ISSN: 0973-4929, Vol. 18, No. (2) 2023, Pg. 795-809

Current World Environment

www.cwejournal.org

Assessment of Spatial Variability Mapping of Soil Properties and its Impacts on Agricultural Productivity using GIS Approach in Siliguri Sub-Division, West Bengal, India

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Abstract

Soil surveying and mapping are extremely important in order to comprehend the characteristics of soil and what applications there are in agriculture, irrigation, urbanisation, and other land uses purposes. A major hindrance to the maximum production of the land is soil degradation brought on by inappropriate land management techniques. Geographical variability mapping of soil parameters is necessary for the agricultural productivity, food safety and environmental modelling. This research was done to identify some of the soil characteristics in the Siliguri Sub-Division. The present study had been conducted in the four blocks of Siliguri Sub-Division, located at the foot hill of the Darjeeling Himalayas in the Terai region of West Bengal, India. To comprehend the geographic variability of soil characteristics using a geospatial technique Soil pH, Phosphorus (P), Organic Carbon (OC), Nitrogen (N), Sulphur (S) and Potassium (K)were measured. To evaluate the current soil status of the area, some important chemical characteristics of the soil were identified. Geographic Information System (GIS) techniques were used to create surface maps of soil attributes, and sampling-broad analysis utilizing GPS was found to be a potentially effective tool. The goal of the study is to use an innovative method to carry out a soil analysis in a newly developed area. The production of digital maps for soil attributes allowed GIS to be used in the study to portray the laboratory results of the soil analysis. Utilizing variable technology, such digital mapping can be utilised in the research on agricultural applications. The result obtained from the research portray that the soil is acidic in nature and the pH value ranges between pH 6.1 to pH 4.5. Moreover, the presence of Nitrogen is between 0.13 to 1.90 %. Organic Carbon ranges between 2.22 to 1.47 %. The range of Potassium

Article History
Received: 25 March 2023
Accepted: 28 June 2023

Keywords
Agricultural Productivity
Geographic Information System (Gis);
Mapping;
Soil Survey;
Spatial Variability;
Soil Properties.

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Doi: https://dx.doi.org/10.12944/CWE.18.2.28

is between 32 ppm to 58 ppm, Phosphorus ranges between 09 to 27 ppm and sulphur content ranges between 10.4 to 32.3 ppm. The investigations will assist the development of a sustainable ecological status and proper agricultural system. Subsequently, it will also help to local government, environmentalists, LULC planners to promote any developmental plan related to agriculture and soil in the Siliguri Sub-division.

Introduction

One of the most important elements of land is the soil. Soil is the foundation of agriculture and the majority of food-producing plants grow in this environment as well.[1] Healthy soils provide healthy crops which nourish people and animals.[2] Food quality and quantity are, in fact, directly correlated with soil quality.[3] Therefore there is an urgent requirement of a better sustainable development of soil and land resource planning. Evaluation of spatial variation of soil features within a landscape is useful information that can be gleaned from mapping soil attributes. In order to make decisions for environmentally friendly land use and increased production, land managers need to have a thorough grasp of aspects such as soil fertility, nutrients distribution, runoff hazards, and other critical elements. In order to map spatial variability, soil samples must be taken at various points throughout the region being studied. The features of these soil samples, including soil texture, pH levels, organic matter content, amount of nutrients, and other pertinent factors, are then examined. The distribution trends & variation of these soil attributes over the terrain are then depicted on maps and spatial models made from the data obtained. Mapping spatial variability enables the identification of regions with particular soil constraints or opportunity for increased productivity. It makes it possible to define management zones inside of a field and landscape where specialised methods can be used to enhance agricultural practises. Farmers can, for instance, apply fertilisers at varying rates across different zones based on the mapping of soil nutrient variability, optimising nutrient usage efficiency and reducing environmental consequences. The main goal of sustainable agriculture is to meet the current needs for food production while ensuring the long-term health and productivity of the natural resources on which agriculture depends. It seeks to strike a balance between economic viability, environmental stewardship, and social responsibility. Sustainable agriculture recognizes that our planet's resources are finite and that agricultural practices must be implemented in a manner that conserves and protects these resources. This approach seeks to maximise resource efficiency while minimising detrimental effects on the natural environment, which involve soil erosion, contamination of water, and habitat destruction.One of the key aspects of sustainable agriculture is soil conservation. Soil is a vital component of agriculture, as it provides the nutrients and support necessary for plant growth. With the use of strategies like crop rotation, the use of cover crops, and minimal tillage, sustainable farming practises aim to preserve the fertility and health of the soil.These methods lessen the requirement for synthetic fertilisers and maintain soil quality for generations to come by preventing erosion, improving soil structure, and fostering natural nutrient cycling.Sustainable agriculture emphasizes efficient water management strategies, such as drip irrigation, precision farming, and water recycling, to minimize water wastage and reduce the impact on freshwater ecosystems. By using water resources responsibly, sustainable agriculture aims to ensure their availability for both agricultural purposes and other societal needs. Sustainable agriculture considers the social and economic well-being of farmers and rural communities. It advocates for fair trade practices, encourages local food systems, and supports the livelihoods of small-scale farmers. By promoting equitable and inclusive agricultural systems, sustainable agriculture aims to create resilient communities and ensure food security for all.[4] For natural resource management, sustainable development, and intensive agriculture, accurate quantitative assessment of information of spatial variability in soil is significant. The spatial distribution patterns of soil characteristics have a significant role in bio-physical processes and are a common feature of natural communities of living organisms.[5,6] Agricultural productivity of the seven major crops in the Siliguri Sub-Division is moderate in nature. Ghoshpukur has the highest API with 1.29 points and lowest API (Agricultural productivity index) is present in Hatighisa and Moniram which is 0.81 and 0.88 respectively. Other Gram Panchayats such as Naxalbari, Bidhannagar-I, Bidhannagar-II, and shows good Agricultural productivity index, due to the presence of thick layer of top soil, adequate water supply, sufficient rainfall, whereas Hatighisa,Upper Bagdogra, Raniganj-Panisali, Lower Bagdogra, Moniram, Binnabari, Jalas- Nizamtara has low API. Soil Survey assessment is a tool for assessing, managing, and causing changes in the soil and connects present resource issues to sustainable land use for the environmental practices & soil survey evaluation, which is then utilized to examine the consequences of management on the soil.[7] In order to create a logical land utilization plan for agriculture, forestry, irrigation, drainage, etc., it is essential to have an in-depth understanding of the various soil types and their geographic distribution.[8] Soil survey provides a comprehensive and scientific knowledge of various soil types, their kind, nature, and area of distribution so that predictions about their characteristics and potentialities can be made.[9] It also offers sufficient details about the terrain, terraces, and vegetation.[10]

