Chapter I

Introduction and Background of the Study Area

1.1 Introduction

Agriculture is one of the most important sector which play a vital role in our national economy. As a source of food, employment, and income generation, agriculture plays an indispensable role in ensuring food security, reducing poverty, and fostering rural development. The sector's vitality extends beyond the economic sphere, connecting deeply with India's cultural heritage and social dynamics. More than 70 percentage of the rural population in India is directly connected with agriculture (FAO India). One of the most important factor that governs the agriculture is the properties of the soil in which the crops are grown. If the soil in which the crops are grown is not fertile or if it does not suit the perfect soil condition then the corps will not grow properly and their yield will be less, so one must know the soil condition and its type which is best suitable for growing crops. Hence forth soil properties have a great impact on the agricultural land use pattern. Siliguri Sub-Division is located at the base of the Darjeeling Himalayas. It has large tea gardens and influenced by plantation agriculture and other forms of agriculture but since last decade (2011-2020), the crop yield is decreasing day by day, vast area of land is left uncultivated. In the past few years' production in the field of pineapple cultivation has been declined. Farmers do not get appropriate cost by selling their crops so the main issue is to identify the problems of the soil and help the farmers to increase their production.

All soil contains organic matter, water, mineral particles, and air. The combination of these determine the soil's properties- its texture, structure, porosity, chemical properties and colour. Soil texture is the relative proportions of sand, silt and clay particles in percentage presents in a soil. There are three types of soil properties, namely, (a) Physical Properties, (b) Chemical Properties, and (c) Biological Properties. These three types of soil properties are very essential to understand the plant growth and are most important influencing the agricultural land use. Each soil has a particular type and arrangement of these elements, which results in different soil qualities or "soil types." Land use capability (i.e., compatibility for diverse land uses including grazing against cultivation), drainage & runoff of water, nutrient loss & leaching, soil erosion, and plant growth response are all influenced by soil parameters. Soil properties such as structure, texture, depth, acidity,

salinity, waterlogging or compaction may restrict plant growth even when there are enough nutrients in the soil.

The weathering of parent material that occurred during soil formation are major determinants of a soil's characteristics. The biological, chemical, and physical characteristics of the soil have an impact on plant growth. Making decisions on nutrient planning & land use requires an understanding of soil parameters. An assessment of soil characteristics and their reaction to management is necessary in agriculture and forestry, as well as for decision making in both urban and rural planning, feasibility studies and design analyses in residential and commercial development projects, and numerous engineering tasks. The practical goal of a soil survey is to allow for more numerous, accurate, and valuable predictions to be produced for specific purposes than would otherwise be possible.

Land use differs from land cover due to people's purposefully role in modifying natural land cover to their advantage. The term "land use" implies human intervention and an underlying goal to convert natural land resources into a positive result. This encompasses both the manner in which the land's biophysical features are altered and the goal underlying that manipulation, i.e. the objective for which the land is used. According to the FAO concept, “land use defines the human activities which are directly related to land, making use of its resources, or having an impact on them”. In that context the emphasis is on the function or purpose for which the land is used, and particular reference is made to “the management of land to meet human needs.” The term land use encompasses both urban as well as rural and industrial applications. Land use inevitably encompasses subjects such as maximising land use potential, land evaluation, & land use planning.

The land cover defines the biophysical state of the earth's surface and immediate subsurface, including soil composition, vegetation, and water status. Originally, the phrase referred exclusively to the type of flora that covered the land surface, but it was later enlarged to encompass soils and biodiversity as well.

Agriculture nourishes and defines our contemporary life, but it is frequently destructive to natural ecosystems. This is particularly significant for plant ecosystems, animal populations, soil infrastructure, and water resources. Understanding, analysing, and balancing negative and beneficial agricultural perturbations of water and soil are critical tasks in human endeavours to sustain and promote human well-being. Such understanding informs our growing ethics of sustainability and accountability to future

human populations and ecosystems. Our social evolution has been accelerating since the Agricultural Revolution and has occurred in synergy with human biological evolution as we have grown more dependent on animals and plants that are cultivated on purpose in highly regulated soil-water systems. (Singha, 2018).

While soil is sometimes referred to as a "fertile substrate," not all soils are appropriate for crop cultivation. Mineral contributions (sand: 0.05-2 mm, silt: 0.002-0.05 mm, clay < 0.002 mm), soil organic matter (SOM), air, & water are all balanced in ideal agricultural soils. These components' balanced contributions enable water retention as well as drainage, oxygen in the plant's root zone, nutrients to aid crop growth, and physical support for plants. The time, parent material, organisms, climate, & terrain all influence the distribution of various soil components in a given soil (Jenny, 1941). Each of these factors influences the suitability of a soil for agriculture in a direct and overlapping manner.

Siliguri Sub-Division is an administrative division located in the Indian state of West Bengal. It is part of the Darjeeling district and serves as an important economic and transportation hub for the region. Siliguri Sub-Division encompasses the city of Siliguri, which is the largest urban centre in North Bengal. Siliguri Sub-Division is geographically located in the Terai region at the foot of the Eastern Himalayas. It is at a key strategic location because it shares borders with Bangladesh and Nepal, two nearby nations. The landscape of the area, which ranges from flat to steep terrain, is distinctive. Siliguri Sub-Division has witnessed rapid urbanization and economic growth over the years due to its advantageous location. It serves as a gateway to the north-eastern states of India, connecting them with the rest of the country. Siliguri acts as a major transit point for trade and commerce, with numerous transport routes passing through the region, including road, rail, and air. The economy of Siliguri Sub-Division is driven by various sectors such as trade, transportation, services, and tourism. It is known for its bustling markets, commercial centres, and industrial zones. The region hosts a number of wholesale markets and trading hubs, attracting traders from nearby areas. Siliguri Sub-Division is also a popular tourist destination, serving as a base for exploring the nearby hill stations of Darjeeling, Kalimpong, and Gangtok. The region is known for its tea gardens, scenic landscapes, and wildlife sanctuaries. The Mahananda Wildlife Sanctuary, located on the outskirts of Siliguri, is a notable attraction for nature lovers.

In terms of governance, Siliguri Sub-Division falls under the jurisdiction of the Darjeeling district administration. It is further divided into several administrative units,

including Siliguri Municipal Corporation and rural blocks. The Sub-Division has its own local government bodies responsible for providing essential services and infrastructure to the residents.

Overall, Siliguri Sub-Division is a dynamic and thriving region with a strategic location, robust economy, and vibrant cultural diversity. Its significance as a transportation hub, commercial centre, and tourist destination makes it a crucial part of the larger North Bengal region. Siliguri Sub-division is located in the northern portion of West Bengal and under Monsoon Climate. Also its production capability in terms of agriculture is moderate due to its inherent soil characteristics and lack of irrigation as well as other infrastructural facilities. Yet the introduction of modern technology has been changes not only agrarian sector but also in other socio-economic sphere. Siliguri Sub-Division has a gross cultivated area of 46,000 ha and net cultivated area of 24,500 ha and among this 9,100 ha (i.e. 37.14%) of land has the irrigation facilities. Some of the different types of crops grown are Aman paddy, wheat, maize, winter potatoes, millets, summer vegetables, winter vegetables, ginger, turmeric, mustered, kolai, pineapple, etc. and also has a vast area of land under tea plantation. (District Statistical Handbook, 2013).

Many factors determine the area of study that is chosen. Firstly, it is believed that such a study at the micro level would be a beneficial method to get a more thorough grasp of the region's agricultural difficulties. Second, the Siliguri Sub-Division is located in the Terai region. As a result, the study of agricultural land usage in Siliguri Sub-Division will aid in understanding the Terai region's agricultural geography to some extent. Third, this region is regarded as one of Darjeeling District's best developed agricultural areas. Finally, in recent years, a huge area that was previously used for food grains and vegetables has been allocated to tea plantation & horticulture, resulting in changes in agricultural land use. As a result, studying crop land use and variations in a real strength provides an opportunity to gain a more full knowledge of this Sub-Division's agricultural land use in a time-space perspective.

1.2 Study Area

The Siliguri Sub-Division is the study area located in Darjeeling District, West Bengal. It is the northernmost district in West Bengal, also known as the Terai of Darjeeling District. It largely encompasses thick alluvium and a portion of the piedmont plain of the Mechi-Mahananda interfluves, known as Chicken neck. The study area lies between

26º27’16” N to 26º57’39” N of latitude and 88º07’12” E and 88º31’23” E of longitude and is represented by parts of the Survey of India (SOI) topographical sheet no. 78 B/1, 78 B/2, 78 B/3, 78 B/5. 78 B/6 and 78 B/9 on the scale of 1: 50,000. Siliguri Municipal Corporation and four community development (CD) blocks: Matigara, Naxalbari, Phansidewa, and Kharibari comprise the Sub-Division, which comprises 14 census towns (District Census Handbook, 2011). The study area covers an area of 802.10 km^2. The Sub-Division is flanked on the east by Jalpaiguri district, on the north by Darjeeling district's Kurseong and Mirik Police stations, on the south by Uttar Dinajpur District and partly by Bangladesh, and on the west by Nepal.

Matigara block covers an area of 143.00 km^2 with an average altitude of 127 metres. It has one Census Town, Bairatisal, and five gram panchayats, namely Atharakhai, Champasari, Matigara-I, Patharghata, and Matigara-II. The Naxalbari block has an average elevation of 152 metres above sea level. This block has an area of around 181.88 km^2. This block is made up of one census town, Uttar Bagdogra, and six gram panchayats, namely Gossainpur, Naxalbari, Lower Bagdogra, Hatighisa, Moniram, and Upper Bagdogra. The Phansidewa block has an area of approximately 312.55 km^2 with an average elevation of 98 metres above sea level. This block only has seven gram panchayats: Bidhannagar-I, Chathat-Bansgaon Kismat, Ghoshpukur, Jalas-Nizamtara, Bidhannagar-II, Phansidewa-Bansgaon Kismat, and Hetmuri Singhjhora. The Kharibari block has a total size of 144.88 km^2. This block is mostly rural, having four gram panchayats: Binnabari, Buraganj, Kharibari-Panisali, and Raniganj Panisali. Siliguri Municipal Corporation, part of Siliguri Sub-Division, covers an area of 20.10 km^2. As a result, the total area of the Siliguri Sub-Division is 802.10 km^2.

1.3 Physical setup of the study area

The Siliguri Sub-Division encompasses a diverse range of landscapes, including plains, hills, and a few mountainous regions. It is situated in the northern part of West Bengal, near the international borders with Nepal and Bangladesh. Through the Terai, the Himalayas' mighty, jagged peaks rise gradually from the mountainous flat plains of North Bengal. The gently sloping Terai region is partially covered in river-borne sediments and partially by rocks from farther north. A sequence of earthen terraces from the Pleistocene and Post-Pleistocene ages, each rising higher than the other, divide the Terai's high hill from its flat, gradually sloping plains thus, constructing a string of cliffs with rather flat tops that stare out over the plains. At a height of 500 to 700 metres, these terraces finally

converge towards the foot of the hills. Numerous streams with distant sources in the high hills descend down steep, treacherous gorges before emerging as slow-moving rivers with wide, shallow banks at the debauchers. The majority of these rivers are dry during the winter months, but during the monsoon they can carry enormous flows of silt-filled water, and often flood in the low lying region in the south of the study area.

