



From Rock to River: Exploring the Various Geo-diversity Elements of Kangsabati River Basin

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Abstract:

The Kangsabati River Basin, located in eastern India, is a dynamic landscape that exhibits a rich geo-diversity, shaping both natural systems and human activities. The present study investigates the geological, geo-morphological, and hydrological characteristics of the region. Through an interdisciplinary approach combining remote sensing, GIS, field surveys, and historical data, the research delves into the geological formations, soil profiles, mineral resources, fluvial systems, and landforms that define the basin. The thematic maps have been prepared such as Geology, Slope analysis, soil, Drainage Density, stream Ordering, Contour, Climate, Land use/land cover (LULC), and Agricultural change detection map using GIS software. Additionally, the study explores the anthropogenic impacts on the river basin, including land use changes, mining activities, and water extraction. By understanding the intricate linkages between geology and the river system, this research provides insights for better conservation, land use planning, and resource management within the region. This exploration not only underscores the geo-diversity of the Kangsabati River Basin but also presents a framework for analyzing similar river basins in the context of environmental management and regional development.

Keywords: *Geodiversity, Land use Land cover, GIS, Kangsabati River Basin.*

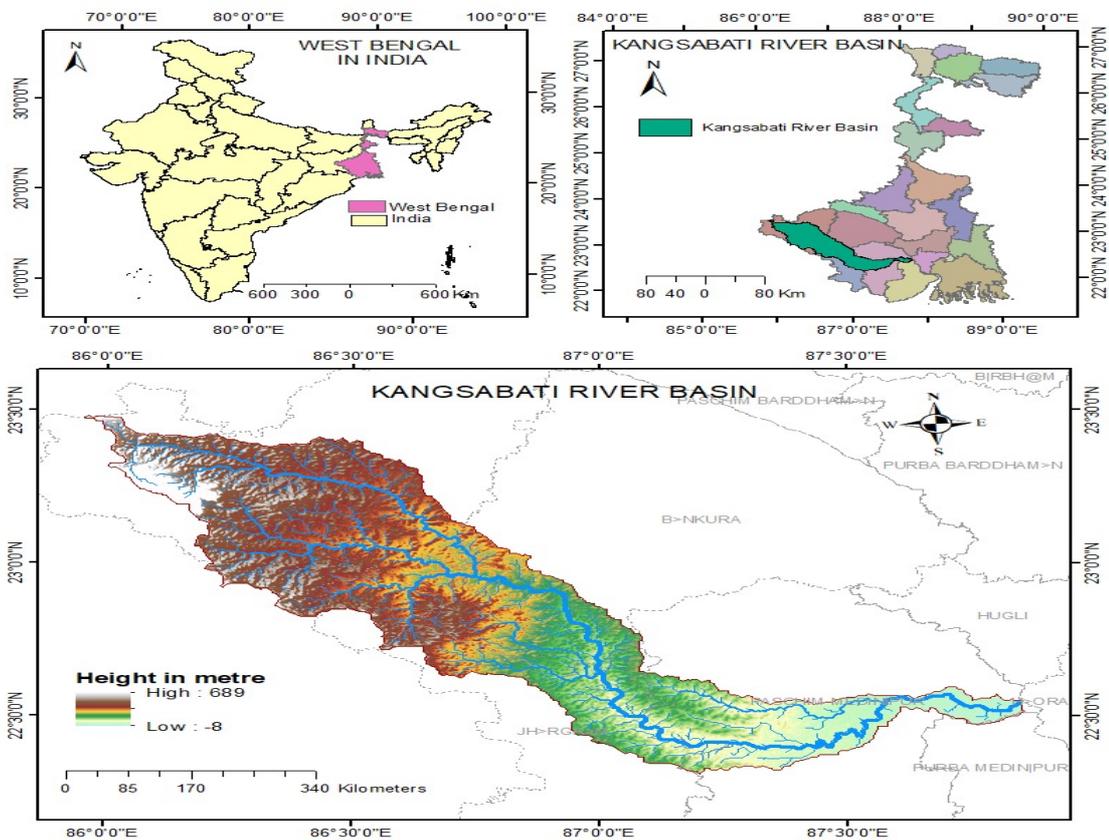
Introduction:

Landscape denotes the description of EARTH'S natural geomorphic features such as mountains, hills, water bodies (rivers, lakes, and streams), sea and biotic features like vegetation and man-made formations such as houses, architecture and also the transitory elements such as weather conditions etc. The major components of geo-diversity are geosite, geo-heritage elements, geo-diversity site & geo-diversity elements. Geo-diversity refers to mineralogical diversity or petrographic diversity (bedrock geology; superficial geology; fossil evidence ;), paleontological diversity (earth history; evolution ;), structural tectonic diversity (continental evolution; structural history; regional and local features), geo-morphological and pedological diversity (geological inheritance; landform history; soil patterns; landscape sensitivity to change). The term "geo-diversity" first appeared in the work carried out in Tasmania by Sharples (1993), Kiernan (1996, 1997), and Dixon (1995). Gray (2004). The concept of geo-diversity succeeds that of biodiversity, which

became widespread after the signing of the Convention on Biological Diversity at the Earth Summit held in Rio de Janeiro in 1992 (Serrano and Ruiz-Flaño 2007). The present importance of geo-diversity stems from renewed interest in the conservation of abiotic elements of the natural environment over the last two decades (Bruschi 2007; Hjort and Luoto 2010). Today, there is a revived interest in geo-diversity and the conservation of the abiotic environment that is generally based around the concepts of geological heritage and geo-morphological heritage. The term “geo-diversity” “first appeared in the work carried out in Tasmania by Sharples (1993), Kiernan (1996, 1997), and Dixon (1995). Gray (2004) defines geo-diversity as “the natural range (diversity) of geological (rocks, minerals, fossils), geomorphologic (land form, processes) and soil features. It includes their assemblages, relationships, properties, interpretation and systems”. More recent definitions of geo-diversity, such as the definition proposed by Serrano and Ruiz-Flaño (2007), include forms resulting from anthropogenic processes and also topography and elements of the hydrosphere. After 20 years of discussion and refinements, the term geo-diversity is currently considered to be the expression of the assemblage of aspects related to the abiotic environment, which include the litho logical, stratigraphic, mineralogical and tectonic characteristics of an area, as well as its geo-morphological, pedagogical and paleontological characteristics”.

