such as irrigation, drainage, and soil conservation methods. These practices can affect soil properties and organic matter content. On-cultivated land with silt soil may be influenced by the natural vegetation cover, which contributes to organic matter input and soil stability. Soil erosion in certain areas may also lead to the deposition of silt in non-cultivated land. Pasture land, which shows moderate variation in pH and organic carbon content, is likely influenced by human activities such as grazing and management practices. These activities can lead to localized variations in soil characteristics.

Malda district: The analysis of different land use patterns in Malda district reveals variations in pH, organic carbon content (O.C.), and soil texture across various land use categories. The land use categories include cultivated, cultivated waste, fallow, non-cultivated, and pasture lands. Each land use category is associated with specific soil characteristics, which can provide valuable insights into the agricultural practices and environmental conditions in the region.

Cultivated land in Malda district predominantly consists of clay loam and loam soils. These soils generally display moderate variation in both pH and organic carbon content. The moderate variation in pH may be attributed to the agricultural practices, including the use of fertilizers and irrigation practices, which can influence the soil acidity. The presence of organic carbon in cultivated lands indicates the input of organic matter from crop residues and agricultural activities.

Cultivated waste land in Malda district is characterized by sandy loam soil, and it exhibits low variation in pH and very low variation in organic carbon content. The low variation in pH could be due to the land's abandonment and lack of regular organic matter inputs. Sandy loam soil, with its sandy texture, tends to have lower nutrient-holding capacity, which contributes to the very low variation in organic carbon content.

Fallow land, on the other hand, displays moderate variation in both pH and organic carbon content, with soil textures ranging from sandy clay to sandy loam. The moderate variation in pH may be related to the previous agricultural practices and the management during the fallow period. Sandy clay soils tend to retain more water and nutrients compared to sandy loam soils, which can influence the variation in organic carbon content.

Non-cultivated land in Malda district primarily comprises sandy soils. These sandy soils exhibit moderate variation in both pH and organic carbon content. The variations in pH and organic carbon content could be influenced by natural soil formation processes and weathering, with sandy soils generally having lower fertility and nutrient-holding capacity.

Pasture land in Malda district is mainly composed of sandy clay soil. It displays moderate variation in both pH and organic carbon content. The moderate variation in pH may be influenced by both natural processes and land management practices, such as grazing. Sandy clay soil, with better water retention properties compared to sandy soils, supports pasture vegetation in the sandy region.

Malda district is likely to have alluvial and sedimentary deposits, contributing to the prevalence of sandy soils in the region. Sandy soils generally have low nutrient-holding capacity and water retention, leading to variations in pH and organic carbon content. The variations in pH and organic carbon content in cultivated and fallow lands are likely influenced by the agricultural practices in the region. The use of fertilizers and irrigation practices in cultivated lands and the management during the fallow period can impact soil characteristics. The low variation in pH and very low variation in organic carbon content in cultivated waste land suggest that these lands have been abandoned or left uncultivated for an extended period, resulting in a less dynamic soil environment. The moderate variation in pH and organic carbon content in non-cultivated land may be attributed to the natural soil formation processes and weathering, which influence soil characteristics over time. The moderate variation in pH and organic carbon content in pasture land can be attributed to the combined impact of natural processes and land management practices, such as grazing.

Nadia District: The analysis of different land use patterns in Nadia district reveals variations in pH, organic carbon content (O.C %), and soil texture across various land use categories, including barren land, cultivated land, cultivated waste land, fallow land, forest land, non-cultivated land, and pasture land. Each land use category is associated with specific soil characteristics, providing valuable insights into the agricultural practices, land management, and environmental conditions in the region.

Barren land in Nadia district is characterized by varying soil textures, including silty clay and sandy loam. The pH and organic carbon content in barren land show moderate variation. The variation in soil texture may be attributed to the geological formations and natural processes, resulting in the presence of different soil types within the barren areas.