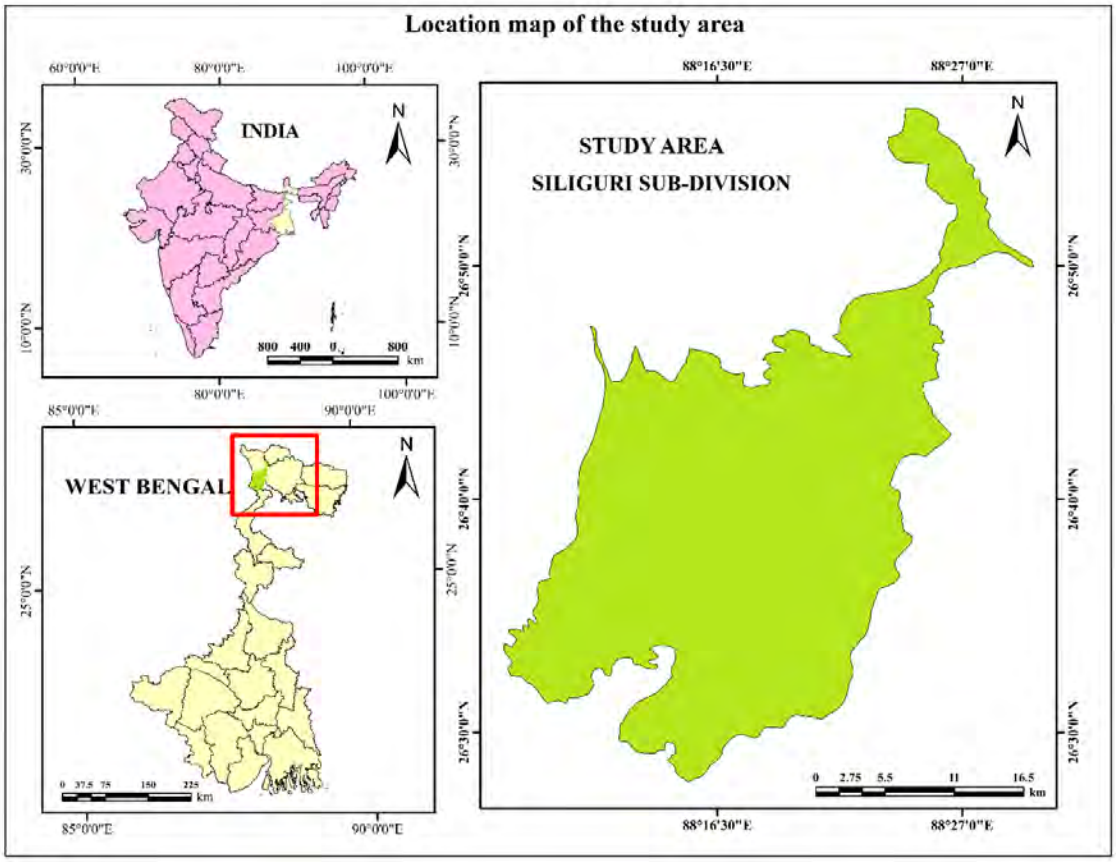


Plate 1.1 Location Map of Siliguri Sub-Division.

According to Dokouchaev, 1893, soil is the function of parent material, biota factor, climate, relief and time. Stratigraphically, the northern region shows an abnormal geological succession with older strata in the higher elevation. The Siwaliks are the first group of rocks encountered while travelling northward from the plains of recent alluvial deposits. They are composed of hard and strongly feldspathic and slightly micaceous sandstones, quartz pebbles, and schist.

Siliguri Sub-Division is located to the southern foothill zone of Darjeeling Himalaya. As the area is bounded in the north by the lofty peaks of the lesser Himalayas and to the south by mild alluvium, the majority of the study area is made up of unconsolidated

materials obtained from the Himalayas and transported down by rivers that originate from these hills. From north to south, the surface elevations range from 1300m to 69m above mean sea level. The overall slope of the area runs north-east to south-west.

One of the distinctive features of the major rivers of North Bengal is that they experience drainage inversion from converging drainage in the mountainous regions to divergent drainage in the plains. Throughout the monsoon season, most of the waterways that are typically dry throughout the dry season drain a significant amount of water. Changes in the gradient of their lengthy profiles are also noteworthy. The majority of the rivers are quite huge. The rivers which pass across this area are regularly braided. North Bengal's rivers are separated into two systems: The Mahananda system and the Tista system. The Tista flows past the study area's eastern border, into Bangladesh, and eventually empties into the Brahmaputra (named Jamunna in Bangladesh). The Terai region of north-east India is where tea is cultivated. The gardens are centred here between the Mechi, old Balasan, and Mahananda rivers. (Lama, 2011).

Soil of the study area is basically porous in nature, deep, slightly course textured, highly acidic, with high organic matter, low Phosphate, Potassium, and micronutrient contents. Soil consists of sands of different sizes and is interspersed with humus along with variable size gravels and boulders. Sediments carried down by rivers from the northern mountainous region and deposited over the southern plain. As a result, loose alluvium is the parent material that forms the entire plain component of the study region. Through pedogenic processes, the upper section of this loose alluvium has changed into soil. The majority of the region's surface is covered with alluvial soils, which range from pure sand to clay but are mostly sandy loam in character.

The climate of the study region, which is adjacent to a hilly tract, is characterised by a humid atmosphere & abundant showers, with temperatures rarely exceeding 30 degrees Celsius. The area experiences considerable rainfall as a result of the South-West monsoon. The area's average rainfall is 275 cm. The rainy season begins in June and lasts until the end of September. The summer temperature in the area is not very hot, with an average of 28ºC, and the winter temperature is around 16ºC. The month of January remains the coldest in the study area (District Statistical Handbook, 2006, 2013). Climate related data like rainfall, temperature, relative humidity, etc. had been collected from the IMD.

Due to the fact that vegetation is primarily influenced by climate and soil, there is a positive association between the vegetation and the soil in a given area (Black, 1968).

The research region has dense vegetation, which is closely related to the type of slopes. The steep slopes in the north and north-west, such as Sukna and Panighata, are densely populated by simul, mixed sal, khair, siris, sissoo, and a big healthy bamboo forest. Smaller trees, such as the wild banana, are most numerous on moderate to gentle slopes, its crown of exquisite leaf contrasting with the small leaved plants among which it nestles. The screw pine, with a straight stem along with tuft of leaves each 3 or 3.5 m long, is located in the southern half of the research area, where the slope is gentle and soils can be easily rooted, as opposed to the area with steep slopes.

The main reasons for thick vegetation in the Terai area's low land are gentle slopes and good fertility. The bamboo plants cover the majority of the region. Twenty to thirty fern species are also found on the lower and upper terraces. The research area's plains are densely covered with weeds and grasses.

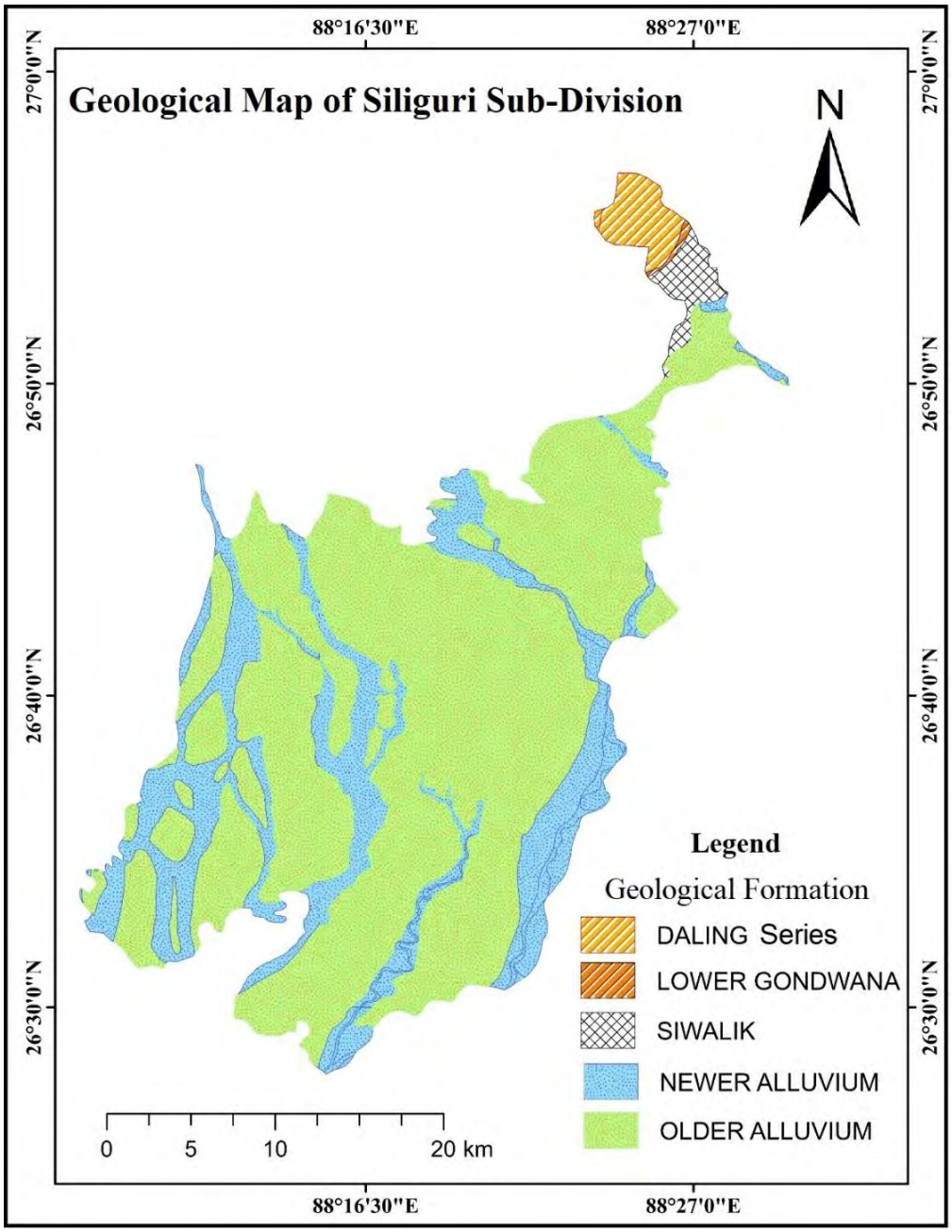
The physical environment, including the geology, drainage, relief, climate, soil, and vegetation, impacts, and other aspects of agriculture. They determine on the kinds of crops grown, when agricultural activities should take place, how much risk is involved, and how to improve agriculture. Numerous features of farming systems are influenced by social and economic considerations as well, yet they are constrained by the physical environment in how they can function. Thus, the physical and environment that appeared to be significant to the pattern of agricultural land use are discussed in this chapter.

1.3.1 Geology

Siliguri Sub-Division is a region characterized by a diverse and intriguing geological landscape. The geological history of Siliguri Sub-Division is a fascinating tale of ancient mountain-building processes, tectonic activities, and the deposition of sedimentary layers over millions of years. Siliguri Sub-Division is situated in the northern part of West Bengal, bordering the foothills of the mighty Himalayas. Geologically, the region lies in the Lesser Himalayan zone and is influenced by the tectonic activities associated with the collision between the Indian and Eurasian plates. The area is marked by complex geological structures and a diverse range of rock formations. The entire area exhibits traits of unusual variety both stratigraphically and petrographically. The region's geological history has resulted in the development of significant structural features. Faults, folds, and thrusts are common in Siliguri Sub-Division, indicating the intense tectonic forces that have influenced the area. The presence of these structural features

has contributed to the formation of the Lesser Himalayas and the surrounding landscapes, creating a breath-taking panorama of mountains, valleys, and ridges.

The Siwalik Group, a prominent geological formation in Siliguri Sub-Division, represents the sedimentary deposits formed during the Miocene and Pliocene epochs. These rocks consist of sandstones, conglomerates, and shale layers, which were deposited in ancient river systems and lake environments. Fossils have provided valuable insights into the region's paleontological history. The Siwaliks which are composed of hard, highly feldspathic sandstones, quartz pebbles, and schist, are the first group of rocks encountered as one travels north from the plains of more recent alluvial deposits. A continuous band of stratified and 16 unstratified gravel, boulder, sand, and clay deposits exists throughout the entire base of this Siwalik zone, constituting a sort of transition between the hills & the plains. The tertiaries are a band of rock that runs east-west from the river Mechi to the Lehti River and is found to the north. It disappears for nearly 64 km until reappearing near the buxa hills. A continuous thrust-fault separates the Siwaliks from the Gondwanas' (Permocarboniferous) limited east-west running strip. The Daling take over this belt's space to the north and east of the Diana River. The Daling series of rocks gives place to a much younger formation of the Buxas farther east. The Siwalik allows the Daling series of rock to encroach deeply into the plains of Bengal lowlands via a number of spurs and promontories. The fertile plains of Siliguri Sub-Division are characterized by extensive alluvial deposits. These deposits, composed of silt, sand, and clay, are the result of erosion and sedimentation processes carried out by the Teesta and Mahananda rivers over thousands of years. The alluvial plains are highly productive for agriculture, supporting the cultivation of rice, jute, tea, and various other crops. The geology of Siliguri Sub-Division is of immense significance in various aspects. It provides valuable insights into the region's geological evolution, tectonic processes, and paleontological history. The diverse rock formations and structural features make the area a geologically intriguing site for research and study. Additionally, the alluvial plains contribute to the agricultural productivity of the region, supporting the livelihoods of the local population.