The river Kangsabati is a lifeline for the area it across. It is of significant geological, ecological, social, cultural, and economic importance. The river cuddles up the heart of South Bengal and flows over the districts Purulia, Bankura, Jhargram, Paschim Medinipur, and Purba Medinipur. The meandering of this river not only serves its vast ecological components and wildlife, but it also plays a pivotal role in daily life. This river is substantiated by tradition and the history of centuries. It witnessed the molding of changes in residents of its bank. This healthy river basin provides a wide range of natural resources, flora, and fauna. These elements are essential for social and economic purposes. Nowadays the river is facing issues with climate variation, overuse of groundwater, disorganized agricultural practices, building settlements on river banks, and sand mining.

The River Kangsabati is an important river in the state of West Bengal in India. It enriched some districts with its variety of Geo-diversity elements. The river originates in Jabourbon (Jabor) hill the eastern part of Chotonagpur pleatue and flows in the east-south direction in Purulia district. It flows through Puruliya, Bankura, Jhargram, Paschim Medinipur, and Purba Medinipur. The river is more or less 432km long and serves as a vital source of water on agricultural lands, settlements, and the industrial belt of Pachim Medinipur. The river are formed by the convergence of small rivers, Saharjhor and Girgiri, near the city Jhalda. After that it flows over Purulia, Khatra and Ranibandh town. It meets with Bhairabanki River at Binpur. In downstream it splits in two branches, the northern named as Palashpai Canal and meets with Rupnarayan River where the southern branch flows as Kangsabati and meet with Keleghai river. Based on the above discussion, present study aims to provide a comprehensive understanding of the geodiversity of the Kangsabati River Basin and its implications for natural resource management, biodiversity conservation, and sustainable development.



Study Area Description:

Kangsabati river basin is a part of Chhotonagpur plateau, located in the eastern part of India. “The river basin sets over the tropical fringe plateau with a total area of 9685 km² (Bhattacharya, 2018). The river basin is extended from 21^o45’ N to 23^o30’ N latitudes and 85^o45’ E to 88^o15’ E longitudes. Kangsabati is one of the most important rivers in the southern part of West Bengal, flowing from northwest to south eastward (Bhattacharya et al., 2020). Geologically the river basin area is constituted by many geological units. That region brought up through a long evolution from oldest Archean’s (Pre-Cambrian) to Tertiary- Quaternary formation” (Mukhopadhyay, 1992).

The river basin area mainly formed with Granite, Gneiss and mica schist. Upstream and middle stream mainly consist with igneous Granite and metamorphic Gneiss. Downstream mainly formed with alluvial deposition and fractured aquifer in upper basin granite gneiss. The name of the basin came from the tropical rain fed river ‘Kangsabati’ which leads to floods and droughts every year in its basin. This river is considered one of the largest rivers in West Bengal.

The climate of the river basin is generally semi-humid in nature. The Southwest Monsoon has the highest rainfall in June, July and August, average rainfall 150-175 cm. “The highest temperature is found in April-May, the first period of summer, varied 40°C-42°C. The lowest temperature is found in December and January months, mean temperature varied 8°C –12°C. Deficiency of subsurface water availability is peek in the months of March, April and May. Bankura and Purulia districts are considered as drought-prone areas in the state of West Bengal. Droughts are mostly caused by some geological and river hydrological factors. The unbearable temperature and high evaporation make the summer extremely dry and accelerate the fast consumption of the groundwater”.

For urbanization and economic development, the maximum catchment area has turned into cultivated land by erasing forests. “Agriculture is considered as the main occupation in this catchment area. Kharif and Ravi crops yield primarily based on the Kangsabati river water. But crop failures, improper growth of plants, soil