Cultivated land, on the other hand, predominantly consists of clay loam, sandy clay, clay, and silty loam soils. The pH and organic carbon content in cultivated land exhibit moderate variation, which may be influenced by agricultural practices, land management, and the use of fertilizers.

Cultivated waste land in Nadia district shows moderate variation in pH and organic carbon content, mainly comprising silty clay and clay soils. The presence of moderate variation may be related to the previous agricultural activities or land use practices in these areas.

Fallow land in the region exhibits moderate variation in both pH and organic carbon content, primarily composed of loam and clay loam soils. The variations in soil texture and organic carbon content could be influenced by the natural regeneration and weathering processes during the fallow period.

Forest land in Nadia district shows a relatively constant pH and organic carbon content, predominantly composed of clay soils. The stable soil characteristics in forest areas may be attributed to the consistent natural processes and organic matter input from decaying plant materials.

Non-cultivated land in the district comprises sandy loam, loam, sandy clay, and silty clay soils, showing moderate variation in pH and organic carbon content. The variations in soil characteristics could be related to natural factors and local variations in soil formation processes.

Pasture land in Nadia district displays moderate variation in pH and organic carbon content, primarily composed of loam, clay loam, and sandy loam soils. The variations in soil texture and organic carbon content may be influenced by grazing activities and land management practices in the pasture areas.

Bankura district's geological formations may include alluvial deposits and diverse soil parent materials. These geological variations contribute to the presence of different soil textures in the region. The moderate variation in pH and organic carbon content in cultivated and cultivated waste lands may be influenced by the agricultural practices, including the use of fertilizers, irrigation methods, and crop residues. The moderate variation in pH and organic carbon content in fallow and pasture lands could be related to land management practices, such as crop rotation, grazing, and organic matter input. Forest land in Nadia district exhibits stable soil characteristics due to the consistent input of organic matter from forest vegetation and limited human intervention. The variations in pH and organic carbon content in non-cultivated land could be attributed to natural processes of soil formation and weathering, resulting in different soil textures across the region.

Paschim Medinipur: The analysis of different land use patterns in Paschim Medinipur district reveals variations in pH, organic carbon content (O.C.), and soil texture across various land use categories, including cultivated land, fallow land, non-cultivated land, and pasture land. Each land use category is associated with specific soil characteristics, providing valuable insights into the agricultural practices, land management, and environmental conditions in the region.

Cultivated land in Paschim Medinipur district consists of loam and sandy soils, with moderate variations in pH and organic carbon content. The variations in pH and organic carbon content may be influenced by agricultural practices, such as the use of fertilizers, irrigation methods, and crop residues.

Fallow land in the district is primarily composed of sandy loam and sandy soils. The variations in pH and organic carbon content in fallow land could be related to the land's temporary abandonment and subsequent natural regeneration processes.

Non-cultivated land in Paschim Medinipur district comprises a mix of sand and silt soils. The variations in pH and organic carbon content in non-cultivated land may be attributed to natural soil formation processes, geological variations, and land cover changes over time.

Pasture land in the region displays variations in pH and organic carbon content, primarily composed of sandy loam and silt soils. The variations in soil characteristics in pasture land may be influenced by grazing activities, land management practices, and the input of organic matter from pasture vegetation.

Paschim Medinipur district's geological formations may include alluvial soils, laterite soils, and sedimentary rocks, leading to the presence of different soil textures and mineral compositions across the region. The variations in pH and organic carbon content in cultivated land may be influenced by the agricultural practices, including the use of fertilizers, manure, and irrigation methods. The presence of fallow land with variations in pH and organic carbon content could be related to land management practices, land cover changes, and temporary abandonment of agricultural fields. The variations in pH and organic carbon content in non-cultivated land may be attributed to natural processes of soil formation and weathering, resulting in different soil textures across the region. The variations in pH and organic carbon content in pasture land can be attributed to the combined impact of grazing activities, which can lead to variations in nutrient cycling and organic matter input. The variations in pH and organic carbon content in pasture land can be attributed to the combined impact of grazing activities, which can lead to variations in nutrient cycling and organic matter input.