Source: Geological Survey of India, Kolkata.

Figure 1.2 Geological Map of Siliguri Sub-Division.

1.3.2 Relief

The Siliguri Sub-Division is situated in the southern foot hill region of Darjeeling Himalaya. As the region is influenced by the mild alluvium and tall slopes of the lower Himalayas in the north. The majority of the study region is made up of unconsolidated rocks that were generated from the Himalayas and transported down by rivers that came down from these hills. The general slope of the study area is from north-east to south-west directions. By examining the cross-section, it can be observed that there are several

break of slope and variations at various heights, which point to a region where tectonic activity is taking place.

The study area is divided into three micro-divisions based on the slopes, contours, and cross sections, as well as the kind of erosion, the composition of the materials, and drainage characteristics:

A. Structural Hills

B. Piedmont Plains

C. Terai Plains

A. Structural Hills

A relatively small northern region of the study area, which is a part of the Siwalik formation, is generating hogbacks and cuestas with high relief, a rough character, and some structurally regulated drainage. The general height of the Siwalik is between 900m and 1100m above mean sea level. Significant features in this study area include scarp face, somewhat steep slope in the highest section of the hills, and headward erosion by the rivers in the Siwalik. The dip runs parallel to the topographical slope with a direction towards the southwest. As a result, the bottom portion of the hill has developed a flat terrain, and the higher portion of the hill is heavily divided by rivers and streams. The structural hill has dense vegetation.

B. Piedmont Plains

The Siwalik and the smaller Himalayas provided the raw ingredients for the long, sloping lands that extend from the hills towards the plains known as Piedmont lowlands. These gently sloping plains were created by the lateral coalescence of numerous distinct but interconnecting alluvial fans.

C. Terai Plains

It is located on the Piedmont Plain, slightly sloping in the direction of the south. The presence of a spring line, from which several springs emerge, clearly marks the intersection of the Terai plain with the Piedmont plain. The study area is largely covered by this plain. The usual height of this pain ranges between 40 to 120 metres above mean sea level.

1.3.3 Drainage Systems

Siliguri Sub-Division, located in the mesmerizing state of West Bengal, India, boasts not only a network of beautiful rivers but also a well-defined and intricate drainage system.

This system, consisting of rivers, canals, and water bodies, plays a crucial role in the region's ecological balance, agricultural productivity, and the overall well-being of its inhabitants.

Nestled in the foothills of the Eastern Himalayas, Siliguri Sub-Division is blessed with numerous rivers that flow through its picturesque landscape, making it a place of great natural beauty and significance. The rivers of Siliguri Sub-Division play a vital role in shaping the region's topography and providing a source of livelihood for the local communities. These rivers not only enhance the scenic beauty of the area but also contribute to the rich biodiversity that thrives in and around their banks. One of the prominent rivers in Siliguri Sub-Division is the mighty Teesta River. Originating from the glaciers of the Himalayas, it gracefully traverses through the lush green valleys, offering breath-taking views along its course. The Teesta River is not only a lifeline for the people residing in the region but also a popular destination for adventure enthusiasts who seek thrilling river rafting experiences.

Another notable river is the Mahananda River, which flows through the outskirts of Siliguri town. Originating from the Singalila Range, this river is known for its serene surroundings and is often considered a haven for nature lovers. The Mahananda River also acts as a natural boundary between the states of West Bengal and Bihar, adding to its significance. Apart from Teesta and Mahananda, there are several smaller rivers that enrich the beauty of Siliguri Sub-Division. The Balason River, and Mechi River are among the notable ones, each with its own unique charm and significance. These rivers not only provide a source of irrigation for agricultural activities but also support the region's diverse flora and fauna. The riverbanks serve as habitats for a variety of aquatic plants and animals, making Siliguri Sub-Division a hotspot for ecological enthusiasts and wildlife admirers. The rivers of Siliguri Sub-Division have also played a significant role in shaping the cultural and historical heritage of the region.

The rivers in Siliguri Sub-Division, such as the Mahananda, Teesta, Balason, and others, form the backbone of the drainage system. These rivers, originating from the Himalayas, meander through the landscape, carrying the runoff water from the hills and ensuring the smooth flow of excess water during monsoons. The rivers serve as channels for collecting and dispersing water, preventing waterlogging and maintaining a harmonious balance. The drainage system of Siliguri Sub-Division is essential for sustaining agricultural activities in the region. The rivers and canals serve as a reliable source of water for irrigation, enabling farmers to cultivate crops throughout the year.

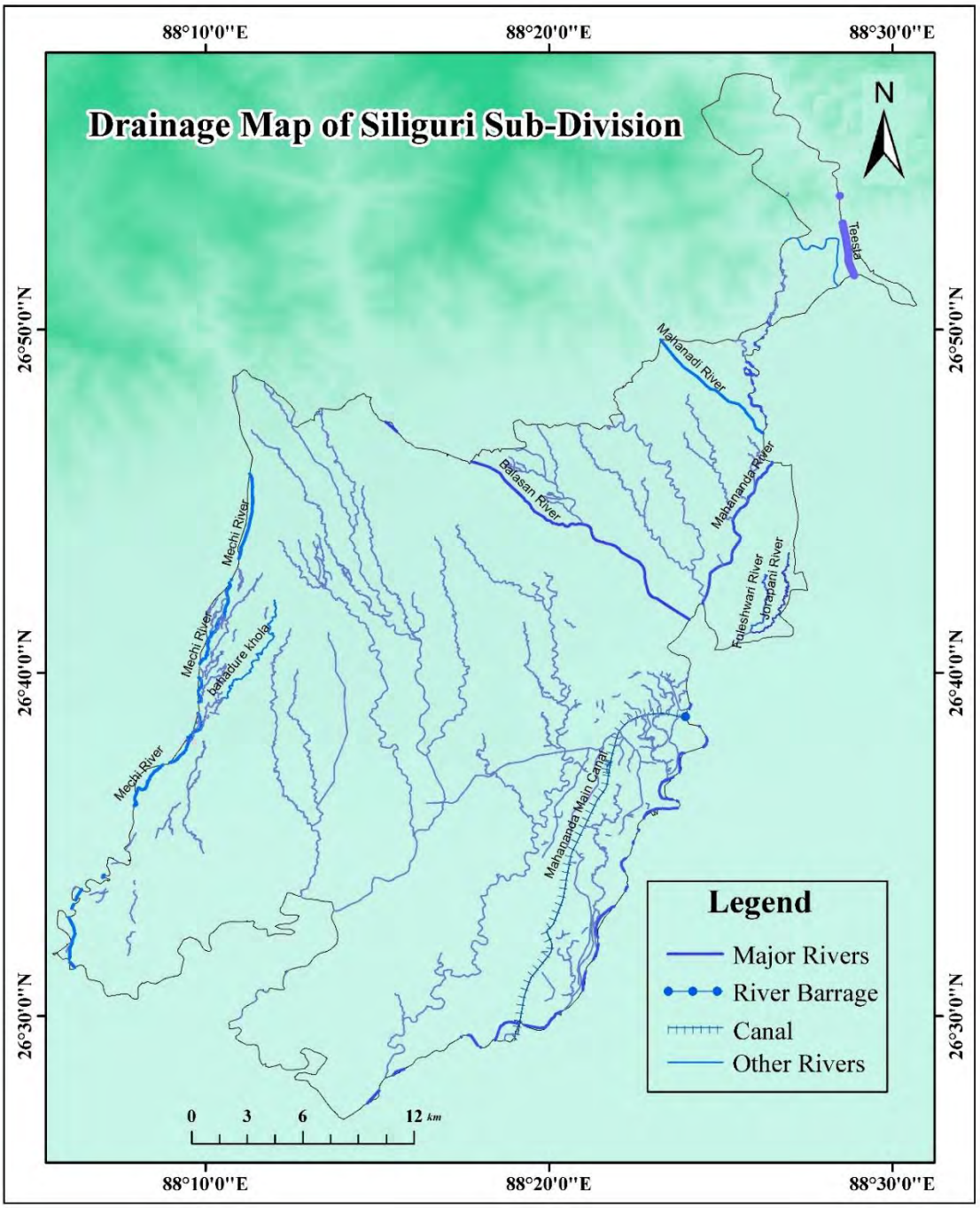
The controlled release of water through canals and irrigation channels ensures optimal moisture levels for the fields, enhancing agricultural productivity and supporting the region's economy. Apart from their functional significance, the rivers and water bodies in Siliguri Sub-Division hold immense cultural and recreational value. They are integral to the region's cultural practices, where religious ceremonies and festivals are often conducted on the banks of these rivers. Additionally, these water bodies provide opportunities for recreational activities like boating, fishing, and nature appreciation, attracting tourists and locals alike. The drainage system in Siliguri Sub-Division plays a crucial role in maintaining the ecological balance of the region. The rivers and their tributaries provide habitats for diverse flora and fauna, supporting the local ecosystem. The natural drainage channels help in the purification of water, filtering out pollutants and maintaining water quality. The conservation and protection of these water bodies are of paramount importance to preserve the biodiversity of the region.

1.3.3.1 The Mahananda River

The Mahananda River, which has its source in Mahaldiram located in the Darjeeling district at an elevation of 2060 metres, forms the eastern border of the study area. Its catchment area experiences heavy monsoon rainfall. The Mahananda runs south after debouching the hills until it reaches Siliguri, where it turns southwest and marks the border between the study area and Jalpaiguri district. It then flows into Bangladesh flow via Chapai Nawabganj District. Finally, the river empties into the Ganges. There are many tributaries, including the Trinai, Ronchandi, & Dauk.

1.3.3.2 The Balason River

Lepchajagat Hill on the Ghum is the source of the Balasan. Once it enters the plains with an altitude of 300 metres, the Simana flows south approximately parallel to the 88°15' E meridian before turning south-east and entering a valley that is larger than the Mahananda's. The Old Balasan and the New Balasan split off as it entered the plains and joined the Mahananda nearer to Siliguri. The mountain's foothills are covered in a variety of terraces. The new channel receives a sizable amount of water flow. The river has a lot of tributaries. To name a few, there are the Chenga, Manjwa Jhora, Manjwa Jhora, Rangbang Nala, and Dudhia Jhora.



Source: Based on Satellite imagery, Landsat 8

Figure 1.3 Drainage map of Siliguri Sub-Division.

1.3.3.3 The Mechi River

It originates at an elevation of 905 m south of the west-facing Rangbang spur in the Singalila range and runs through a deep gorge along the hilly course to form the border between Nepal and India. It enters the Bhabar tract, where its bed abruptly enlarges. Through the Lohagrah tea garden, the Mechi runs. The Ashi Jhora along with the Mana

Jhora join the Kiyang Khola, at left bank tributary of Mechi, at a height of 635 metres. In response to floods as well as other tectonic phenomena, it alters its route multiple times. The old and new Mechi flow in the same direction despite being several km apart. In terms of irrigation, the river is significant.

1.3.3.4 The Tista River

The Teesta River originates from the Tso Lhamo Lake in the Tibetan Plateau, located in south-western China. It then enters India through the state of Sikkim and flows through the northern parts of West Bengal, including Siliguri Sub-Division. The river eventually merges with the Brahmaputra River in Bangladesh. The Teesta River stretches for approximately 315 kilometers (196 miles) in length. It covers a vast drainage area, which includes the Himalayan region of Sikkim, parts of West Bengal, and a portion of Bangladesh. The total drainage area of the Teesta River is estimated to be around 12,159 square kilometers (4,700 square miles). As the Teesta River flows through Siliguri Sub-Division, it cuts through the stunning landscape of the Eastern Himalayas. The river's course takes it through deep gorges, steep valleys, and verdant forests, creating a breath-taking natural backdrop. The surrounding terrain is characterized by rolling hills, tea gardens, and agricultural fields, making it a picturesque region. The Teesta River is fed by numerous tributaries along its course. Some of the significant tributaries of the Teesta River include the Rangpo Chhu, Lachen Chhu, Lachung Chhu, Rangit River, and many others. These tributaries enhance the water volume and contribute to the overall flow and hydrological dynamics of the Teesta River. Several hydroelectric projects and barrages have been constructed along the Teesta River to harness its water resources for power generation and irrigation purposes. The Teesta Barrage, located near the India-Bangladesh border, is one such important infrastructure. These projects not only contribute to power generation but also help regulate water flow and manage water resources efficiently. The Teesta River plays a crucial role in supporting the livelihoods of the local communities in Siliguri Sub-Division. The river's waters are used for irrigation, supporting agriculture and the cultivation of crops such as rice, jute, and tea. Additionally, the river's hydroelectric projects contribute to the region's power supply and support the local economy.