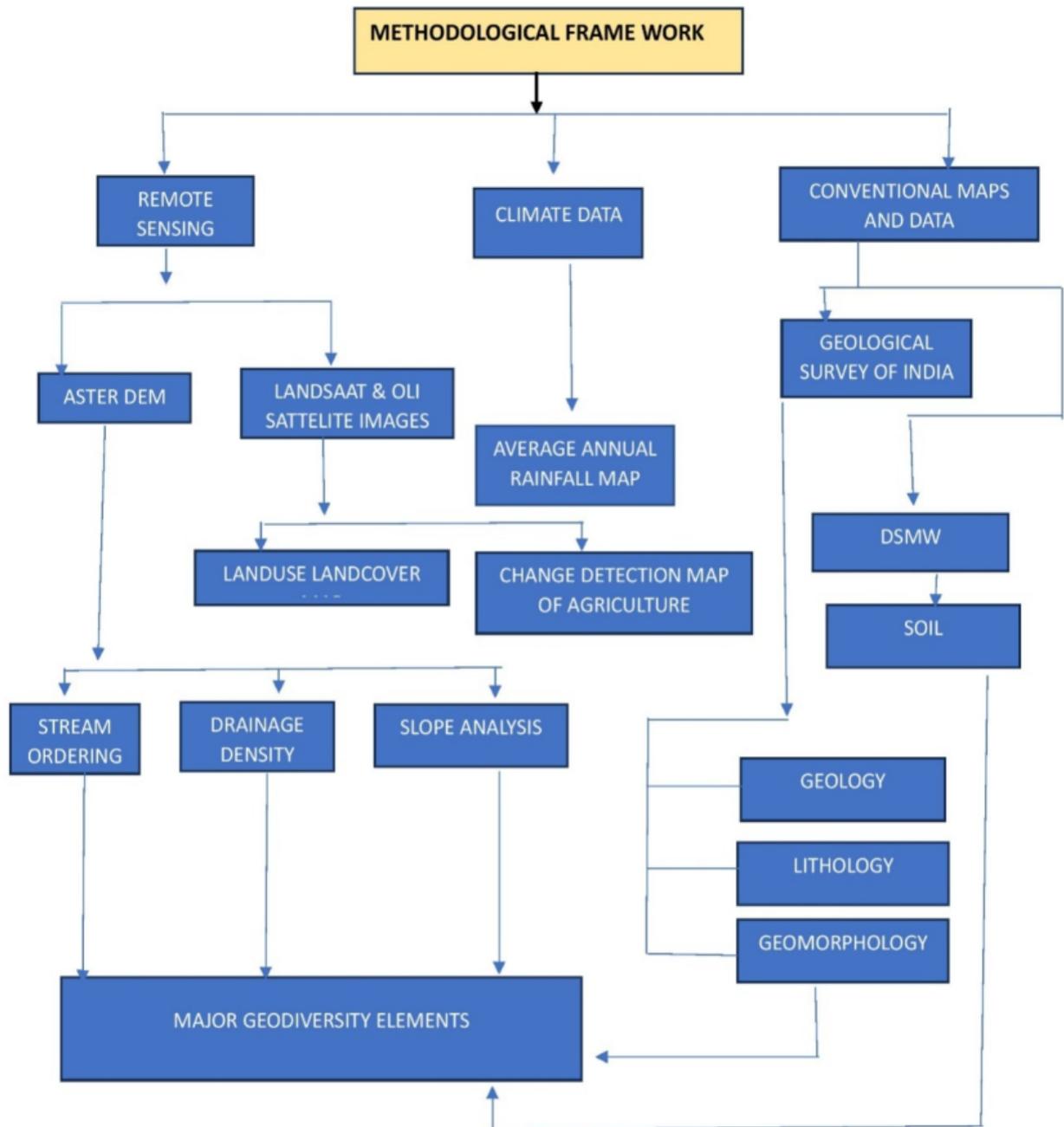
erosion occur every year due to the inadequate supply of water. To resolve the problems, the Government of India and the Government of West Bengal mutually decided to build a reservoir on Kangsabati channel namely Kangsabati irrigation Project at Mukutmanipur, in Bankura district near the confluence of the Kangsabati and the Kumari River. The reservoir was mainly built to provide the sufficient water for the irrigation in dry pre monsoon period to protect the agriculture and to supply the fresh drinking water for the people in lower catchment areas. The natural flow of the river was interrupted for the artificial reservoir and the river basin was bifurcated into two portions. After a while it was observed that the local ecology and the environment have gradually changed. The supply of the water was unequal to both the up and down streams. As a result, two different types of conditions prevailed in the same river basin. The irrigation project was unable to fulfil the demand”.

Data and Methodology:

In earlier days many methods were used to assess geo-diversity such as descriptive (qualitative), and numerical (quantitative) (Zwolinski et al.,2018). The paper focuses on the diverse elements of geodiversity elements of the Kangsabati River, for which thematic maps of geology, slope, lineament density, TWI, soil, climate, and agricultural thematic maps are prepared with the help of geospatial technology (Table 1). A methodological framework is ready and shown in Fig....In the first step, all the geospatial data is accumulated from different sources, and the database is generated with the help of Arc GIS10.8. From the SRTM (DEM) data slope, lineament density, stream ordering, and TWI maps are prepared. Spatial analysis tool extensively used in Arc-GIS 10.8. Drainage network maps were created using ASTER DEM 30M data, where flow accumulation, flow direction tool used for stream ordering, and line density tool used for drainage density map. LULC was prepared using Esri land cover raster data. This method allows for a detailed analysis of Geodiversity elements in the Kangsabati River basin area.

Table-1Sources of Data used for thematic layer preparation

Thematic layers	Data Type	Data Sources
Geology	Polygon	Geological Survey of India. https://bhukosh.gsi.gov.in/
Slope	Raster	USGS https://earthexplorer.usgs.gov/ 2014
Stream ordering	Raster	https://earthexplorer.usgs.gov/
Drainage Density	Raster	https://earthexplorer.usgs.gov/ 2014
Geomorphology	Polygon	Geological Survey of India. https://bhukosh.gsi.gov.in/
Soil	Polygon	DSMW- http://www.fao.org/
Climate		https://chrsdata.eng.uci.edu/
Land use Land cover	Raster	Esri Land Cover (arcgis.com)
Change Detection Of Agriculture	Raster	Esri Land Cover (arcgis.com)



Result And Discussion:

Geology:

The geological map brings forth important information for understanding the region’s tectonic history. The geological map (Fig: 2.) describes the mineral content, groundwater distribution, etc. of the Kangsabati river basin based on geological formation. Each unit of the different era and deposition of both ancient and recent is evidence of various tectonic and environmental factors for shaping the area over time. This map highlights the spatial distribution of geological features. The various types of geological formations of the place are explained on the map. The south-eastern part of the river is a deposit of quaternary age which appears as a branch of new geological formations. This part shows the location of new sediment accumulation, sedimentation by the river. Paleoproterozoic rocks dominate the central and northern parts. Archaean-Paleoproterozoic and Proterozoic rock formations are scattered across the river basin area.