Bankura District: The analysis on different land use patterns of soil samples in Bankura district reveals variations in pH, organic carbon content (O.C.), and soil texture across various land use categories, including barren land, cultivated land, non-cultivated land, and pasture land. Each land use category is associated with specific soil characteristics, providing valuable insights into the agricultural practices, land management, and environmental conditions in the region.

Barren land in Bankura district is characterized by varying soil textures, including sandy loam, clay loam, sandy clay, and sand. The pH and organic carbon content in barren land show moderate variations, which could be influenced by the natural weathering processes and lack of significant organic matter input.

Cultivated land, on the other hand, predominantly consists of clay loam, sandy clay, and sandy loam soils. The pH and organic carbon content in cultivated land exhibit moderate variations. The variations may be related to the agricultural practices, such as the use of fertilizers, irrigation methods, and crop residues.

Non-cultivated land in Bankura district primarily comprises clay, clay loam, sandy loam, and sandy clay soils. The variations in pH and organic carbon content in non-cultivated land could be influenced by natural soil formation processes, geological variations, and land cover changes over time.

Pasture land in the region displays moderate variation in pH and organic carbon content, primarily composed of sandy clay, clay, and clay loam soils. The variations in soil texture and organic carbon content may be influenced by grazing activities, land management practices, and the input of organic matter from pasture vegetation.

Bankura district's geological formations may include laterite soils, alluvial deposits, and sedimentary rocks, leading to the presence of different soil textures and mineral compositions across the region. The moderate variations in pH and organic carbon content in cultivated land may be influenced by the agricultural practices, including the use of fertilizers, manure, and irrigation methods. The variations in soil characteristics in non-cultivated land may be related to land management practices, land cover changes, and natural processes affecting soil formation and fertility. The variations in pH and organic carbon content in pasture land can be attributed to the combined impact of grazing activities, which can lead to variations in nutrient cycling and organic matter input. The presence of different soil textures, including sandy loam, clay loam, sandy clay, and sand in barren land, could be a result of weathering and erosion processes affecting the parent material.

Purba Medinipur: In Purba Medinipur district, the land use pattern consists of forested areas, cropped land (pre-kharif), barren land, current fallow land (6 months), and fallow land. Each land use category exhibits distinct soil characteristics, pH levels, organic carbon content, and soil texture, which can be attributed to specific factors relevant to the district**.**

The forested areas in Purba Medinipur district show a diverse range of soil characteristics. The soils in forested regions have slightly acidic to neutral pH levels. The organic carbon content is relatively higher in the samples which is collected from planted forest of Haldia due to the presence of plant debris and leaf litter contributing to organic matter. The sample which is collected coastal planted forests have low organic carbon content. There are two types of soil texture found in the forest area of Purba Medinipur. Coastal forests have sandy soil and the forest in Haldia has clay soil texture. Organic carbon contains relatively lower in coastal forests because of the sandy soil.

Cultivated lands before the Kharif season display a range of soil characteristics in Purba Medinipur district. The pH levels are slightly acidic to neutral, possibly influenced by agricultural practices, including the use of fertilizers. Organic carbon content varies, indicating the impact of crop residues and organic inputs. It has been found that the crop land of pre kharif season has higher soil organic carbon than any other soil sample collected from land use pattern found in Purba Medinipur. The application of organic manures, probiotics and temperature might be another reason Temperature plays a vital role in the decomposition of organic matter and the increase in organic carbon content. In suitable temperatures, the decomposition rate in crop lands is higher, facilitating the breakdown of organic residues and their conversion into stable organic carbon. Warmer temperatures often enhance microbial activity, leading to faster decomposition rates, which can result in increased organic carbon accumulation in the soil. The prevalence of clay and clay loam textures is likely due to compaction from cultivation and irrigation practices. (Kaur et al., 2008).