1.3.4 Climate

Siliguri Sub-Division experiences a unique climatic pattern influenced by its geographical location. The region falls under the subtropical climate zone, characterized by distinct seasons and moderate temperatures throughout the year.

Summers (March to May): Summers in Siliguri Sub-Division are generally hot and humid. The average temperatures during this season range from 28°C (82°F) to 38°C (100°F). The region experiences relatively high humidity levels, making the weather feel even warmer. However, the proximity to the foothills of the Himalayas provides some respite from the intense heat, as the cool mountain breeze occasionally sweeps through the area.

Monsoons (June to September): The monsoon season brings abundant rainfall to Siliguri Sub-Division, as the region lies in the path of the southwest monsoon winds. The area receives heavy showers during this period, with the average annual rainfall ranging from 2,500 to 3,000 millimetres (98 to 118 inches). The monsoon season contributes significantly to the overall water resources of the region, supporting agriculture and maintaining the ecological balance.

Autumn (October to November): After the monsoon season, Siliguri Sub-Division experiences a transition period characterized by pleasant weather. Autumn brings relief from the rainfall, and the temperatures gradually start to drop. The days become clearer, and the humidity levels decrease, creating comfortable conditions for outdoor activities. Temperatures during this season range from 20°C (68°F) to 30°C (86°F).

Winters (December to February): Winters in Siliguri Sub-Division are mild and pleasant. The temperatures during this season range from 7°C (45°F) to 22°C (72°F). While the days remain sunny and pleasant, the nights can get chilly, especially in January and February. The region experiences relatively low humidity during winters, making it a popular time for tourists to visit.

Microclimatic Variation: Siliguri Sub-Division exhibits microclimatic variation due to its proximity to the Himalayas and the Terai region. The foothills of the Himalayas contribute to cooler temperatures and occasional foggy conditions, especially in the early morning hours. On the other hand, the Terai region, located to the south, experiences relatively higher temperatures and humidity levels. The northern parts of Siliguri receive more rainfall due to their proximity to the hills, resulting in a subtropical climate with higher humidity. In contrast, the southern parts, shielded by the mountains, experience

comparatively drier conditions and lower rainfall. This variation in precipitation leads to diverse vegetation patterns and agricultural practices within Siliguri.

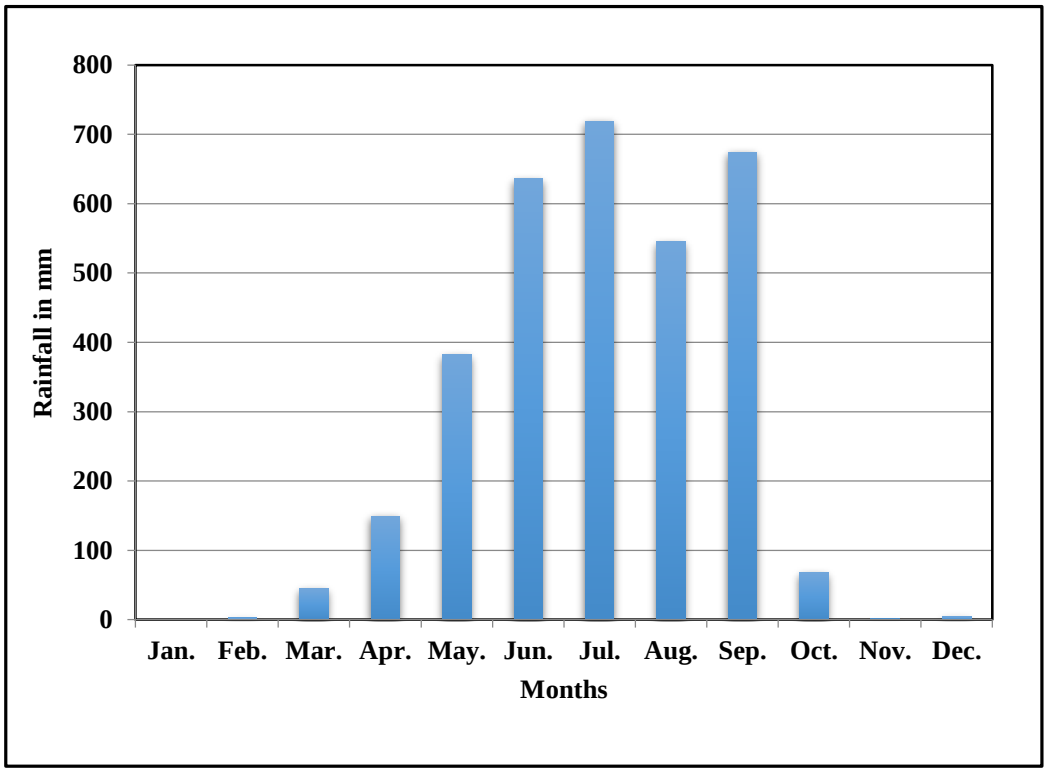
Siliguri Sub-Division enjoys a moderate climate with distinct seasons. The region's proximity to the Himalayas and the Terai region adds to its climatic diversity. The monsoon season brings ample rainfall, supporting agriculture, while the mild winters and pleasant autumns make the region an attractive destination for visitors throughout the year.

Table 1.1 Mean monthly rainfalls in Siliguri Sub-Division.

Months	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rainfall in mm	0.1	2.7	44.5	149	381	635	719	545	674	68	1.2	4.9

Source: India Meteorological Department, Kolkata.

A Bar-graph showing total rainfall of different months in a year in Siliguri Sub-Division



Source: IMD, Kolkata.

Figure 1.4 Month-wise rainfall (mm) in Siliguri Sub-Division.

1.3.5 Natural Vegetation

Siliguri Sub-Division, situated in the enchanting state of West Bengal, India, is blessed with a rich and varied natural vegetation cover. The region's unique geographical location, nestled between the foothills of the Himalayas and the fertile plains of the Terai, contributes to a diverse range of ecosystems and habitats. There is a significant relationship between vegetation and the soil in an area since vegetation primarily depends upon climate and soil. The research region has a dense vegetation cover, which is closely related to the type of slopes. Sukna, Panighata, and other locations with steep slopes to the north and north-west are heavily covered in simul, mixed sal, khair, siris, sissoo, and vast, flourishing bamboo forests. The main causes of the lush abundant vegetation in the Terai area's low terrain are the area's gentle gradual slopes and high fertility. The numerous bamboo bushes cover the majority of the land. Both the upper and lower terraces contain twenty to thirty different species of fern. Plains in the research area are heavily overgrown with weeds and grasses.

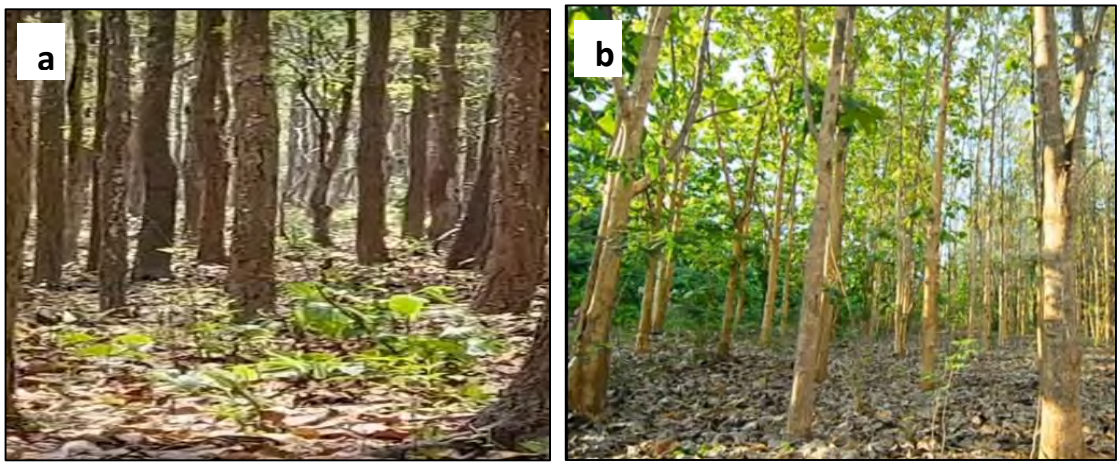


Plate 1.1 The presence of sal and teak forests in Siliguri Sub-Division suggests that the soil in the region is relatively fertile and well-drained. Sal and teak trees prefer loamy soils, which provide the necessary nutrients for their growth. These forests are often found in the Terai and Bhabar regions, which are characterized by fertile alluvial soils brought down by rivers from the Himalayas. a) Sal forest at Bengdubi b) Teak forest at Sukna.

1.3.5.1 Tropical Deciduous Forests

The lower altitudes of Siliguri Sub-Division are adorned with tropical deciduous forests. These forests are characterized by trees that shed their leaves during the dry season. Sal trees (Shorearobusta), teak (Tectonagrandis), and various species of bamboo are

prevalent in these forests. The deciduous forests provide habitat for a variety of wildlife, including elephants, deer, monkeys, and numerous bird species.

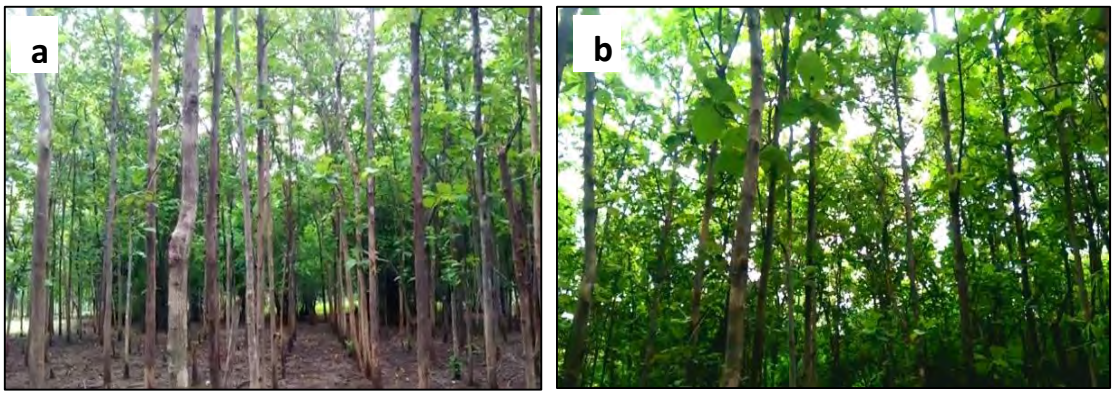


Plate 1.2 The tropical deciduous forest in Siliguri Subdivision is influenced by tropical monsoon climate, characterized by distinct wet and dry seasons. The forest receives abundant rainfall, promoting lush vegetation growth. In the dry season, the trees shed their leaves to conserve water. This shedding of leaves contributes to the nutrient-rich soil, enhancing its fertility. a) Sal forest in Tukhriajhar b) Teak Forest at Jogibhita.

1.3.5.2 Subtropical Broadleaf Evergreen Forests

As the elevation increases towards the foothills of the Himalayas, in Sukna area of Matigara Block, subtropical broadleaf evergreen forests dominate the landscape. These forests are characterized by dense vegetation, including a mix of broadleaf evergreen trees, such as oak (Quercus spp.), chestnut (Castanea spp.), and rhododendron (Rhododendron spp.). The sub-Himalayan tracts of Siliguri Sub-Division are particularly rich in these forests, supporting a diverse range of flora and fauna.

1.3.5.3 Tea Gardens

Siliguri Sub-Division is renowned for its vast tea gardens, which contribute significantly to the region's economy. The rolling hillsides are carpeted with lush green tea plantations, creating a scenic and productive landscape. The tea gardens primarily cultivate *Camellia sinensis*, the plant from which tea leaves are harvested. The cultivation of tea not only adds to the aesthetic beauty of the region but also provides employment opportunities and sustains the local economy. All the four blocks of Matigara, Phansidewa, Naxalbari and Kharibari Block has vast tea gardens. The soil of Siliguri Sub-Division is very suitable for growing Tea as this region is sandy and porous in nature and allows the water to easily percolate into the soil. So there is no water logging in this region except a swamp

in Bara Pathuram in southern region of Matigara Block due to the presence of Mahananda Barrage.