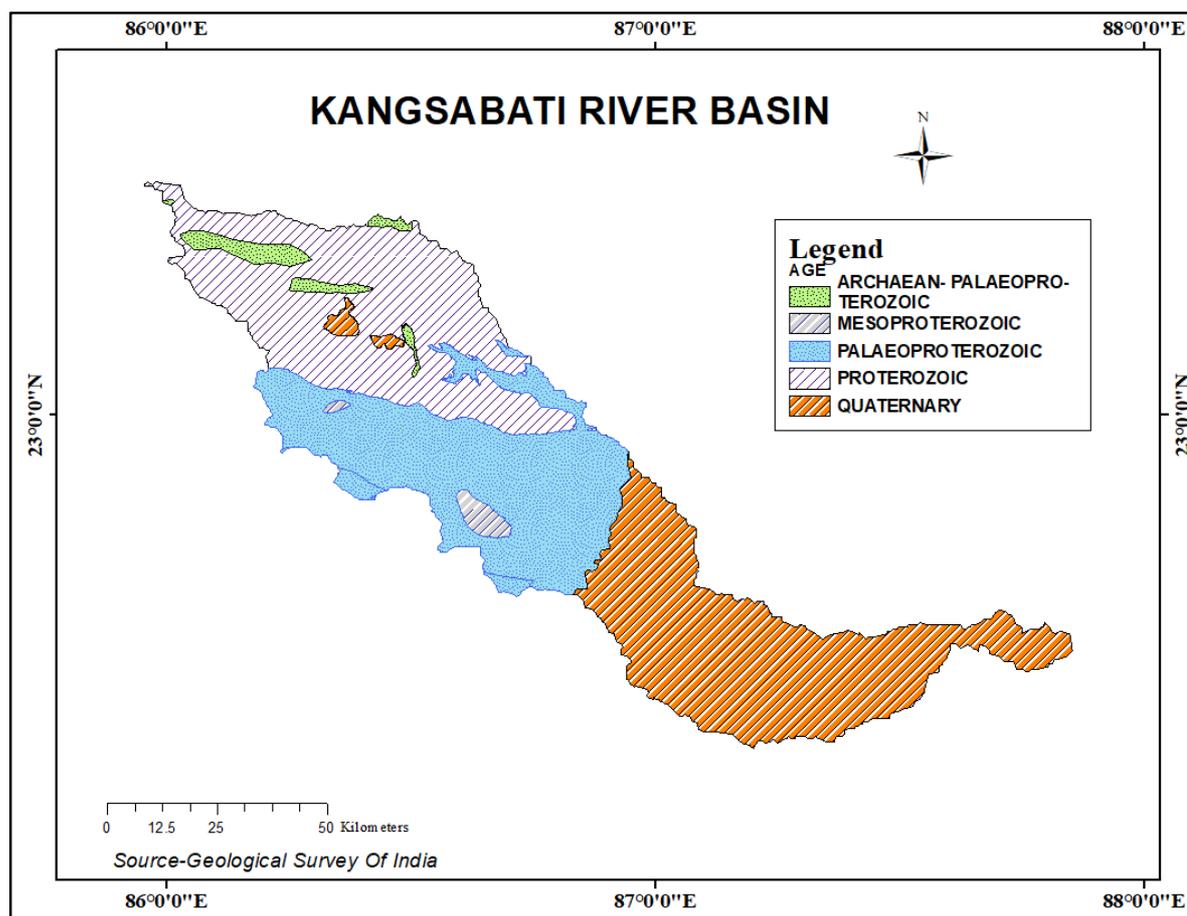


Fig.2 Geological map of kangsabati river basin

Lithology:

The Kangsabati River basin mainly consists of Granite, Gneiss, and mica schist. “Upstream and middle stream areas primarily contain igneous granite and metamorphic gneiss, while the downstream region is characterized by alluvial deposition and fractured aquifers. The river plays a crucial role in the region’s ecology, biodiversity, and flood vulnerability and efforts are ongoing to rejuvenate its ecosystem” (Ghosh et al 2022).

Geological history and dynamic process shaping the area. Biotite gneiss, granite, hornblende schist, quartzite are the usual igneous and metamorphic rocks that indicate the dynamic process.

A high temperature and pressure condition in this region creates metamorphism which reflects by mica schist, “chlorite schist, graphite sillimanite schist formations. The accumulation and transformation of sediments throughout the basin area over time is evidenced by sand, silt, clay and alluvium composition”.