The development of GIS technology and its enormous potential for enhancing soil statistics has created new opportunities to achieve this goal because it provides an expedited, repeated, spatial, and temporal synoptic perspective.GIS is a type of computer software that is used to manage huge amounts of data and can help with spatial statistical analysis.[11] The implementation of such programmes that allow academics and decision-makers to gain access of the enormous amount of data and maps which may be used efficiently by using techniques of collection, storage, and conventional or traditional analysis may be challenging in the absence of rules.[12] Therefore, it is important to prepare rules in geographic information which will help to aid in accounting and also help in the analysis of accomplishments and maintenance plans, it is now crucial to use systems like GIS. Using GIS instead of more traditional approaches plans and processes for data collecting and analysis can be developed instantaneously.

Study Area

The study has been conducted in a ‘Terai’ region of Darjeeling district. 'Terai' is the name for the southerly sloping area in the Himalayan foothills. There are swamps and pebbles almost everywhere. In Siliguri Sub-Division, there are four CD block viz. Kharibari, Matigara, Naxalbari, Phansidewa and, including a small section of Siliguri Municipal Corporation which is included in the Siliguri Sub-Division. The study area extends between 26^{o}27’16” N to 26^{o}57’39” N of latitude and 88o07’12” E and 88o31’23” E of longitude. The study area has an area of 802.10 km^2. The average elevation of Siliguri Sub-Division is 122 mts above the mean sea level. The region is surrounded on the east by the Jalpaiguri district, on the north by the Kurseong & Mirik of the Darjeeling district, which is in the south by the Uttar Dinajpur district, and in the west by Nepal and Bangladesh to a lesser extent.

The Darjeeling Himalaya's southern foothill region includes the Siliguri subdivision. The major portion of the research area is formed of especially incoherent materials which were obtained from the great mighty Himalayas and transported sloping downward by the rivers which developed within these mountains, given that this region is enclosed by the steep slopes of the lower Himalayas of the north and the relatively mild alluvium present in the south.[13, 14,15] Average altitude is, accordingly, 840 m to 69 m above mean sea level when measured from the north to south. Along the north-east to south-west orientations make up the area's general slope.

The main rivers of North Bengal are distinguished by drainage inversion, which occurs when a converging of drainage system within the hills changes to a diverging drainage of the system towards the plains. Significant alterations have also occurred in the gradient of their lengthy profiles.[16] The majority of the rivers are substantial. The rivers that run through this region frequently produce braided channels. The Mahananda river system and the Tista river system are the two river systems that flow through North Bengal. The Tista, flows through the eastern boarder of the study area, and enters Bangladesh and finally empties into the Brahmaputra (called Jamunna in Bangladesh). In north-eastern India, tea is grown in the Terai region. The tea gardens are mainly located between the river Mechi, old Balasan River, and Mahananda River in this area. The soil in the study area is mostly porous, slightly coarse in texture, very acidic, with moderate organic matter, low phosphorus, potassium, and micronutrient levels. The soil is made up of rocks and gravels of varying sizes, as well as sands of various sizes, and humus.[17] The sediments brought down by rivers from Northern hilly region and are deposited over the plain in south. Therefore, the parent material of the entire plain part of the study area is loose alluvium. The upper part of this loose alluvium has transformed into soil through the pedogenic processes.[18] The greater part of the region is covered with alluvial soils.