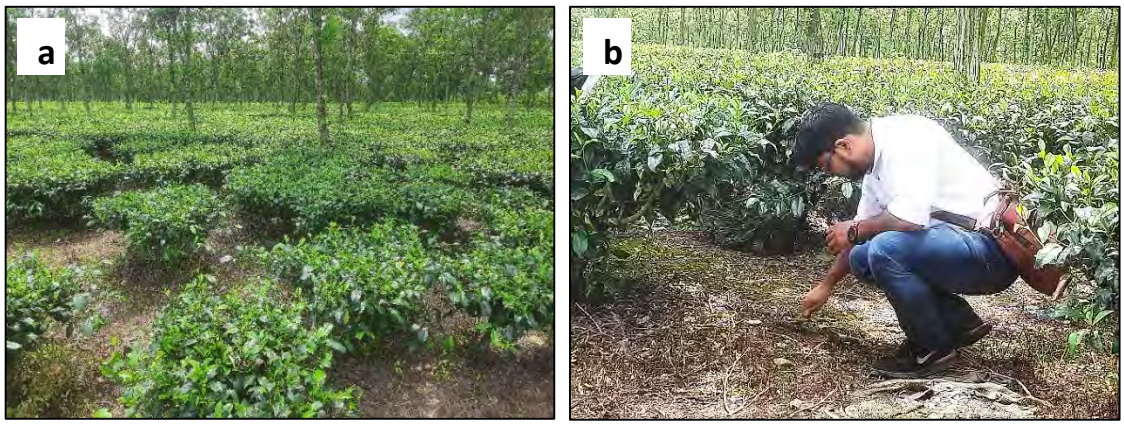


Plate 1.3 Tea plants thrive in well-draining, acidic and sandy loam soil with sufficient nutrients and organic matter suggesting that the region is rich in soil nutrients and the acid nature of soil suits for the luxuriant growth of tea plantation in Naxalbari block. The soils are being collected by the researcher for the laboratory testing and analysis of soil data for the purpose of research and agricultural growth of the region. a) Tea garden in Naxalbari. b) Researcher collecting soil sample.

1.3.5.4 Marshy area of Mahananda Barrage Reservoir

Siliguri Sub-Division is having a marshy area in the reservoir of Mahananda Barrage which support a unique assemblage of plant life. These ecosystems are characterized by water-tolerant species, such as reeds, grasses, sedges, and floating plants like water lilies. This marshy area plays a crucial role in maintaining the hydrological balance, filtering water, and providing habitats for several species of birds, amphibians, and other aquatic organisms.

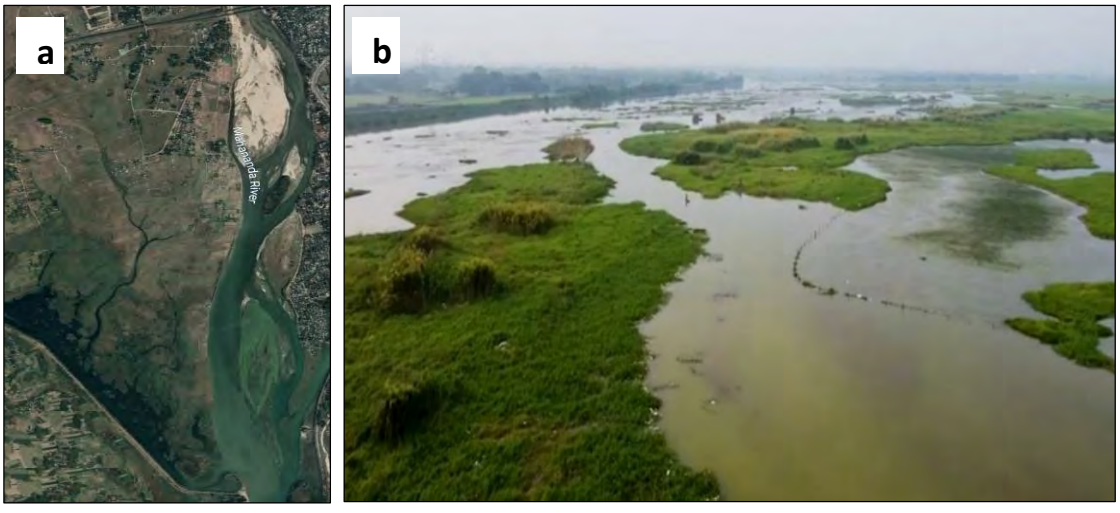


Plate 1.4 Mahananda Barrage Reservoir plays a very important role during the non-monsoon season as it supplies water to the agricultural fields of the Phansidewa Block for the irrigation purpose. a) Satellite image of the Mahananda Barrage reservoir Landsat 8. b) The real drone view of the same marshy area of Mahananda Barrage reservoir.

1.3.7 Land use and Land cover

Land use and land cover are two related concepts used in the field of geography and urban planning to describe the way land is utilized and the physical characteristics of the land surface.

Land use refers to the human activities or purposes for which land is used. Siliguri Sub-Division encompasses various categories such as residential, commercial, industrial, agricultural, recreational, and institutional land uses. Land use is influenced by social, economic, and environmental factors and reflects the decisions made by individuals, communities, and governments regarding the utilization of land resources. There is an urgent need for land use planning and zoning regulations in Siliguri Sub-Division to help manage and regulate the allocation of land for different purposes, ensuring optimal utilization and sustainable development.

Land cover, on the other hand, refers to the physical characteristics of the land surface as observed from above. It describes the natural or man-made features and materials that cover the land, such as forests, grasslands, croplands, water bodies, urban areas, barren land, and wetlands. Siliguri Sub-Division has a wide range of forest area and as well as croplands and barren lands. Land cover is typically classified into various categories based on its composition and physical characteristics. Remote sensing technologies, such as satellite imagery, are often used to assess and map land cover at regional and global scales. Understanding the agricultural geographical regions of the Terai region will benefit significantly from the study of the Siliguri Sub-Division's agricultural land use.

While land use focuses on human activities and purposes, land cover focuses on the physical characteristics of the land surface itself. These two concepts are closely related because land use decisions directly impact the physical characteristics of the land cover. For example, a piece of land designated for agriculture (land use) would typically have a land cover characterized by crops or cultivated fields. Understanding land use and land cover patterns is essential for land management, environmental planning, and policy development. It helps in assessing the impacts of human activities on the environment,

monitoring changes over time, and making informed decisions regarding sustainable land use and resource management.

1.3.7.1 Impact of soil properties on Land use and land cover

Soil properties play a significant role in determining land use and land cover patterns in Siliguri Sub-Division. The characteristics of soil in this area directly influence its suitability for different land uses and the types of vegetation that can thrive on it. Soil properties such as texture, fertility, moisture-holding capacity, and drainage influence the suitability of land for agriculture. The soil of Siliguri Sub-Division is loamy and fertile and supports good deal of agriculture. Soils with good fertility and adequate moisture-holding capacity are favourable for crop cultivation. Phansidewa Block and Naxalbari Block in Siliguri Sub-Division is very ideal for the cultivation of various types of crops. Different crops have specific soil requirements, and farmers consider soil properties when selecting the appropriate crops to grow. For example, well-drained soils are preferred for cultivating vegetables, Haribhita, Dhambhita, Dandrajhar, Bagulahagi, Bandar Gachh etc, regions are very good for the cultivation of vegetables. While water-retentive soils are suitable for paddy cultivation, the regions such as Bakshipara, Hakimpur, Bhajanpur, Rupandhigi, etc area are very rich in the cultivation of paddy.

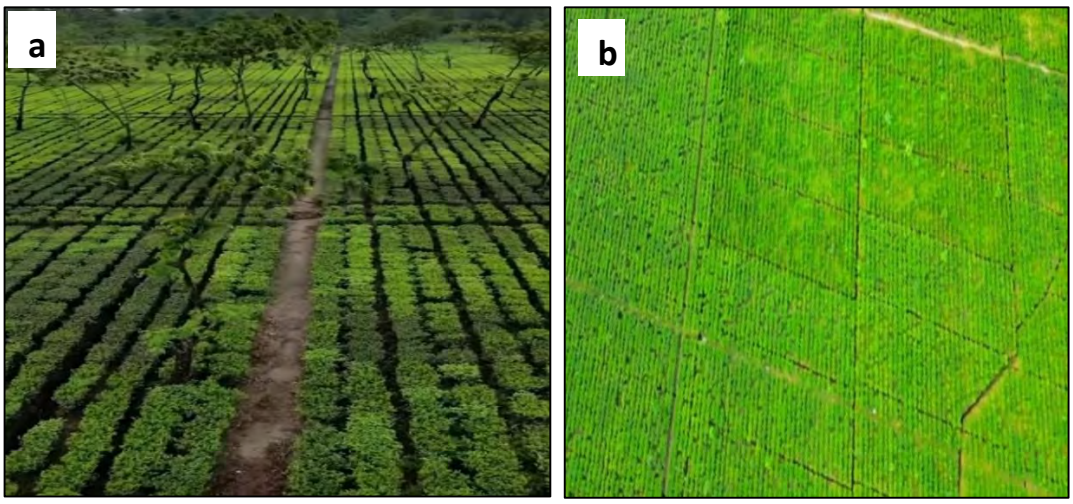


Plate 1.5 Patharghata GP has well drained soil with higher percentage of sand with mild sloppy topography that does not allow any water logging in the area therefore the soil and the topography supports the growth of large teagardens in this area. The drone view image of this region shows burgeon sprawl of vast teagardens. a) A tea garden at Patharghata. b) Drone view of Tea garden.

Sub-Division encompasses of well drained fertile soil very productive in tea plantation and pineapple cultivation. Siliguri Sub-Division comprises of large tea estates such as Sepoy Dhura Tea Garden, Mohorgon Tea Garden, Chamta Tea Garden, Putinbari Tea garden, Saptiguri Tea garden, Longview Tea Garden, Marionbari Tea Garden, Simulbari Tea Garden, Panighatta Tea garden, Manjha Tea Garden, Lohaghar Tea Garden, Azamabad Tea Estates, Bataik Tea Garden, Mishra Tea Garden, etc. Soil properties affect the growth and distribution of natural vegetation, including forests, grasslands, and shrublands. Soils with good water-holding capacity and nutrient content support the growth of diverse plant species. Siliguri Sub-Division has a luxuriant forest such as Sevoke Forest, Mahananda Wildlife Sanctuary, Dalkajhar Forest, Panta Pari forest, Tukraijhar Forest, Eco Park Ghoshpukur Forest, etc.

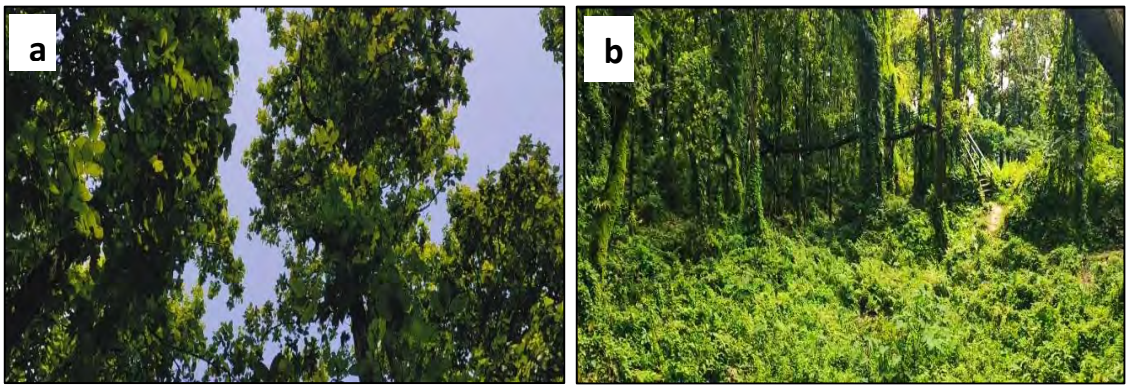


Plate 1.6 The eco-park forest of Ghoshpukur is situated in a distinctive biological environment. Well-drained and fertile soils sustain a vast variety of vegetation, offering a diverse home for species and fostering overall ecosystem stability. Understanding and protecting the natural characteristics of the soil is essential to maintaining the biodiversity and lush vegetation that make Ghoshpukur Eco-park a vibrant natural gem that both locals and tourists can enjoy. a) Eco-park forest of Ghoshpukur. b) Dense forest of Jogibhita.