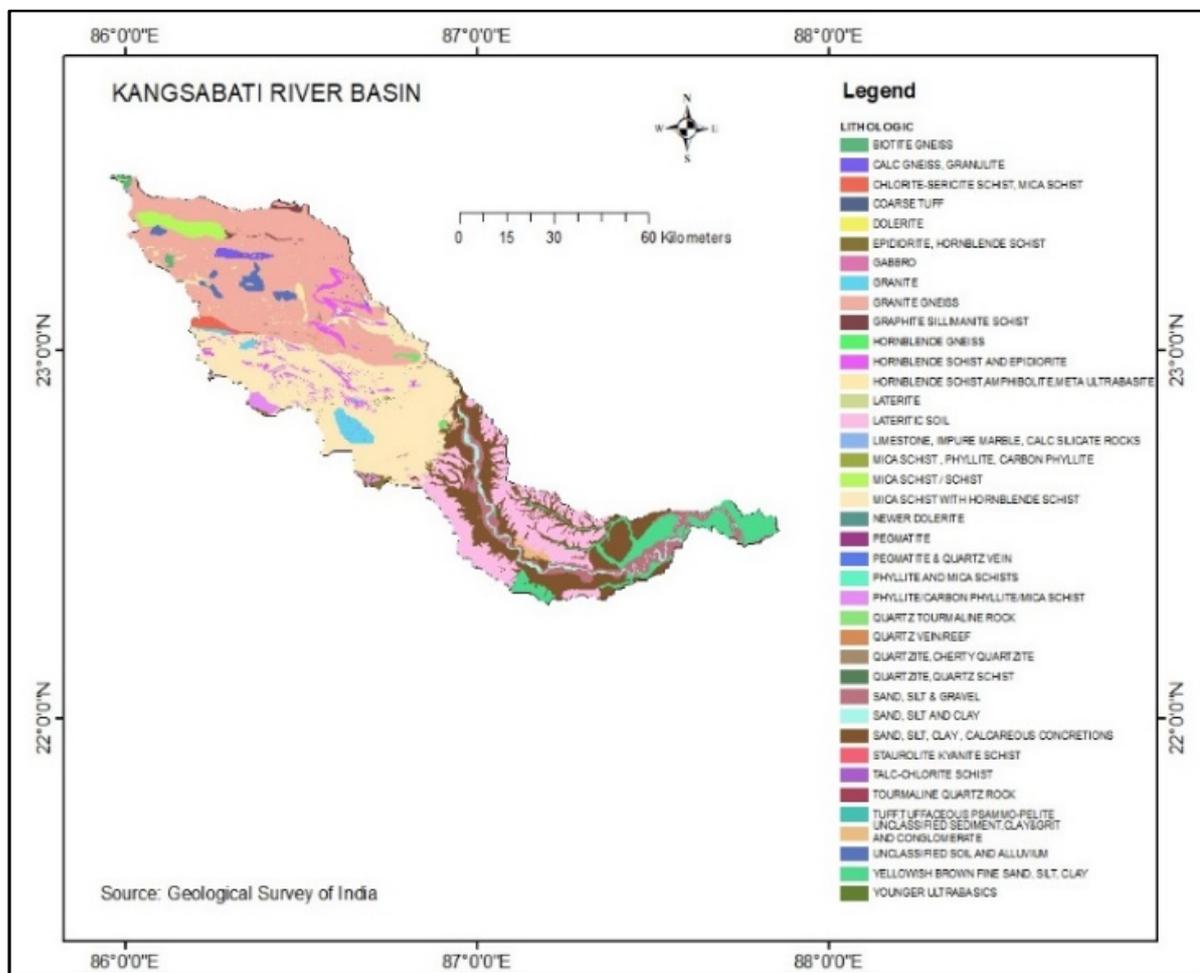


Fig.3: Lithology of kangsabati river basin

Geomorphology:

In eastern India, Kangsabati basin is rich with diverse Geomorphologic features. This area is located in West Bengal and some parts of Jharkhand. Climate, fluvial dynamics, and geology is responsible for shaping the various geomorphologic traits. The lower course of the area has deposition of fine sediments like sand, clay, and silts over the time and lay the foundation of wide alluvial plain which is mainly used for agriculture for its fertile soil composition. In Purulia district and some parts of Jharkhand the upper reaches of river, there are hilly regions. This hilly area mainly comprised of ancient Precambrian rocks. The central part of the basin area is predominated by less fertile laterite, reddish colored, iron-rich soil which is generated from intense weathering. This area named by Lateritic upland. Some parts of Jharkhand, Jhargram district and Paschim Medinipur district having this kind of topography. Throughout the basin area gently sloping flat surfaces named Pediplain are found resulting from the erosion from the hills over the time. In some part of Purulia, Bankura, and East Singhbhum district are characterized by deeply incised valleys, rugged terrain, and dissected lower plateaus. The remnants of harder rock found in various parts of the basin area, particularly closer to the river’s headwaters. These ridges have resisted the erosion. The abandoned banks of the river, and the accumulation of sediments, bear witness to the change in the course of the river at various times, which is symbolic of the topographical features of the region. They form river terraces and channels. To fulfill the irrigation in dry period and to supply drinking water in Mukutmanipur large reservoir has created which has altered the natural flow of the river. This man-made dam effected the hydrology and morphology of the river. In the western hilly area tors, composite rocks feature is present. The dendritic drainage system of the river, with umpteen tributaries feeding into the principal river channel.

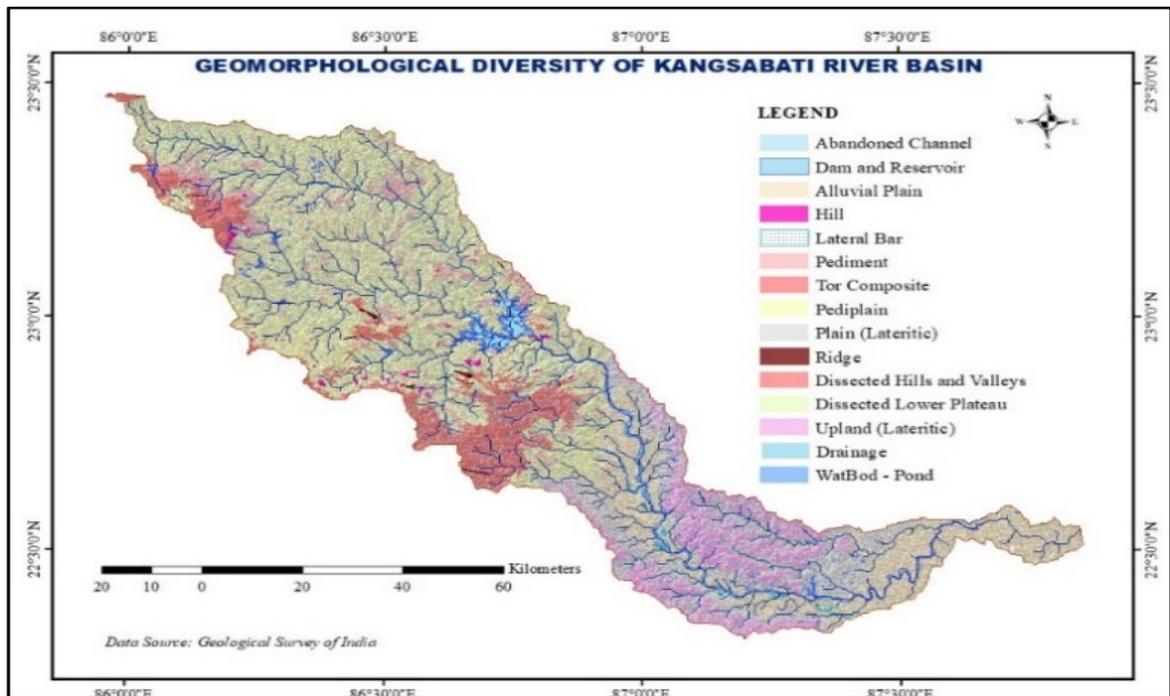
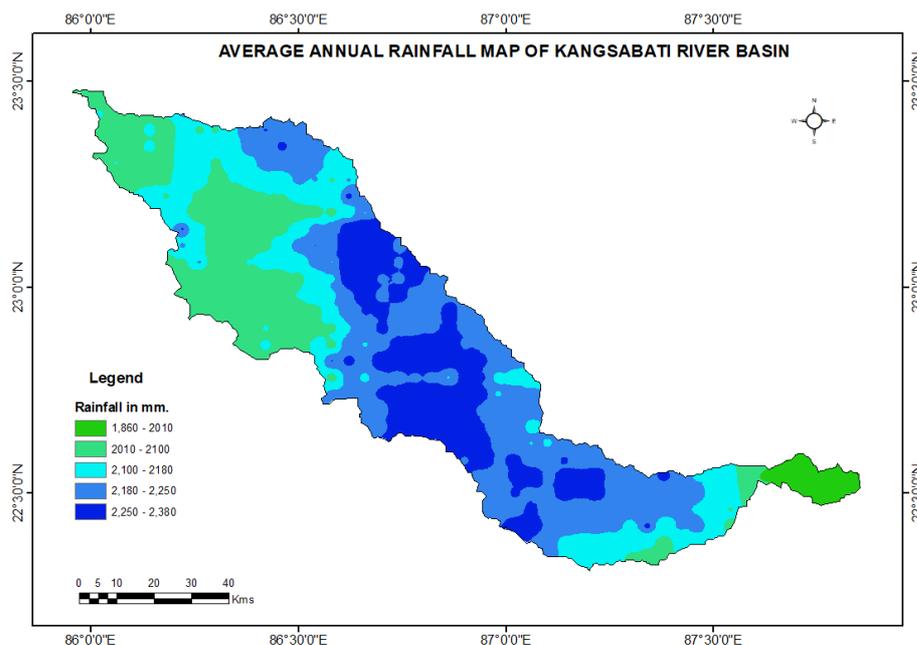