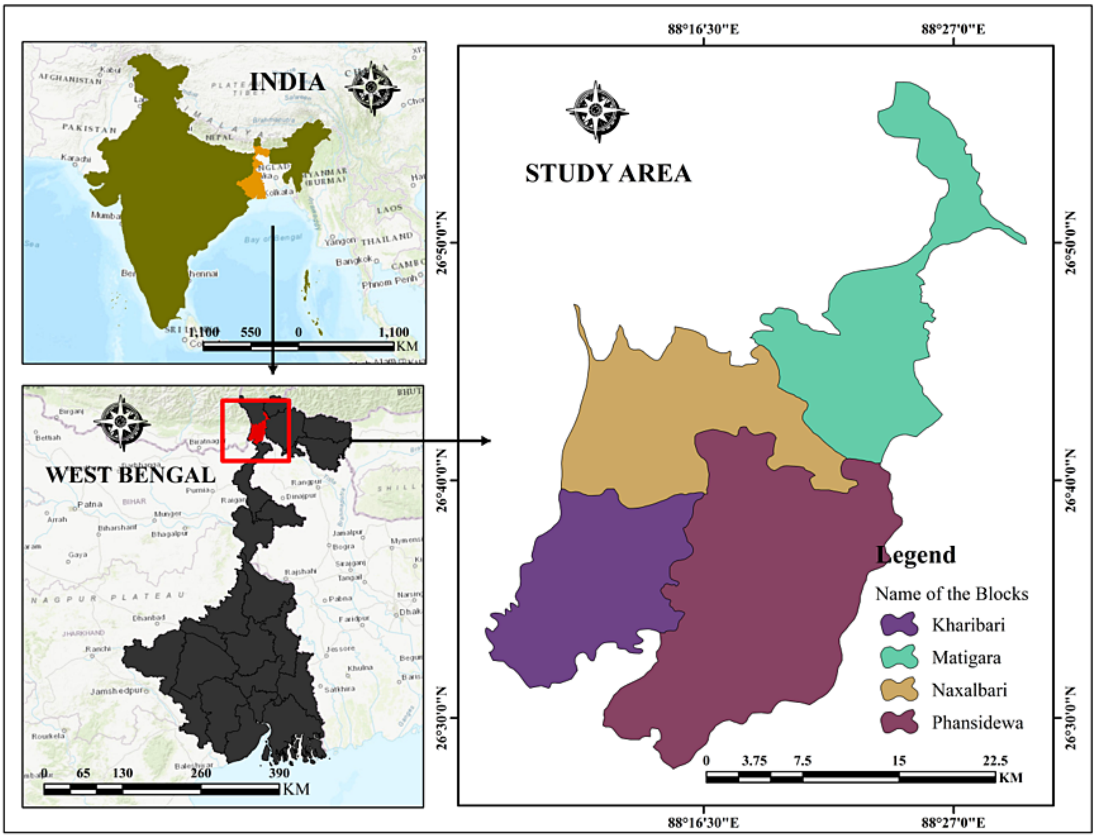


Fig. 1: Location map of the study area

The Data sources and the Methodology

This work has been conducted in the four blocks of Siliguri Sub-Division present in Darjeeling District of the West Bengal, India. At first a pilot survey was conducted by the researchers in the entire Sub-Division. Then, all the four blocks were divided into grid square of 4km * 4km in length and breadth. About 50 square grids were chosen by the researcher which falls almost entirely within the boundary of Siliguri Sub-Division. The sample soils were collected and gathered from the suitable site of each grid and the coordinates were noted. Collected sample soils were air dried and made ready for test. The soils were tested by the researcher in the soil Laboratory.[19] Soil pH was tested with the help of Digital Soil pH meter, soil organic carbon was tested by the process of Walkley-Black Rapid Titration Method. Soil Potassium, soil Nitrogen and soil Phosphorus was tested by Soil Kit Box analysis and Sulphur estimation in the soil was done by Turbidimetric method. The tabulated data was arranged in the MS- excel and converted into point data in the ArcGis software. Finally, the Spatial Zonation maps of all the selected parameters have been prepared by using IDW techniques in Spatial Analysis Tool in ArcGis Software.[20] The spatial resolution of all maps of chemical properties is 30 m * 30 m. The final spatial maps help to identify the current status of the soil properties in the study area. These maps were later analysed by the researcher for better agricultural management, sustainable development and land useplanning.[21,22]

In this study, the M. Shafi's technique (1984) is used to calculate agricultural productivity. Seven major crops—rice, wheat, jute, maskalai, Til, mustard, and potato—were chosen for the study. When taking into account all cropping seasons, these crops take up over 65.40 percent of the total land that is cultivated. Shafi's method sums up the entire yield of every crop grown in a block divided by the total area planted with those crops in a block. The position thus obtained is then compared to the sum of the total yield of all the crops taken into consideration at the district level divided by the total area planted with those crops.

The algorithm of M. Shafi is:

$$Pi = (y1/t + y2/t + y3/t \ldots\ldots): (Y1/T + Y2/T + Y3/T\ldots\ldots) \quad \ldots(1)$$

Where,
Pi=Productivity Index
y= Yield of 1 to nth crops at block level
t= Area under crops 1 to nth at block level
Y= Yield of the 1 to nth crops at district level
T= The total area of crops 1 to nth at the district level