Barren lands in the district exhibit near-neutral pH levels with minimal organic carbon content. The soil sample of barren land collected from coastal area of Ramnagar 2 block and salinity made this land barren. These areas lack vegetation cover and leading to lower organic carbon and fertility. The presence of sandy clay soil indicates erosion and poor soil structure in barren land. (Bhattacharyya et al. 2011)

Current fallow land, which is left fallow from previous kharif cultivation, shows decreased pH levels compared to other land use categories. The organic carbon content is relatively lower than forest land but higher than barren land, as organic matter starts to accumulate during fallow periods. The predominance of clay loam and clay soils suggests initial soil regeneration.

Fallow lands in Purba Medinipur district exhibit a slightly higher pH compared to current fallow. Organic carbon content is moderate, signifying ongoing organic matter accumulation during the fallow period. The presence of sandy loam and clay loam textures indicates potential improvement in soil structure and fertility during fallow phases.

Analyzing the NDVI values of Purba Medinipur for the years 2003, 2013, and 2023, a significant conversion of agricultural land to fishing ponds has been observed. This conversion has had a significant effect on the environment and overall yield of the district, which is an alarming sign for Purba Medinipur. Loss of fertile agricultural land can result in reduced food production and potential disruptions to the local food supply chain. Moreover, the removal of natural vegetation and soil disturbance during pond construction can negatively affect the local ecosystem, leading to habitat loss and potentially harming the biodiversity of the region.

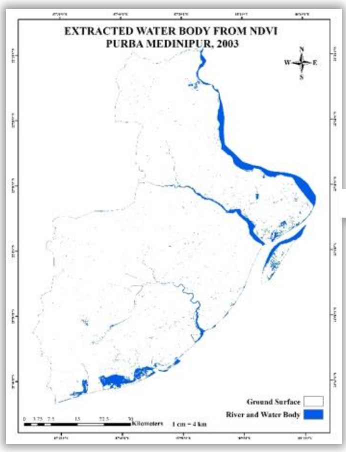

Figure 34. Water Body 2003

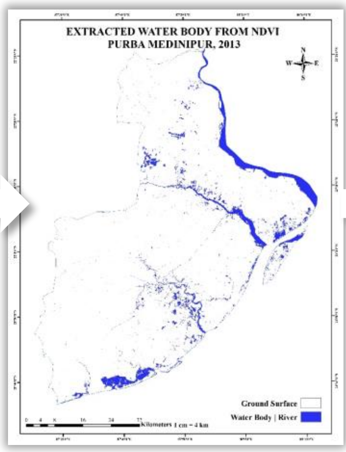

Figure 35. Water Body 2013

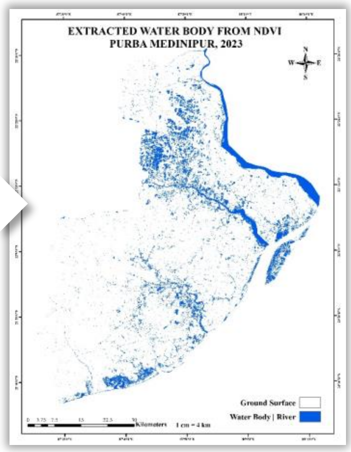

Figure 33. Water Body 2023

Chapter 7: Conclusions

7. Conclusions

The present thesis titled "Assessment of Soil Quality Indicators under Different Land Use Patterns in West Bengal" aimed to investigate the relationship between land use patterns and soil quality indicators, specifically soil texture, soil pH, and soil organic carbon in six districts of West Bengal: Purulia, Malda, Nadia, Paschim Medinipur, Bankura, and Purba Medinipur. The research has provided valuable insights into the state of soil health in these regions and has shed light on the impacts of various land use practices on soil properties. Based on the comprehensive laboratory tests and analysis of soil samples from different land use patterns, the following conclusions have been drawn:

The research demonstrated a significant relationship between land use patterns and soil pH levels. Agricultural regions, especially those with a history of excessive chemical fertilizer use, exhibited lower soil pH values, indicating higher acidity. In contrast, forested or vegetated areas displayed more neutral to slightly alkaline pH levels. Maintaining appropriate soil pH through sustainable agricultural practices is crucial for optimizing nutrient availability and supporting crop growth.