Fig.4 Geomorphology of Kangsabati river basin.

Climate:

In the research area, rainfall plays crucial role in hydrological cycle. It recharges the groundwater storage through infiltration and sustains the region's rivers hydrological cycle. The rate of infiltration is influenced by both the amount and duration of rainfall. Short, intense rain events lead to more surface runoff and reduced infiltration, while longer, lighter rains promote greater infiltration over runoff (Adhikary et al., 2018; Bera et al., 2020; Ibrahim-Bathis & Ahmed, 2016). This study analyzed rainfall data from 2015 to 2020, with annual rainfall ranging from 1860 to 2010 mm. Using the IDW method in ArcGIS, a geographical distribution map of rainfall was produced. The rainfall levels were classified into five classes: very low (1860–2010 mm), low (2010–2100 mm), moderate (2100–2180 mm), high (2180–2250 mm), and very high (2250–2380 mm) (Fig.5).



Slope:

The river Kangsabati is an important river basin area specifically located in the state of West Bengal and Jharkhand. The slope of the river basin varies across different sections. Slope, a key topographical trait, represents the steepness of the land surface. The grade of the slope is vital for evaluate groundwater risks, sediment movement, and has a direct influence on surface water dynamics. A lower slope angle indicates flatter topography, while a higher slope value marks steeper land. On steep slopes, water flows downward rapidly, in a short time for precipitation to infiltrate, in limited recharge potential. In contrast, areas with gentle slopes having a slower water flow, facilitating groundwater recharge. Consequently, regions dominated by gentle slopes are more conducive to groundwater replacement than those with steep slopes. For this study, a Digital Elevation Model (DEM) was used to produce the slope map, which classified the slope data into five categories: flat (0.00° - 2°), gentle (2° - 4°), moderate (4° - 8°), steep (8° - 16°) and very steep slopes ($>16^{\circ}$), (Fig. 6)

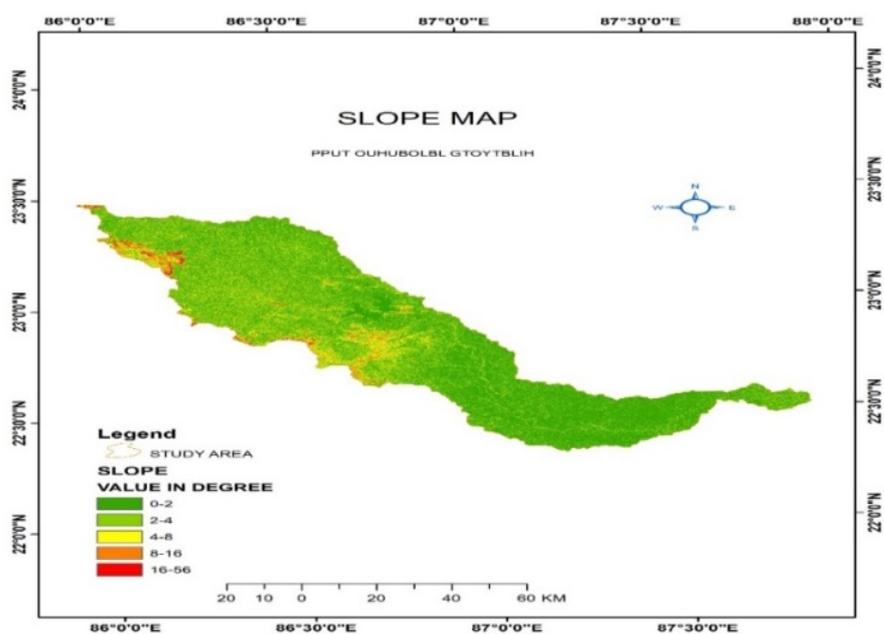


Fig.6 Slope map

Stream Order Analysis:

Based on hierarchical classification of streams stream ordering is done which is the initial step of drainage analysis. Here the method used to analyses the stream order was evolved by Strahler (1964).