Results and Discussion

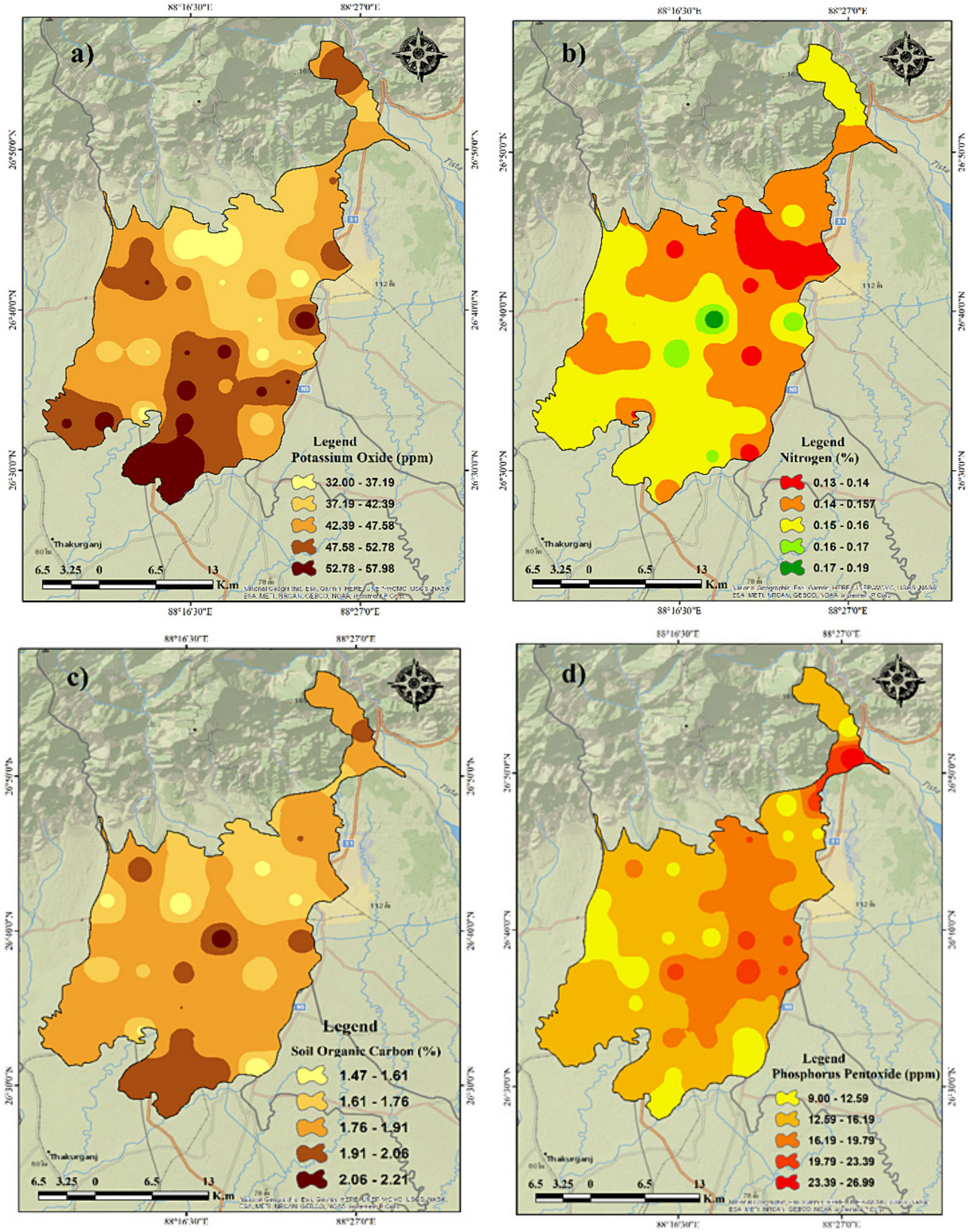
Soil pH

Soil pH is regarded as a key variable to determine the alkalinity or acidity of the soil. A pH reading is actually a measurement of hydrogen ion concentration.[23] The availability of vital nutrients to plants is modulated by soil pH. The solubility of several nutrients varies depending on the pH. The pH extremes could result in toxicities or nutritional deficiencies, which will have an impact on crop development and yield. The pH in the soil affects the composition and activity of soil microorganisms. Many beneficial soil microbes, including bacteria and fungi, have specific pH preferences. Changes in pH can alter the microbial community structure, affecting nutrient cycling, organic matter decomposition, and disease suppression. Maintaining an optimal pH range supports a diverse and healthy microbial population, which contributes to nutrient availability and overall soil fertility. When choosing crops for a location, the pH of the soil is an essential consideration to take into account. Different crops have specific pH preferences for optimal growth. Acid-loving plants like blueberries and rhododendrons thrive in acidic soils, while alkaline soils may be suitable for crops like asparagus or melons. Matching crop choices to the soil pH of the agricultural land can enhance productivity and reduce the need for extensive soil amendments.[24] The pH of the soil affects how much of the nutrients and other substances dissolve in the water in the soil and are thus available to plants. A strongly alkaline atmosphere makes it simpler for some nutrients to be absorbed, while an acidic one makes it better for others.[25]

The soil in the research area has a pH that is acidic in nature, it ranges between pH 4.57 to 6.09. The north eastern mountainous region of Matigara Block has the lowest soil pH of 4.57 which is highly acidic in nature and the pH level increases as we move down towards the south. A total of 191.27 km^2 of area has very low pH level that is about 25.44 % of the study area. This region located at the foot hill of Darjeeling Himalayas and mostly comprises of large tea estates. The soil is porous and contains coarse sand and very little percentage of silt and clay which make it fall under the loamy sand category in Soil Texture Triangle chart. The northern regions of Naxalbari Block havelow pH level of 4.78 which comprises of 137.37 km^2 area which is 18.28 % of the total area. The southern region the pH ranges between 5.18 and 5.48, and the total area in this category is highest with 244.91 km^2 that is 32.60 % of the total area. The entire Kharibari block has pH value ranging between 5.18 and 5.48 comprising of area 99.13 km^2 and it is 13.20 % of the total area. In Phansidewa Block there is a variation of soil pH found, in the northern region the pH is between 4.87 to 5.18. The pH level increase as we move towards the south, it is between 5.18 to 4.48, further south the pH ranges between 5.48 and 5.79 and in the extreme south it has a highest pH of 6.1. Some portion of Phansidewa block and Kharibari block comprises of large Tea Estates while other majority part of the land is comprised of agricultural land, total area comprising of 78.75 km2 which is 10.48% of the total area.

Soil Organic Carbon (SOC)

SOC is essential to agriculture, reducing climate change, and identifying sustainable food sources.[26] It is an organic substance that can be found in soil that acts as a natural energy source and is highly desired by biopolymers.[27] SOC boosts soil's capacity to hold water while also improving the soil's chemical, biological, physical, and structural stability. It is crucial for the production of the organic acids in soil that are necessary for the dissolving of soil minerals, making them available to plants, and nutrient leaching.[28] SOC will prevent soils from abrupt pH alterations and create reserves of soil organic matter (SOM), which are essential for a variety of soil processes and ecosystem services.[29] SOC sequestration is an unambiguous method for enhancing soil health and quality, achieving food security, and reducing land use change.[30]