Forests tend to flourish on deep, well-drained soils with high organic matter content. In contrast, arid regions with shallow and infertile soils may have sparse vegetation cover. Soil properties influence the suitability of land for urban development. Soils of Siliguri Sub-division has a good load-bearing capacity and stability are preferred for constructing buildings, roads, and other infrastructure, but it should be kept in mind that fertile soil suitable for agriculture should not be taken into consideration. Unsuitable soils, such as expansive clay or loose, unstable soils, may require extensive soil stabilization measures or may be avoided altogether for construction purposes. Certain

soil properties contribute to the formation of wetlands and marshy areas found in the summit area of Mahananda Barrage Reservoir. Soils with high water table levels and poor drainage often lead to waterlogged conditions, creating suitable habitats for wetland vegetation and wildlife. Wetland areas are crucial for biodiversity conservation and serve as valuable ecosystems for water purification, flood mitigation, and carbon sequestration. Soil properties can contribute to land degradation and desertification processes. Soil erosion, nutrient depletion, compaction, and salinization are examples of degradation processes that can impact land use and vegetation cover. Degraded soils may become unsuitable for agriculture or support only limited vegetation growth, leading to changes in land use patterns.

Plate 1.7 The cyclical nature of tea cultivation is what causes fallow land to appear in the tea gardens of Bhaktaram in the Naxalbari district. After a certain period of tea production, tea bushes may become less productive or susceptible to diseases, during this regeneration process, portions of the tea garden may be left fallow temporarily. Proper management and strategic planning are essential to minimize fallow land and ensure the sustainable productivity.

Understanding soil properties is essential for effective soil conservation and management practices. Soil testing and analysis help determine the soil's nutrient status, pH, and other characteristics, enabling farmers and land managers to make informed decisions about fertilization, irrigation, and land management practices. Implementing soil conservation measures, such as contour ploughing, terracing, and agroforestry, can help prevent soil erosion and maintain soil fertility.

1.3.7.2 Land use & land cover of Siliguri Sub-Division

The Siliguri subdivision exhibits a varied and dynamic pattern of land use and land cover. Being mostly an agricultural area, the terrain is dominated by vast farmlands that are used to grow products including tea, rice, and different fruits. Urbanisation has also resulted in the growth of residential and commercial districts, along with a corresponding increase in the number of infrastructures and industries. In addition, the area has natural features including marshes, woods, and bodies of water, which add to its ecological diversity. Siliguri subdivision's development and environmental protection must be balanced effectively to ensure sustainable growth and the preservation of the region's natural resources.

1.3.7.2.1 Land Use

Urban Areas: The urban area of Siliguri Subdivision presents a dynamic and vibrant landscape that embodies a convergence of modernity and cultural diversity. Siliguri, the major urban centre of the Sub-Division, is characterized by residential neighbourhoods, commercial zones, educational institutions, healthcare facilities, and government offices. It serves as a significant transportation hub, with railway stations, bus terminals, and other transportation infrastructure.

Plate 1.8 Rapid growth of population in Siliguri town led to the development of urbanization encroaching the land for the infrastructural development in the sub urban fringe. An over view of Matigara block depicting four lane roads and the infrastructural development of the nearby fallow land.

Residential Zones: The Sub-Division encompasses various residential areas, catering to different socioeconomic groups. These zones consist of traditional housing, apartment complexes, and gated communities, providing essential amenities for residents. The scattered small towns and villages all over the Sub-Division is symbolises that the city of Siliguri is growing and expanding at an abrupt rate. The nearby towns of Matigara, Shivmandir and Bagdogra is expanding very fast.

Plate 1.9 The strategic location of Siliguri as a major gateway to Northeast India and its economic opportunities have attracted a large influx of people seeking better prospects and livelihoods. As the population continues to surge, the demand for housing and infrastructure has escalated, leading to encroachment on open lands and green spaces. Unplanned urbanization and lack of effective land-use management have resulted in the encroachment of agricultural and forested areas, posing significant challenges to the city's environment and sustainable development.

Agricultural Land: The fertile alluvial plains along the Teesta and Mahananda rivers support agricultural activities. Farmers cultivate a variety of crops, including rice, tea, jute, fruits, and vegetables. Agriculture plays a crucial role in the livelihoods of many residents and contributes to the local economy. Tista-Mahananda link Canal serves the need of the whole of Siliguri Sub-Division. It not only provides water for the Siliguri town but also provide irrigation facilities for the agricultural purposes and also it is used to generate electricity from the canal.

Plate 1.10 The success of spinach cultivation in Phansidewa block indicates well-draining soils with a loamy or sandy texture this allows for adequate root aeration in one of the river deposited ox-bow lake of river Buri-Balason in the winter month of early December.

1.3.7.2.2 Land cover

Forests: Siliguri Sub-Division encompasses forested areas, mainly in the hilly regions. These forests consist of a variety of tree species, providing habitat for wildlife and contributing to the conservation of biodiversity. Some of the forest of Siliguri Sub-Division are as Sevoke Forest, Mahananda Wildlife Sanctuary, Dalkajhar Forest, Panta Pari forest, Tukraijhar Forest, etc.

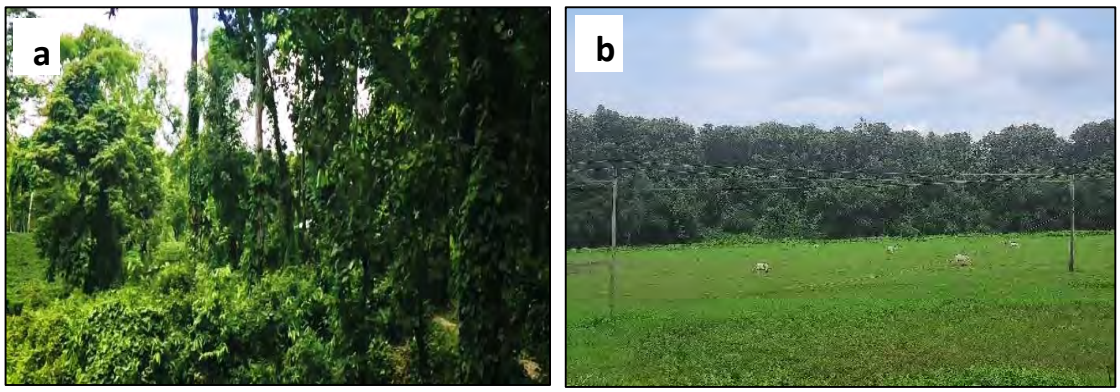


Plate 1.11 Subtropical climate characterized by mild winters and hot summers with moderate to heavy rainfall during the monsoon along with the mix of sandy loam and clay loam soils, which contribute to good water retention and nutrient availability for vegetation shows the growth of lush exuberant forest at Tukriajhar in Kharibari Block. A gazing low land adjacent to the forest depict the fecund growth of grass as a fodder for the cattle of this region. a) Dalkajhar Forest. b) Tukraijhar Forest.

Agricultural Land: The alluvial plains of Siliguri Sub-Division support agricultural land cover, including cultivated fields, paddy fields, tea gardens, and other agricultural practices. The two blocks of Naxalbari and Phansidewa is very active is agriculture and mostly all kinds of crops grow here and Aman Paddy is the dominant crop. Along with rice, maize, jute, wheat and different kinds of vegetables grow here.

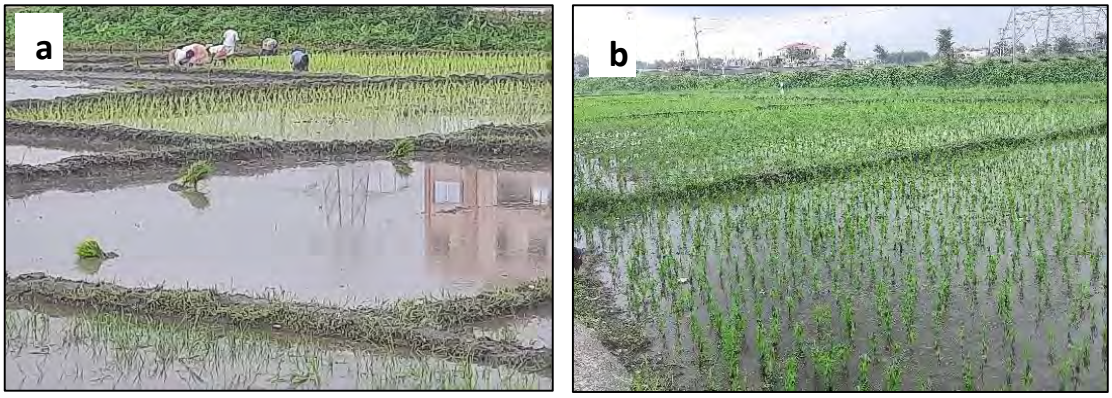


Plate 1.12 Fragmented land holdings led to the use of subsistence agriculture by the farmer in Phansidewa block. A farmer seen growing paddy by using traditional tools to plough and cultivate their land depicting the financial constraints and lack of scientific knowledge in the adoption of modern technologies. The occurrence of sufficient rainfall, presence of organic matter and soil nutrient helps in the stagnation of water in these agricultural field even though the soil is porous and sandy in nature. a) Fragmented land holding at Naxalbari b) Stagnation of water at Purba Bansgaon.

Water Bodies: The Sub-Division is traversed by the Teesta and Mahananda rivers, along with smaller water bodies such as streams and ponds, contributing to the land cover of water bodies.

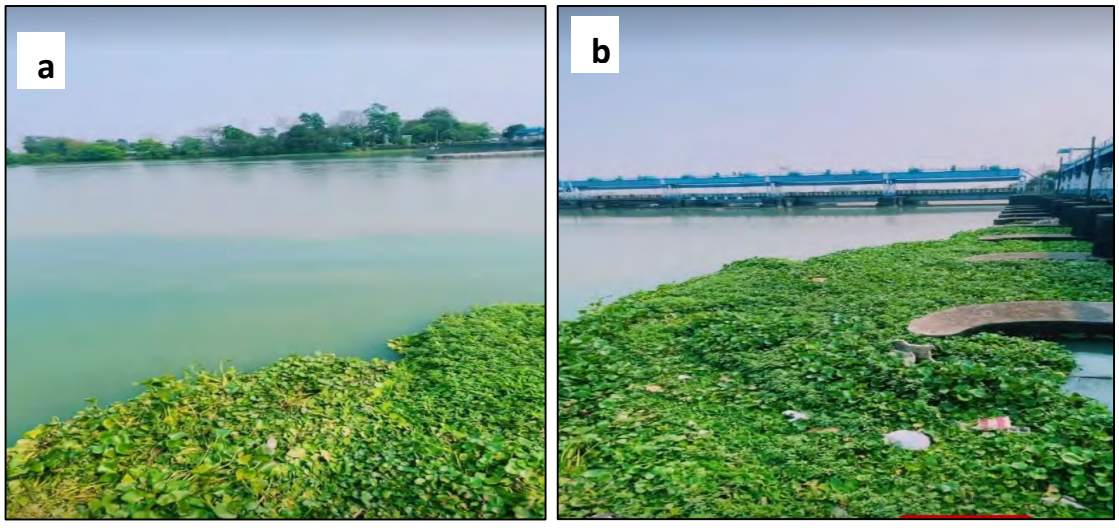


Plate 1.13 Mahananda Barrage reservoir plays a very crucial role in the progress of agriculture in the study area as well as providing safe drinking water for the people of Siliguri city. During the non-monsoon period this reservoir supplies water to the agricultural fields through canals which helps to meet the irrigation problems in the Phansidewa block. a) Reservoir of Mahananda Barrage b) Mahananda Barrage

Urban Areas: Urban land cover includes residential areas, commercial and industrial zones, transportation infrastructure, and built-up structures.

Barren Land and Open Spaces: Some areas in Siliguri Sub-Division may consist of barren land, open fields, or undeveloped spaces.