According to this method, the smallest tributaries are identified as 1st-order stream. When two 1st -order streams to meet each other creates the 2nd -order, similarly 3rd – order formed by two submerging 2nd – order tributaries and this pattern continues. The highest-order stream identified as the mostly water carried through it. The process to select the order is influenced by the shape, size, and relief characteristics. (Haghipour and Burj,2014).

The basin has various order of streams. In 1st order, there are 335 number of stream have been recorded. In 2nd order 122 number of stream have been recorded, in 3rd stream order, 86 number of streams have been identified, in 4th order 55 number of streams have been recorded and in 5th order 61 number of streams have been found. In 4th stream order, the lower number reaches across the basin indicate lower water availability and potential water stress condition.

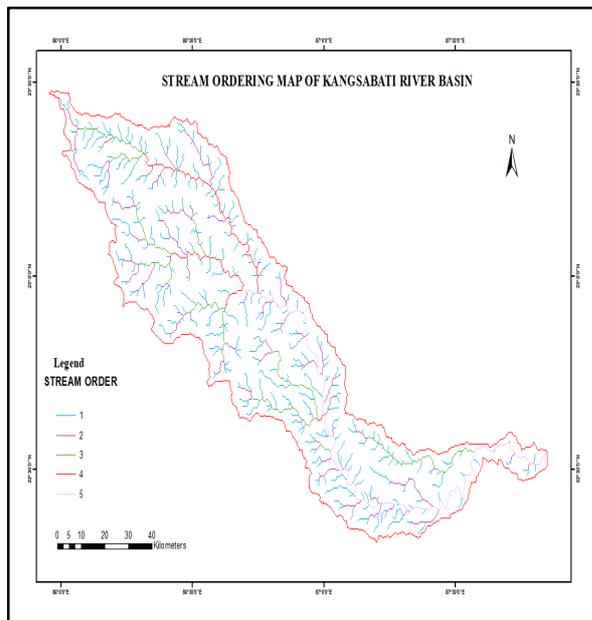


Fig: 7 Stream Ordering

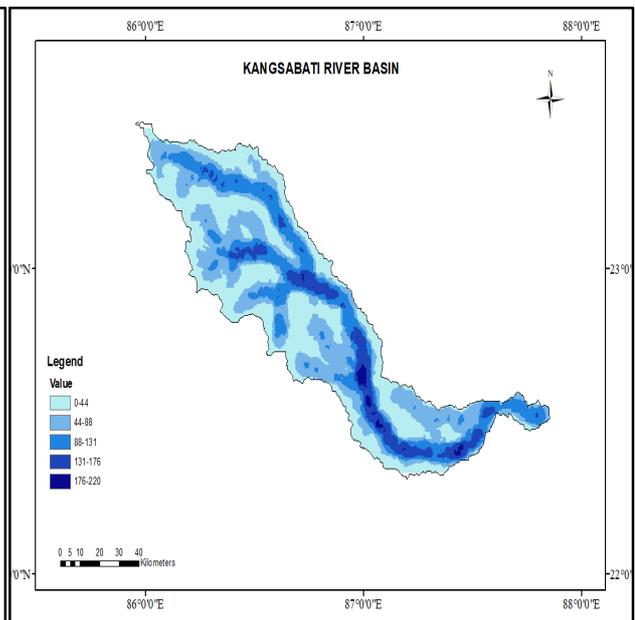


Fig: 8 Drainage Density

The term drainage density refers to the ratio of stream length per unit area within a basin area (Horton, 1932; Strahler, 1952). “Several factors, including geological formations and structural properties of rocks, soil properties, and slope gradients significantly affect drainage concentrations” (Manap et al. 2013). The measurement of drainage density is determined by the proximity of the channels to each other. Conversely, drainage density acts as a functional property against permeability in river basins. A higher drainage concentration leads to increased surface runoff, which in turn reduces surface water infiltration and vice versa (Bera et al. 2019). In this context, $\sum Di$ represents the cumulative length of streams within the grid (km), while A denotes the area of the grid (km^2). (Fig:8)

Table-2 Drainage Density of Kangsabati River Basin

DRAINAGE DENSITY	
Drainage Density (m^2)	Area(km^2)
< 44	2488.809
44-88	2201.774
88-131	1380.447
131-176	605.0943
> 176	57.2112

$$Dd = \sum_{i=1}^{i=n} \frac{Di}{A} (\text{Km}^{-1})$$

Where $\sum Di$ denotes the cumulative flow length within the grid (km) and A represents the grid area (km^2). The drainage density of the Kangsabati river basin is divided into five distinct categories: very low (0–44 m/km^2), low (44–88 m/km^2), moderately low (88–131 m/km^2), high (131–176 m/km^2), and very high (176–220 m/km^2), covering areas of 2488.8087 m/km^2 , 2201.7744 m/km^2 , 1380.447 m/km^2 , 605.0943 m/km^2 , and

57.2112m/km² /km², 9 ig). Areas characterized by low and very low drainage density collectively account for about 57.2112m/km² percent of the overall area and have higher weight values than areas exhibiting high drainage density.

Soil Map:

The total basin area is comprised of deep to very deep alluvial soil. Based on structure, the soil formed in the whole basin area falls into six types of soil groups, such as Eutric Cambisols, Eutric Gleysols, Uthosols, Ferric Luvisols, Orthic Luvisols. (Fig. 9). Mostly the area of the river basin has consisted of alluvium or Ferric luvisols (5414.62sq/km.Table-3). The upper part of the basin in Purulia District and some portion of Bankura, Jhargarm consist by an azonal soil which is fragmented by weathered rock named Uthosols(952.59km²). In the lower basin area there are, fluvial humas soil named as Orthic Luvisol(275.29km²) present in the district Paschim Medinipur. Some part of the lower basin area are featured by Eutric Cambisols (121.83km²) and very small part of the Purba Medinipur district is covered by Utric Fluvisol (9.16km²). Where the river meets with Keleghai it is composed by Eutric Gleysols(0.23km²). This soil is commonly loamy with siltrated soil.