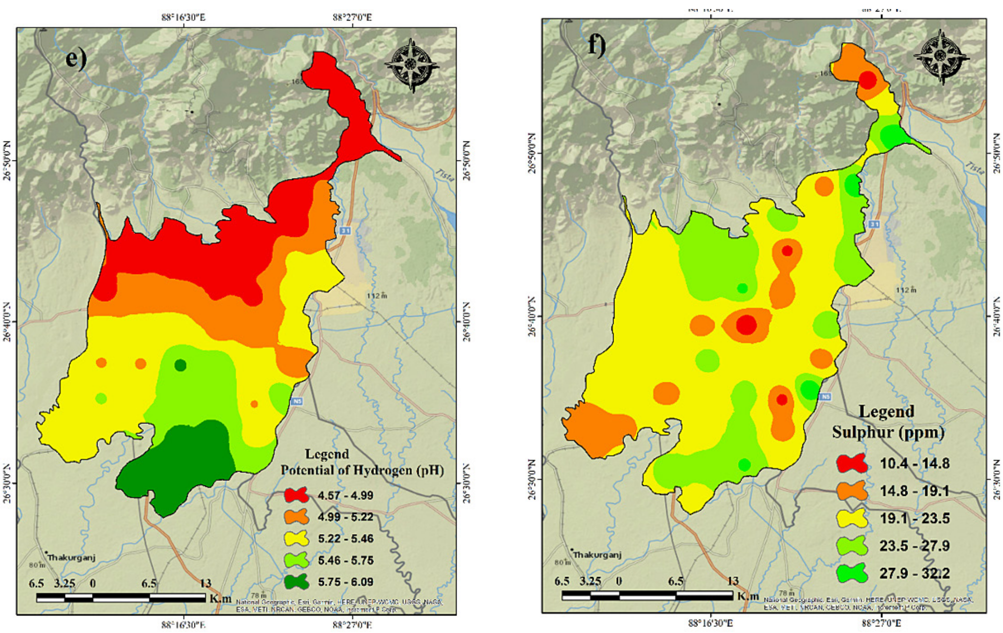


Fig. 2: represents the spatial distribution of chemical properties of soil in the study area: a) Potassium (P), b) Nitrogen (N), c) Organic Matter, d) Phosphorus (P), e) Potential of Hydrogen (pH), f) Sulphur (S).

The above map of organic carbon portrays that 248.89 km^2 of the study area has been found witha moderate organic carbon value ranging from 1.76% to 1.91%. Some regions in Matigara block and Naxalbari block has soil organic carbon ranging from 1.61% to 1.76% which comprises of the total area of 266.58 km^2 that is about 35.52% of the total area. Southern region of the study area has a good proportion of soil organic carbon value ranging from 1.91% to 2.06% of total area is 111.99 km^2 and 14.90 %. Some pockets of low soil organic carbon of 1.47% to 1.61% can be found in Matigara Block, Phansidewa Block and Naxal bari Block which comprises of.5.34 km2 area and 0.71 % of the total area.

Soil Nitrogen

Nitrogen is said to be the most common element present in the atmosphere and is necessary for life. Nitrogen is found in soils and plants in addition to being naturally present in both drinking water and air. It is essential for the development of plants, which makes it essential for the production of the food we eat.[31] It is also vital for our survival. But like all things, balance is key, a lack of nitrogen hinders plant growth, which lowers agricultural production, Plants and the environment may both be at risk from too much nitrogen. Lack of nitrogen resulted in yellowing, reduced development, and smaller fruits and flowers for plants. Fertilisers with nitrogen can be applied to crops by farmers to increase crop growth. The loss of as much as one-third of the crops necessary for our food supply as well as other forms of agriculture is predicted by scientists to occur in the absence of nitrogen fertilisers.[32] However, we must be aware of the precise amount of nitrogen required for plant growth because excess nitrogen can contaminate streams and harm aquatic life.[33]

Major portion of the study area has Nitrogen content of 0.15% to 0.16% which is 41.33 % of the study area and comprises of 310.51 km^2 area. Matigara block (except the mountainous region) have Nitrogen content of 0.14 to 0.157% and southern region of the Matigara block has low Nitrogen content of 0.13% to 0.14% respectively. It consists of the 14.2% of the study area and about 121.34 km^2 of area comprise of 16.14% of the total land. And only 17.20 km^2 that is 2.29 % of the land has very high amount of Nitrogen in the soil.

Soil Phosphorus

Soil phosphorus (P) is one of the essential nutrients for plant growth and is considered crucial for agricultural productivity. Phosphorus is a vital component of adenosine triphosphate (ATP), a molecule that stores and transfers energy within plant cells. ATP is involved in various metabolic processes, including photosynthesis, respiration, and the synthesis of proteins and nucleic acids. Adequate phosphorus availability in the soil ensures efficient energy transfer and storage, supporting plant growth and development. Adequate phosphorus levels in the soil are crucial during early plant growth stages, as they help establish a robust root system, improving plant establishment and nutrient acquisition capabilities. Phosphorus availability influences the nutritional composition and quality of crops. It contributes to the accumulation of essential compounds such as sugars, proteins, and vitamins. Adequate phosphorus levels in the soil promote the synthesis of these compounds, enhancing the nutritional value and quality of harvested crops. Additionally, immature plants and seedlings require it. Plant growth is hindered without phosphorus. Plants are wiry and stunted, with short roots. Other signs of a deficit include withering leaves, red pigment at the bases of leaves, and dull, greyish-green leaves. Phosphorus shortage is challenging to detect, and by the time it is, it might be too late to take action. When phosphorus is later added to plants that were starved of the mineral as seedlings, they might not recover. Phosphorus is a very stable element chemically.[34] As fertiliser phosphorus reacts with soil quickly, it does not spread far away from the application location. The pH of the soil rapidly bonds with both aluminium and iron when it drops below 5.0, rendering it inaccessible to plants.

Very high phosphorous content can be seen in the Matigara Block ranging from 23.39 to 26.99 ppm which covers about 2.25% of the land and has an area of 20.32 km^2. Most of the region in the study area is covered with phosphorus ranging from 12.59ppm to 16.19ppm with an area of 344.07 km^2 that comprises of 38.23% of the land. Some patches of low phosphorus can be found in Kharibari and Phansidewa block about 172.29 km2 of an area comprises of 19.14% of the total land. Moderate Phosphorous is found in most of the places in the study area covering 244.95 km2 and 27.12% of the land.