1.4 Statement of the Problem

Siliguri Sub-Division is located in the foot hill of the Sub-Himalayan belts of the Eastern Himalayas which have a complex geological structure, extensive network of rivers, rivulets, *jhoras*, undulating topography, superfluous luxuriant forest cover etc. which make it one of the most beautiful place not only in India but also all over the world. However, the beauty seems to be disrupted due to over exploitation as well as unscientific modification of natural resources and agricultural techniques. Unscientific way of agriculture, urbanization, haphazard construction work and unscientific bed material extraction, suction of water from river bed during non-monsoonal period, over use of chemical fertilizers, thus leading to an adverse effect on the quality of soil. The soil type is mostly sandy and subjugate under the process of leaching. As it gets heavy rainfall and the area has a moderate slope, thus, there is some soil loss due to surface runoff. The study area is situated at the foot hill of the Himalayan Mountain, and so the soil of the study area is composed of colluvium and the other alluvial fan material brought down by different natural agencies. The water holding capacity of soil is moderate to poor due to dominance of macro-pore spaces (Lahiri 1974). The soil is acidic in nature and its pH value ranging from 4.45 to 6.47 due to the effect of leaching. There is a considerable addition of humic acid due to decomposition of dried leaves from a large number of trees of deciduous forest especially *sal, teak, shimul, sishu*, etc during hot summer season. The variation in soil texture is one of the important controlling factor for different categories of different land use and land cover. Also the mineral content in the soil possess the acidic properties as the land is having a moderate slope, where alkaline material mostly gets washed away during the monsoon period, leaving the acidic component like oxides of

silica, iron, aluminium etc. in the soil (Sparks, 1999). Another important problem is that iron content in the soil in this region is very high, that is effecting the chlorophyll of the plants and trees even human habitation. At some places the iron content is so high that the water in the well and shallow tube well is not at all healthy for drinking.

These properties have a great influence on the land use and land cover of the study area. Load bearing capacity is very high, thus slumps or any kind of subsidence cannot be seen in the plains of this region (Lahiri 1974). In the hilly region along the river Tista some landslides can be seen due to presence of easily splitable metamorphic rocks like slate, phyllite, etc and heavy rainfall in the monsoon period which act as a lubricating agent. As the soil is porous and sandy and have a moderate to gentle slope, even in the monsoon season rain water do not remain stagnant and flows down to the south very rapidly. This geographical setup is in favour of wide spread tea plantation. The soil is porous and the region is mostly fed by monsoon rain, thus water does not retain in the soil for long time during summer months. Hence deciduous type of vegetation can be seen in this region. (Sarkar, 2010)

Since the last decade there are some changes took place in the field of agriculture in the study area. Some changes can be seen in the field of land use and land cover. Agricultural productivity has been decreasing day-by-day. Once there was a luxuriant pineapple cultivation done in the southern part of the Phansidewa Block in Bidhannagar region, but in recent times (2016-2020) the size of the pineapple has been reduced and even the farmer is facing low yield rate. Most of the cultivation in this region is done depending on monsoon rain and suffers good irrigation system. Siliguri Sub-Division is the fastest growing region in North Bengal. Its population rapidly increased and nearby land is brought into construction. In the beginning the major part of the study area was under the forest cover, but due to increase in population, the forest area is converted into tea plantation. But since last decade the change can be seen in the drastic manner. The places where used to be tea plantation now they are engulfed into the purpose of construction. The land of Chadmoni in Matigara Block is the best example. Also in Chamta, Patharghata, Dhukuria region, the tea gardens are vanishing and the places are transforming into human settlement. Some of the agricultural fields in the Phansidewa has been transformed into tea gardens. Absence of proper irrigation facilities also hamper the level of crop production during the summer months.

1.5 Aims and Objectives

1. To examine the soil properties and to correlate with the existing agricultural land use.
2. To assess the level of agricultural productivity with respect to its soil properties.
3. To examine the characteristics of the surface soil to enable the farmers for better land use planning with special reference to land capability of USDA.
4. To identify major problems in agricultural development of the study area.

1.6 Hypothesis

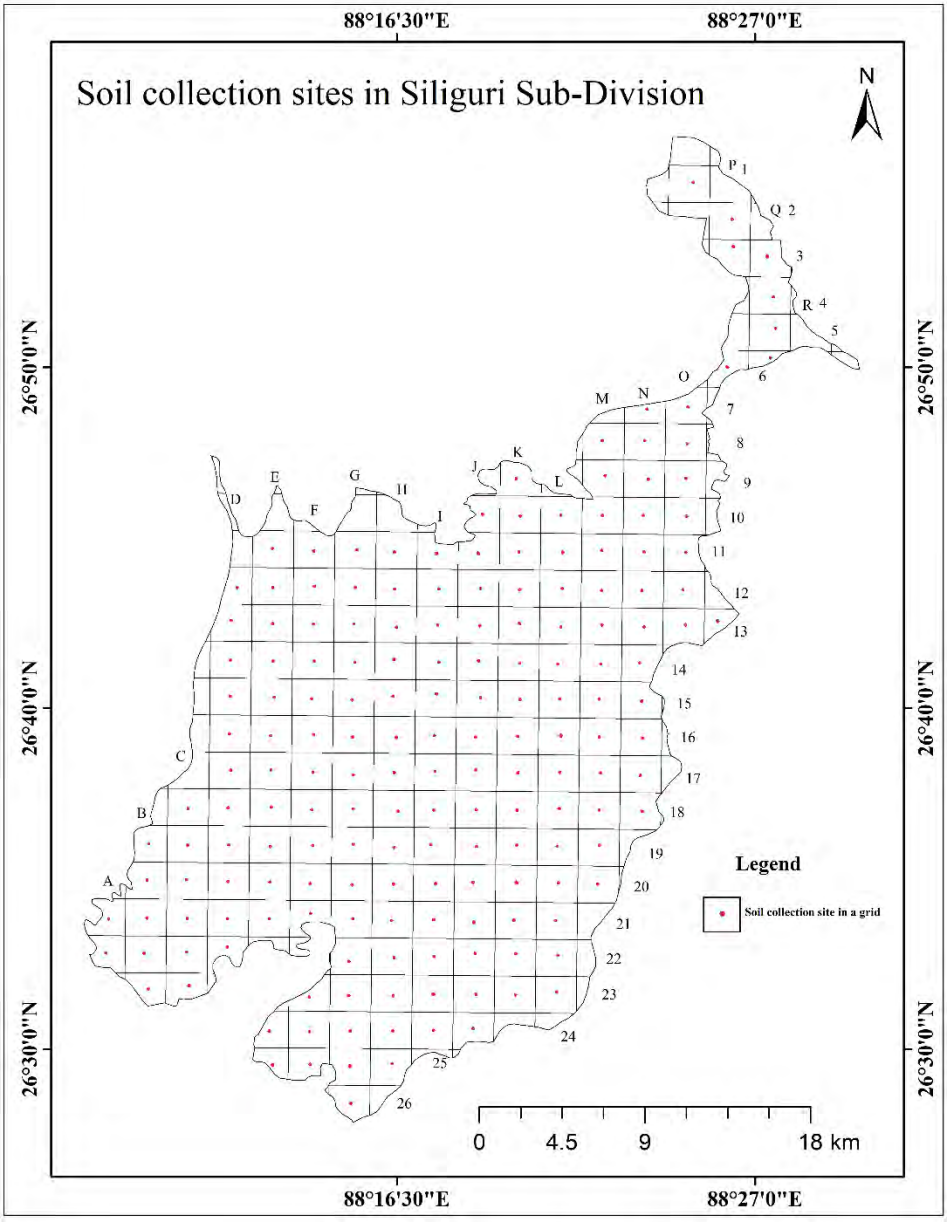
1. Existing land use is the reflection of soil properties.
2. Variation in productivity is the result of soil characteristics.
3. Land use planning and soil characteristics are interrelated.
4. Modern agricultural development is related to the perception of the farmers.

1.7 Methodology

In order to bring a reasonable outcome of the work with keeping in view certain parameter and circumstances, the following methods had been followed:

A pre-field study was carried out with consultation of literature, maps, data, research paper, articles, etc. Data and information have been collective through intensive field visit covering different season in a year. The secondary data have been collected from the various government offices. Data and other information was also collected by questionnaire and interview method in consultation with the farmers. Surface soil sample was collected approximately from the centre of each 2 km by 2 km grid. There were 180 soil samples collected covering the entire study area of Siliguri Sub-Division and land use in and around the site of collected sample were to be noted simultaneously.

Detailed study was conducted for the physical properties of soil. Soil texture by mechanical analysis (Robinson Method), was be done to know the particle size and the values have been incorporated in the USDA Triangulation chart to check the type of soil. It is related to water percolation, runoff of the soil and the development of roots. Soil density (Keen Raczkowski measurement) has been measured to check the compactness of soil, as highly compact soil reduces the growth of crops. Soil porosity was measured to know whether the soil is well-aerated or not. Water holding capacity has been done to check whether the soil is capable enough to hold enough water for the proper growth of crops, and soil colour by Munsell colour chart.



Source: Prepared by the researcher.

Figure 1.5 Soil collection sites in Siliguri sub-Division.

Soil pH has been checked with the help of soil pH metre. Soil pH is one of the most important soil characteristics that suggest us the types of crops that can be grown in that particular soil (Jackson, 1967). Another important characteristic that has been studied was NPK. The test was conducted done by the help of Kit Box analysis, NPK determines the growth, strength, and health of the plant. The achieved soil data has been compared to the existing land use and check which type of agriculture is best suitable for that particular soil.

Secondary data was gathered from numerous sources. The physical layout of the research region will be developed using relief maps, slope zone maps, soil maps, drainage maps, natural vegetation maps, and so on based on Survey of India Topographical sheets 78 B/1, 78 B/2, 78 B/3, and 78 B/5. 78 B/6 & 78 B/9. Other information about the research area will be evaluated and mapped using data from the Statistical Hand Book, Census Hand Book, District Gazetteer, and Government Publications.

Satellite imageries (LANDSAT 8) have been used for the preparation of land use and land cover maps using supervised (maximum likelihood method) classification technique to detect the land use types in ArcGIS 10.5 software. An intensive field survey was conducted throughout the research region utilising the Global Positioning System (GPS) prior to the formation of land use category classifications. This study was conducted to acquire accurate locational point data for every land use class included in the categorization method, as well as to create training sites and to generate signatures. An attempt has been made for accuracy assessment by taking help of Kappa Coefficient method.

Agricultural productivity was measured as the ratio of agricultural outputs to agricultural inputs. For this purpose, productivity index of individual crop per unit area has been calculated by following the technique proposed by M. Shafi (1984). According to Shafi's method, the total yield of all the crops in a gram panchayat is added together and divided by the total area confined to the same crops in that gram panchayat. The position thus obtained is then compared to the total yield of all the crops taken into consideration at the Sub-Division level and combined with the total area devoted to those crops at the Sub-Division level.

Perception of the farmer in the adoption of the modern agricultural technology had been calculated with the help of Kendall’s w coefficient. It was done by interviewing the farmer on a random basis 40 farmers from each block and by grading the perception of the farmer on the basis of rank 1 to 5. Rank 1 is highly acceptable by the farmer whereas rank 5 is disregarded by the farmer. All the data are incorporated in the Microsoft Excel software and then with the help of SPSS software the calculations are done.

USDA Land Capability classification has been done. Both primary and secondary data was used to calculate Land Capability Index. Primary data on components such as rainfall, soil fertility, irrigation capacity, soil erosion, water logging, and forest density were collected. Drought and flooding information was derived from maps or gathered through field studies and oral interviews. Secondary data sources include unpublished

theses, novels, census data, as well as remote sensing data. Ms-Excel and ArcGis10.5 were used for the computations. It was used for mapping and visualization.

The Land Capability Index was used to calculate the capability of the land and also by judging all the parameters of soil land capability classification was done. The United States Department of Agriculture's (USDA) Soil Conservation Service (SCS) pioneered land capability classification (Klingbiel & Montgomery, 1961). According to that, land capability is roughly grouped into two classes based on the land's constraints. 'Group 1 Lands' refers to the first group, which includes all cultivable lands. 'Category 2 Lands' refers to the remaining category, which includes all lands that are unsuited for cultivation. These two groupings are further subdivided into four classes. Thus, 'Group 1 Lands' consists of cultivable 'Land Classes I to IV' while 'Group 2 Lands' consists of non-cultivable 'Land Classes V to VIII'. The researcher will study the parameters and judge the limitations of the soil and decide which soil will fall under which class group. The Land Capability of UK method is basically modified form of the USDA method. Therefore, the USDA method of Land Capability was followed in the present study.