The study revealed distinct variations in soil texture across the six districts under different land use patterns. Areas under intensive agricultural practices exhibited higher proportions of fine-textured soils, while regions with more forest cover or natural vegetation tended to have soils with coarser textures. These variations highlight the importance of considering soil texture in land management decisions to optimize crop suitability and water retention capabilities.

The study also found that land use patterns strongly influenced soil organic carbon content in the six districts. Ongoing cropping land has higher soil organic carbon than any other land use pattern Forested and natural areas showed higher levels of soil organic carbon, indicating better carbon sequestration potential and soil health. Conversely, regions with intensive agricultural practices demonstrated lower soil organic carbon content, indicating higher susceptibility to soil degradation. Implementing measures to enhance soil organic carbon content in agricultural lands can contribute to soil fertility and long-term sustainability.

Overall, the research has highlighted the complexity of the relationship between land use patterns and soil quality indicators in West Bengal. It emphasizes the importance of sustainable land management practices, especially in areas experiencing intensive agricultural activities and urban expansion, to mitigate soil degradation and maintain soil health. Additionally, the findings underscore the significance of preserving natural vegetation and adopting agroforestry practices to enhance soil quality and promote ecosystem resilience. The knowledge gained from this study can serve as a valuable resource for policymakers, land managers, and agricultural practitioners in West Bengal to develop targeted strategies for soil conservation and sustainable land use planning. However, it is essential to recognize that soil quality is a dynamic process influenced by various factors, including climate change, land management practices, and human activities. Therefore, continuous monitoring and further research are necessary to ensure the long-term health and productivity of the soils in the region.

In conclusion, this thesis contributes significantly to the understanding of soil quality indicators under different land use patterns in West Bengal, providing valuable information to support informed decision-making and fostering sustainable land management practices for a resilient and productive agricultural future.

Chapter 8: Future Scope

8. Future Scope

After Assessment of Soil Quality Indicators under Different Land Use Patterns in West Bengal provides valuable insights into the current status of soil quality in the region based on laboratory tests of soil samples from various land use patterns. The study establishes a foundation for understanding the impact of land use practices on soil health, which is crucial for sustainable land management and agricultural productivity. Building on this foundational work, the study opens up several potential avenues for future research and enhancement of the study:

To gain more comprehensive insights, extending the study over a longer duration with regular soil sampling and analysis would allow researchers to observe trends and changes in soil quality indicators over time under various land use patterns. Expanding the research to include more regions or locations beyond the initial study area can help identify regional variations in soil quality responses to different land use practices. Considering the influence of climate change on soil quality indicators could be an essential extension. Future research could focus on assessing the soil biota and microbial diversity in response to different land use patterns, as microorganisms play a crucial role in soil health and nutrient cycling. Developing predictive models that incorporate soil quality indicators, land use patterns, and climate data can help forecast the potential impacts of various land management practices on soil health in the future. Investigating and promoting sustainable land management practices, based on the findings of the study, can help farmers and land managers make informed decisions to enhance soil health and productivity. Integrating remote sensing and Geographic Information System (GIS) techniques can provide a broader spatial understanding of soil quality indicators under different land use patterns, enabling better land use planning and decision-making. Involving local communities, policymakers, and relevant stakeholders in the research process can lead to more practical and effective soil management strategies that consider local needs and priorities. Conducting an economic analysis of the various land use patterns and their impact on soil quality can provide valuable information to policymakers and landowners on the long-term benefits of sustainable practices.

"Assessment of Soil Quality Indicators under Different Land Use Patterns in West Bengal" lays the groundwork for understanding soil health in the region. However, the future scope of research extends beyond the current study. By exploring long-term trends, climate change impacts, varying land use intensities, soil biota, crop-related aspects, and practical soil management strategies, this research can contribute significantly to sustainable land use and agricultural practices, ultimately supporting food security and environmental conservation in the region.

Chapter 9: References

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