Soil Potassium

Potassium is considered as an essential element for plant development and reproduction. It deficiency makes plants less tolerant to heat, drought, and excess water.[35] Additionally, they have lower resistance to worm assaults, illnesses, and pest infestations. Potassium is referred to as the "quality" nutrient since it enhances the general health of developing plants and aids in their defence against illness, Soil Survey (Staff, 1983).Potassium is essential for healthy plant growth. In reality, most of the crops that contain more amount of potassium other than any other nutrient, that includes nitrogen (N), at all stages of growth. While significantly higher amounts of potassium are incorporated to regulate the water interactions in the plant, smaller amounts are required to maintain many of the essential enzyme functions within the plant. Additionally, potassium is necessary for the transfer of sugars and other photosynthetic by-products which transfer from leaves to the storage organs. In order for a crop to produce its maximum amount of yield, adequate potassium levels are necessary. Additionally, it has significant effects on a wide range of other quality variables, such as grain shape as well as colour, size of the tuber, oil content, the amount of dry matter & starch content, sugar content, fruit ripeness, and quality.[36]

Therefore, it is hardly unexpected that crops suffer substantially in difficult growing seasons when they lack plant-available potash. Weaker, less vigorous crops are the result. Potash may not have much of an impact during favourable growth conditions, especially for crops like cereals, but during challenging years, it will significantly contribute to the highest yields possible. In order to protect against unfavourable conditions during challenging growing seasons, adequate potassium is consequently a form of "insurance". Different plants absorb potassium at different times. But compared to nitrogen and phosphorus, potassium is often absorbed by plants at an earlier stage of growth.[36]

A very high potassium content can be seen in the southern region of Phansidewa block whose value ranging from 52.78 to 57.98 ppm covering 147.71

km^2 of an area and covers 19.56% of the study area. Low Potassium can be found in Naxalbari Bock and Matigara block of 81.99 km^2 area and 10.91% of the total land. Moderate potassium is mostly found in Kharibari Block and western part of Naxalbari block of area181.97 km^2 and 24.21% of land. Moderately high potassium is found in Phansidewa Block ranging between 47.58 to 52.78 ppm covering an area of 191.43km^2 and 25.47% of the land.

Soil Sulphur

Soil sulphur (S) is a crucial nutrient component for soil fertility & plant development. Amino acids, which serve as the foundation for proteins, must contain sulphur.[37] In the synthesis of enzymes, the organisation of cells, and the transfer of nutrients, proteins are essential to the growth and development of plants. A variety of physiological processes in plants are supported by the presence of sulphur in the soil, which ensures protein synthesis. Sulphur influences how well plants absorb and use nutrients. It contributes to the production of the vitamins, enzymes, & coenzymes necessary for nutrition metabolism. Because it helps plants use nitrogen more effectively, sulphur is particularly crucial for nitrogen metabolism. A balanced plant's nutrition is supported by adequate sulphur availability, which promotes effective nutrient uptake and utilisation. Compounds that support plant defence mechanisms are produced using sulphur. It participates in the production of secondary metabolites with sulphur, like phytoalexins and glucosinolates, which support plants' defences against pathogens, stresses, and pests. Due to weakened defences caused by sulphur deficiency, plants are more vulnerable to biotic and abiotic stressors. Due to sulphate in the form of sulphur leaching underneath the plant's root zones in grazing plants during rainy years, a sulphur deficit can significantly impair output in meadows with sandy soils. Sulphur is prevalent in almost all soils in varying amounts.[38] Because of the original parent rock's nature, clay and gravel soils typically contain more sulphur. More organic sulphur, which gets mineralized into sulphate sulphur that is available to plants, is found in soils that contain a lot of clay and gravel. Higher rainfall regions with sandier soils are unable to stop the leaching of water-soluble sulphate sulphur. Symptoms of sulphur deficiency in cereals frequently match those of nitrogen deficit, including pale green or yellow leaves. Examine the plant in detail to identify the source of the deficit. In contrast to nitrogen shortage, which affects the oldest leaves, sulphur deficiency causes the youngest leaves of plants to turn yellow.[39]

Very small patches of high sulphur ranging between 10.4 to 14.8 ppm is found in the mountainous region of Matigara block and in the western Phansidewa Block with total area of 64.54 km2 and only 8.51% of the total land. Moderately low sulphur is found in Naxalbari block ranging between 14.8 to 19.1 ppm covering 24.30 % with total area of 180.09 km^2. Moderate sulphur is found in almost all the whole blocks ranging between 19.1 to 23.5 ppm covering an area of 300.6 km^2 and 39.72 % land. Moderately high sulphur is found in northern Naxalbari block total area of 177.11 km^2 covering 23.59 % land. And very low sulphur is found in a small patch in Champasari region of Matigara Block with 29.05 km^2 area and 3.86 % of land.

Table 1: Spatial distribution of soil properties in Siliguri Sub-division

Soil properties	Class	Area in sq./km	Area in %
Soil pH	4.57 – 4.99	191.27	25.45
	4.99 – 5.22	137.36	18.28
	5.22 – 5.46	244.90	32.59
	5.46 – 5.75	99.13	13.19
	5.75 – 6.09	78.75	10.48
Soil Organic Carbon (%)	1.47 – 1.61	118.34	15.74
	1.61 – 1.76	266.85	35.51
	1.76 – 1.91	148.39	33.12
	1.91 – 2.06	111.99	14.90
	2.06 – 2.21	5.32	0.71

Soil Nitrogen (%)	0.13 – 0.14	106.72	14.20
	0.14 – 0.15	195.64	26.04
	0.15 – 0.16	310.54	41.32
	0.16 – 0.17	121.34	16.15
	0.17 – 0.19	17.20	2.30
Soil Phosphorus (ppm)	9.00 – 12.59	172.29	19.14
	12.59 – 16.69	344.07	38.23
	16.69 – 19.79	244.95	27.21
	19.79 – 23.39	118.35	13.15
	23.39 – 26.99	20.32	2.26
Soil Potassium (ppm)	32.00 – 37.19	81.99	10.91
	37.19 – 42.39	148.31	19.73
	42.39 – 47.58	181.97	24.21
	47.58 – 52.78	191.43	25.47
	52.78 – 57.98	147.71	19.65
Soil Sulphur (ppm)	10.4 – 14.8	64.54	8.51
	14.8 – 19.1	180.09	24.30
	19.1 – 23.5	300.61	39.72
	23.5 – 27.9	177.11	23.59
	27.9 – 32.2	29.05	3.86