Soil productivity is directly related with soil fertility. It is quantified in terms of inputs vs. outputs, which in agronomic contexts relates to water and fertiliser input versus crop yield. In order to find the effect of soil properties on agricultural land use the existing land use categories of the soil sample site has been noted (including photograph as field evidence). Finally, the output of the study was presented with the help of an appropriate cartographic technique.

1.8 Scope and Purpose

1. To help the farmers to grow suitable crops according to the soil fertility.
2. To help the farmers to introduce an appropriate amount of fertilizers to their fields.
3. It will help the farmers to earn maximum profit from their agricultural land.

1.9 Literature Review

O'Malley's (1907) contribution is immeasurable. He is found to be the most resourceful person to provide information about the study area. Bengal District Gazetteer of Darjeeling District provides enormous information about soil, agriculture, forest and land use. This book enriches us with information that the northern part of the study area, that is, the Terai region of the Darjeeling District was once covered with dense malarious forest but the scenario is very different. The luxuriant forest is reduced to transform the

place with tea gardens. His research on Darjeeling District helped a lot to understand the study area properly. He has also provided information about the historical background of the study area. This will help the researcher to understand the place properly and correlate the past with the present. (Bagchi & Mukherjee, 1983) state about the soil type and condition. According to them the foot hill region of the study area is subjected to drastically leached typical gravelly grey podzols cover most of the area where there is accumulation of iron, aluminium, as well as silicate clays at the lower level with total or practically absent of $CaCO_3$ in the solum. There observation says that the soil of the surrounding areas of Siliguri is generally composed of Bhabar and is azonal type of soil which comprises of low percentage of organic carbon (0.61%). The productivity rating is around 4, with heavy percolation and leaching. Where as in the southern part of the study area the productivity level goes up in the finer soil of the peripheral zone. Over all the net soil productivity is of moderate levels of 22 and 21 respectively. (Chatterjee, 1970) classified the soil of the study area under the Terai soil group. He said that the Terai soil is highly porous and well drained. Water logging condition develop only during the wet season when the rainfall amount is greater than the percolation and infiltration. His study suggests that the soil of the Terai region is characterised by low clay percentage and high acidity. (Bose, 1968) has equipped us with valuable information about the soil and vegetation cover of the sub Himalayan foot hill region. He said that these areas comprise of tropical mixed evergreen forest. Much of the forest is moist deciduous and here *sal* is the most common and valuable tree. The soil of the forest is naturally rich with humus. Along the river beds and channel bars the soils are found to be sterile sand and pebbles.

(Brady, 2001) gives a brief definition of soil and it's characteristic. It provides us information about the importance upon the evolution of modern concept and differentiated from the primitive concept, which would be very instinctive in understanding the proper meaning of soil and categorizing the soil into various classifications. It would help us to comprehend the different soil profile and further it will befall an exemplar during soil swatch collection. The importance of sand, silt and clay in the soil depict the nature of soil and help us to reckon. (Karmakar, 2011) had given some basic idea about the soil of North Bengal in his book A Geographical outline of North Bengal. According to him the soil of North Bengal is directly affected by the Himalayan Mountain. The rivers fluxing from the mountain erode the rocks and deposit the soil in the foot hill of the Himalayas that is the study area. He also portrayed the

relationship of soil with climate and vegetation. (Stamp, 1948) and his volume summarizes the work and findings of that field-to-field survey, carried out mainly in 1931 to 1934. A description of the record made by the Survey and the general pattern of land use is followed by chapters dealing separately with the distributions of permanent grass, arable land, orchards, market gardens, moorland, healthy land, rough grazing, forest, woodland, and settlements. The four different blocks of the study area may encompass the regional variability in soil. Stamp in his book brought about the procedure of field survey that is very helpful in the accomplishment of the thesis. (Foth, 1984) stated about the land use pattern evolved due to different types of soil. Multifarious types of soil can be seen in the study area which embroils in the various land use pattern. Land use is a very important aspect of soil. Soil that is suitable for agriculture must not be used for construction purpose. It helps the researcher to suggest the proper soil utilization. The researcher can fathom the change in the land use pattern; this change will help him to perceive knowledge about the effect of urbanization on the soil. According to Foth in his book, he has explained the different stages of soil development, and have recognized the five stages. He also said that soil development is having a direct relation with climate. He has mentioned about the role of precipitation, climate change and soil properties. This helped the researcher to understand the various stages of soil development and would help in the study of soil development. (Hudson, 1971) stated that vegetation and rivers play an important role in the soil dynamics. According of them the presence of water and the flow of river causes the regeneration of the land use pattern. The study area forebear extensive rainfall and possess numerous rivers flowing down from the mountains of Himalayas. The researcher tries to correlate the soil with the rainfall and the multifarious rivers that is present in the study area. According to the researcher the soil of the study area may subjugate because of the presence of rivers and the nature of rainfall. Some regions of the study area are under deforestation leading to the serious effect on the soil. He laid stress on the rainfall as an important factor responsible in soil dynamics. (Morgan, 1995), stated about causes and the effect of soil erosion. The need of conservation is very essential, hence to protect the study area from soil erosion, conservation is needed. Morgan in his book gave an outline sketch of suitable soil conservation based on soil erosion. So the researcher can induce the suitable procedure of soil conservation in the study area to protect the land. (Arakeri, 1984) also gave an account on the conservation of soil as a necessity for the mankind. So soil conservation has a monumental importance for both land use and land cover. (Retallack, 2001) proclaimed that there is a various use

of soil. The meaning and importance of soil varies from person to person. According to him the soil has a different importance to a farmer than the same soil to an engineer. He explained the concept of *soilscape* in his book namely “Soils of the Past”. He said that the vegetation cover is very important for the regeneration of soil. It would help the researcher to understand and differentiate the soil characteristics of the places within vegetation cover and the soil characteristics of those places that are not under vegetation cover. In the words of (Joffe, 1953) plants, water and fertilizers play an important role in the soil of the agricultural field. The characteristics of the soil can be altered by the introduction of fertilizers by the farmers. (Havlin, 2007) stated that the artificial fertilizers can hamper the growth and development of the soil. Modern day farming and irrigation involve the use of artificial fertilizers for better production of the crops. But this process of ignorance can cause a serious land degradation and permanent loss of soil fertility. An enormous portion of the study area is under vegetation cover, mostly forest cover and tea plantation. In the words of (Black, 1968), there is a direct foremost relationship between the soil and plant cover. Plant cover help the soil to regain its soil fertility, it also helps to restore the soil nutrients. Some portion of the study area has well fertile soil and the plants and crops grow well but there are many places where the soil fertility is very poor. In the historical past the soil was fertile but in due course of time the soil lost its fertility, the organic matter present in the soil may be very low, so the productivity is also very low. This would coerce the researcher to test the soil and rummage the possible cause.

In his book "Systematic Agricultural Geography," Husain, M., stated that Agricultural Geography emphasises the description, interpretation, as well as explanation of spatial variations in land use, cropping patterns, crop concentration and productivity, agricultural regionalization, along with regional disparities in agricultural productivity, with the goal of formulating strategies for agricultural planning and development. Agricultural Geography also includes models and ideas of agricultural land use, which serve as a solid theoretical foundation.

In their article titled "Changes in Cropping Pattern in Madhya Pradesh," Mishra, R.P., and Shukla, S., examined the changes in land usage and related cropping patterns between 1956 and 2001. In Madhya Pradesh, significant changes in agricultural patterns and land use have been seen. The amount of uncultivated and arid land has greatly decreased. Food grains no longer make up the majority of the gross planted area. These adjustments are crucial since even a small shift in this area could have a significant impact on the socioeconomic situation in a given area.

In his work "Agricultural land use in India: a case study," Mohammad, N., made an effort to research the agricultural land usage in Ghaghara-Rapti Doab using local surveys in the chosen villages. He made an effort to explain how agricultural land is used in the seven villages of Ghaghara-Rapti Doab that were chosen.

In his study titled "Spatio-temporal Change of Crop Diversification in Murshidabad District, W.B.," Pal, S., examined the relationship between the choice of cropping system and physical and technological parameters. Understanding the changing structural pattern of crops for an area depends critically on the temporal and spatial structure of agricultural diversification. Crop diversification is crucial for an in-depth knowledge of agricultural planning programmes, and agricultural regionalization at the meso and micro levels is essential. As a result, the author made an effort to research how crop diversification changed between 2002–2003 and 2004–2005 in the Murshidabad District, whereas more than 80% of the whole population is employed in agriculture.

Sen, S., examined the spatial and temporal variation in agricultural production and regionalization in the 31 blocks of the Barddhaman District between 1996 and 2007 in his paper titled "Spatio-temporal variations of agricultural and its regionalization tends within Barddhaman District, West Bengal." The method of crop combination depicts the assortment of different crops cultivated in a same location. Crop diversification denotes the transition from monoculture to polyculture, from subsistence to commercial farming, and from low value to high value crops. Understanding the driving force behind agricultural land use change is made possible by agricultural production and efficiency.

In their article titled "Agricultural land use pattern in Solapur District of Maharashtra," Todkari, G.U., Suryawanshi, and et al. analysed the agricultural land use pattern at the micro level in Solapur district using secondary data. Here, an effort is made to research the crop combination areas within this district for the 2004–2005 growing season. Weaver's method of crop combination was used to compute the crop data. In this district, the pattern of agricultural land use is influenced by physiography, temperature, rainfall, soil, and drainage.

Vishwakarma, D.D., emphasises on the size of holdings and caste structure as the predictor of inter and intra-community variance in agricultural land use in his work, "Inter and Intra-community Variation in Agricultural Land Use in Chhindwara District, M.P." The ability of mankind to treat and manage the land determines how much of it can be used for agriculture. The amount of holdings and the actual investment have a

clear correlation with agricultural development measures, albeit agricultural land use differs by community. The relationship between agricultural inputs, productivity, land usage, and population change in South Australia is examined by Uyanga (1978). Uyanga concluded that there is a link between relative production and farm depopulation. In order to create soil and land evaluation maps for Scottish landuse management and planning, Davidson et al. (1986) investigated a land resource information system. The land resource database was created using a variety of sources, including available satellite imagery, maps, data from the field, census, air photographs, and statistical sources. In an article that was published in 1994, Nguyen-Huu-chiem presented the Mekong delta's current and historical cropping patterns. He conducted research on the agricultural landuse & cropping patterns in relation to the water availability, landforms, soil, and conventional rice farming techniques.

In-depth research on "Modelling of landuse through Land Information System (LIS) to village level in Albania" has been produced by (Tafaj et al. 2011). By utilising GIS technologies and a land information database, they concentrated on the changes in landuse from 1991 to 2009. They came to the conclusion that a decision support system built on a GIS would be a useful tool for all stages of the landuse planning process. Additionally, it has been determined that Albania's agricultural land use has decreased as a result of urbanisation during the study period. In Bikaner, which is prone to drought, (Malhotra et al. 1976) conducted a thorough study on land use and agricultural conditions. They came to the conclusion that the landuse pattern is subpar and that land use, cultivation, land holding size, and the growth pattern of major crops were the natural constraints on the development of agriculture. Doon Valley and Application of GIS RS in the Study of "Population Growth and Its Impact on Landuse in Part of Western" is an all-encompassing project work developed by Jha in (1999). He tracked changes in land use and land cover using the Arcinfo GIS programmes ILWIS and ERDAS Imagine. He came to the conclusion that the main causes of the decline in landuse as well as land cover are population growth, the exploitation of the environment, and agricultural practises. The landuse status of the Ashwani Khad watershed was studied by Mahajan et al. (2005) using IRS I-D, LISS III FCC satellite data, and GIS tools.

They noticed that the primary influencing elements of the agricultural region are height and slope. They came to the conclusion that mid-latitudes, mid-slopes, and irrigation systems are advantageous for expanding agricultural area. Shamsudheen et al. (2005) conducted a study on "Landuse and land cover modelling in the coastal area of

North Karnataka" using remote sensing data. They used stratified sampling techniques, the IRS-ID, LISS III pictures, and 8 supervised maximum likelihood approaches. The characteristics of the landuse changes include physiographic units including pediments, river coastal alluvial plains, and alluvial plains.In a research-based book published in 2010, Suryawanshi used GIS techniques to explore the crucial elements of tribal agriculture landuse & the regionalization of different crops in Nandurbar district, Maharashtra. Landuse, agricultural landuse/land cover, general changes, and agricultural landuse were therefore investigated in diverse ways and at varied depths.

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