Impacts of Soil Properties on Agricultural Productivity

The main crop farmed across the Sub-Division is rice.Rice is cultivated mostly during the monsoon season. All the three types of rice *Aus*, *Aman*, *Boro* are grown here, but the dominant one is Aman which is sown in the rainy season especially in the month of June - July and harvested during the winter season. Boro rice is grown in the northern region of the study area especially in the Hatighisa, Upper Bagdogora and Panighata region. Rice production in Raniganj-Panisali is highest which is 8112 kg/hec and Matigara II is lowest which is 4147 kg/hec. This is mainly due to the water holding capacity of the soil and soil pH level which suits the Buraganj, Kharibari-Panisali and Raniganj-Panisali region where rice is grown abundantly. Wheat is dominant in Atharakhai, Patharghata, Matigara-II, Lower Bagdogra, Hatighisa and Raniganj-Panishali regions.Wheat is a winter crop that needs irrigation, has been extensively supported in these areas. It is mainly sown in the month of November and harvested during the month of March. This is possible because these areas have loamy texture of soil, good structure and moderate water holding capacity, the soil present in this region has adequate proportion of sand, silt and clay to grow wheat. Raniganj-Panisali dominates with highest production of wheat which is 2011 kg/hec. Maskalai is grown in Patharghata, Binnabari, Atharakhi, Phansidewa-Bansgaon Kismat, Hatighisa, Naxalbari, regions. The production is notso high as wheat and rice, Patharghata is the highest producer of Maskalai in the Sub-Division, with 783 kg/hec along with Binnabari, Buraganj, Kharibari-Panisali and Raniganj-Panisali where Maskalai is being cultivated in recent times.

Mustard is grown extensively in Chathat-Bansgaon Kismat, Jalas- Nizamtara, HetmuriSinghijhora, Phansidewa-Bansgaon Kismat regions. Chathat-Bansgaon Kismat region is the highest producer of mustard with 1144 kg/hec. and Matigara I, Matigara II, and Champasari region does not grow mustard at all. Since the study areacomprises of well drained sandy loam with pH 6.0 hence mustard thrives well here.Til is grown in some of the regions only, Naxalbari, Binnabari, Buraganj, Kharibari-Panisali, Raniganj-Panisali region.Phansidewa-Bansgaon Kismat in the highest producer of Til with 630 kg/hec and Atharakhai, Matigara I, Matigara II, Patharghata, Champasari does not grow til at all. Due to the available irrigation facilities, well drained light to medium textured soil make it favourable to grow Til. Potato is cultivated extensively all over the Sub-Division, it is mainly sown in the month of December or January as a Rabi crop. The ideal period to plant is during the times when the maximum and minimum temperatures, respectively, range from 30°C to 32°C and 18°C to 20°C.Potato is widely grown in Chathat-Bansgaon Kismat, Ghoshpukur, Jalas-Nizamtara Bidhannagar-Ii, Phansidewa-Bansgaon Kismat, Hetmuri Singhijhora. The highest producer of potato is Hetmuri Singhijhora with 29035 kg/hec. Jute is not grown so extensively, total jute cultivation amounts to only 216.07 kg/hec only among which HetmuriSinghijhora is the highest producer of jute in the Sub-Division with 11.35 kg/hec production, and Champasari with lowest jute production. Due to the presence of fertile alluvial soil and sandy loamy soil cultivation of jute is possible here.

Table 2: Gram panchayat wise crop productivity (kg/hectare) in Siliguri Sub-division

Gram panchayat	Rice	Wheat	Maskalai	Mustard	Til	Potato	Jute
Atharakhai	4322	1776	763	657	0	21679	9.98
Matigara- I	4178	1770	750	0	0	21680	9.1
Matigara -II	4147	1767	752	0	0	20147	9.3
Patharghata	4240	1841	783	655	0	21679	9.98
Champasari	4068	1677	730	0	0	20412	9
Gossaipur	6810	1921	763	511	600	22922	10.22
Hatighisa	6701	1923	766	501	600	21456	9.18
Lower Bagdogra	6879	1901	722	511	0	21324	9.01
Naxalbari	6844	2014	775	651	612	22922	10.22
Moniram	6595	1966	736	602	601	22932	10.21
Binnabari	7982	1818	765	492	601	27485	8.64
Buraganj	8056	1820	763	496	605	27549	7.6
Kharibari-Panisali	8101	1966	752	499	600	28141	8.64
Upper Bagdogra	6735	1896	712	515	0	21414	9.1
Raniganj-Panisali	8112	2011	745	488	599	28150	8.78
Bidhannagar-I	7321	1611	741	951	0	28698	10.96
Chathat-Bansgaon Kismat	7570	1678	767	1144	611	29032	11.31
Ghoshpukur	7012	1555	766	1021	587	28794	10.91
Jalas- Nizamtara	7278	1780	763	1071	602	29032	11.02
Bidhannagar-Ii	7205	1601	745	966	0	28965	10.25
Phansidewa-Bansgaon Kismat	7654	1790	763	1071	630	29032	11.31
HetmuriSinghijhora	7352	1720	760	1076	0	29035	11.35

Source: Office of Assistant Director of Agriculture (2016-2017), Kharibari-Phansidewa block and Matigara-Naxalbari block.

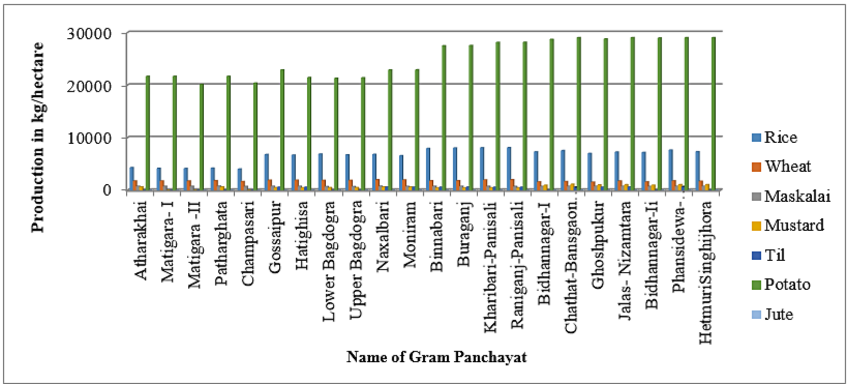


Fig. 3: GP wise crop production in Siliguri Sub-division in the period of 2016-2017

Table 3: average API OF 7 crop productions in Siliguri Sub-division

SL no	GP	Average API of 7 Crops
1	Atharakhai	1.08
2	Matigara- I	1.0
3	Matigara -II	1.10
4	Patharghata	0.92
5	Champasari	0.96
6	Gossaipur	1.31
7	Hatighisa	0.81
8	Lower Bagdogra	0.98
9	Upper Bagdogra	0.83
10	Naxalbari	1.16
11	Moniram	0.88
12	Binnabari	0.96
13	Buraganj	1.26
14	Kharibari-Panisali	1.19
15	Raniganj-Panisali	0.94
16	Bidhannagar-I	1.18
17	Chathat-Bansgaon Kismat	1.07
18	Ghoshpukur	1.29
19	Jalas- Nizamtara	0.92
20	Bidhannagar-II	1.23
21	Phansidewa-Bansgaon Kismat	1.07
22	Hetmuri Singhijhora	1.18

Computed by authors using eq. 1 formula

Table 4: represents the descrptive statistics of soil properties in Siliguri Sub-division (n=50)

Descriptive Statistics	Soil pH	Organic Carbon (%)	N (ppm)	K (ppm)	P (ppm)	S (ppm)
Mean	5.2752	1.81	0.157	47.72	15.42	22.25
Median	5.265	1.83	0.157	46.5	15	22.9
Mode	5.10	1.88	0.162	53	15	22.9
SD	0.39	0.142	0.01	16.49	3.98	4.94
Kurt.	-0.45	0.43	0.96	31.00	0.13	-0.01
Skew.	0.42	-0.01	0.57	4.97	0.55	-0.15
Min.	4.57	1.47	0.136	32	9.00	10.40
Max.	6.10	2.22	0.191	150	27.0	32.30

Descriptive Statistics

The elaborative qualities of soil parameters were shown in table 2. The most significant characteristics of soil are its pH, which has a mean value of 5.27, the median value is 5.26 and the modal class value of 5.1 respectively in the top layers of the soil in the study area. The average organic carbon present in the soil is 1.81%, it has a median value of 1.83 and modal value of 1.88. The SD value is 0.14. Nitrogen is very important for the growth of crops and the study area have relatively good amount of Nitrogen with mean Nitrogen of 0.157 ppm, median value is also 0.157 ppm and mode of 0.162. The SD value is 0.01. The study area has an average Potassium of 47.72 ppm and median value of Potassium is 46.5 ppm and the modal class is 53. The mean value of Phosphorus present in the soil of the study area is 15.42 ppm and the median value as well as the modal value is 15 ppm, with SD value 3.98. Sulphur is another essential element of soil; it has a mean of 22.25 ppm in the soil of the study area. The median value is 22.9 and the modal value is also 22.9. The SD value is 4.94.

Conclusion

For soil protection and environmental modelling, it is crucial to understand geographical distribution and accurately mapping of soil properties at a large scale. To prepare the spatial distribution mapping of chemical soil properties in Siliguri sub-division, authors have been selected six parameters such as soil pH, soil Nitrogen, soil organic carbon, soil sulphur, soil potassium, and soil phosphorus. The study area comprises total four blocks viz. Khoribari, Naxalbari, Pansidewa and Matigara blocks. The aforementioned figures indicate that the soil in the two blocks viz. Phansidewa and Kharibari are very suitable for farming whereas the soil in the Naxalbari block is only moderately suitable for cultivation. In contrast, some of Matigara block's mountainous terrain is unsuitable for farming. Agriculture is practised in a few locations in the southern region of the Matigara block. If proper fertilizers are added and sufficient irrigation facilities is provided, then the two blocks of Matigara and Naxalbari will be made very productive. This works will be helpful to the policymakers and decision taking authorities to take any kind of developmental plan regarding soil conservation and degradation in the Siliguri sub-division.

Acknowledgements

The authors are pleased to offer their heartfelt thanks and respect to everyone who helped this research work be completed successfully. Their invaluable support, guidance, and encouragement have been instrumental in shaping this work. Firstly, and most importantly, we desire to express our gratitude to our supervisor, Dr. D.K. Mandal (Professor), for their unwavering support, expert guidance, and valuable insights throughout the research process. We would like to acknowledge the support and resources provided by the Department of Geography and Applied Geography and the Department of Tea Science soil laboratory of the University of North Bengal. The access to the necessary facilities, equipment, and research materials has been vital in conducting the experiments and analyses required for this study. We are grateful for the opportunities provided by these institutions, which have greatly facilitated the progress and success of our research. Furthermore, NBSS & LUP are gratefully acknowledged by the authors for providing the essential data for the research. We also thankful to the editor and reviewers for give their valuable suggestions to improve this work.

Funding

There is no funding or financial support for this research work.

Conflict of interest

The authors declare that they have no conflict of interests.

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