Table -3 Spatial distribution of soil in Kangsabati River Basin

SOIL	AREA in Km ²	PERCENTAGE (%)
Eutric Cambisols	121.83	1.79
Eutric Gleysols	0.23	3.46
Uthosols	952.59	14.06
Utric Fluvisols	9.16	0.14
Ferric Luvisols	5414.62	79.94
Orthic Luvisols	275.29	4.064

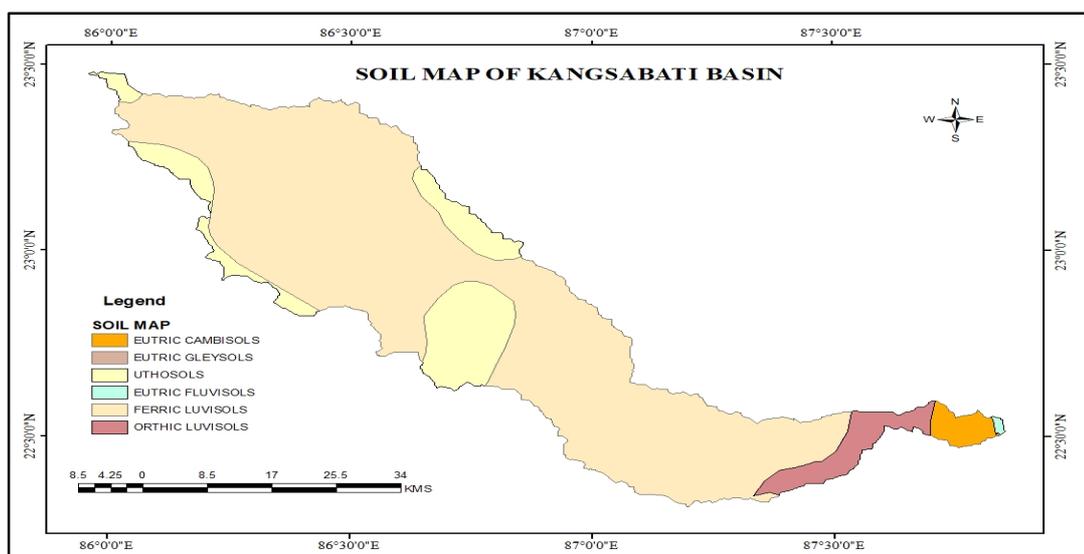


Fig.9 Soil map of Kangsabati river basin (Data source- DSMW-<http://www.fao.org/>)

Landuse Landcover:

Raster data accumulated from ESRI Land Cover (arcgis.com) and land use land cover is divided into six classes namely, water, forest, flooded vegetation, agriculture land, built-up area, built up area and range land of the basin area (Figure 10).

Fallow land and other land categories include non-agricultural land, barren land, wastelands and another category of LULC which is not considered under agricultural land, built-up area, and water bodies. Table 1 shows the area of different land use land cover classes obtained after classification. The agricultural area covers 4047.0159 ha (59.74%), Forest 1330.2242 ha (19.63%), water bodies 136.6487 ha (2.017%), Built-Up area 552.1014 ha (8.15%) and Fallow land and other 000000 ha (0000000%). The maximum area of the study region is covered by agricultural land, followed by Forests, Built-Up areas Water bodies, and others. (Table 1). In the river basin of Kangsabati alluvium soil showed the dominance of Fallow and other land cover classes.

Table-4 Showing LULC of Knagsabati River Basin

LULC	Area (km ²)	Area in (%)
Water Body	136.6487	2.02
Forest	1330.2242	19.63
Flooded Vegetation	1.2125	0.02
Agricultural Land	4047.0159	59.74
Builtup Area	552.1014	8.15
Barren Ground	9.2686	0.13
Range Land	697.2544	10.29

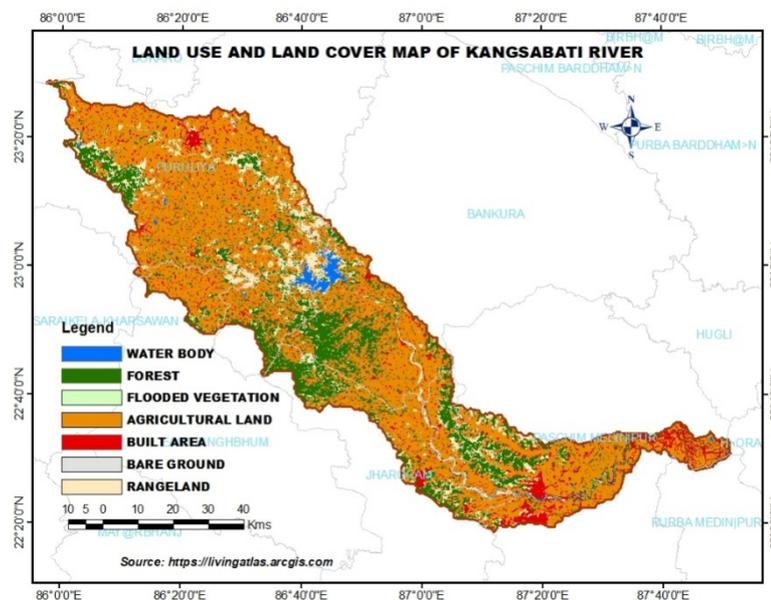


Fig-10 Spatial map of landuse/landcover in Kangsabati river basin area

Agricultural Area Changes in Basin Area:

The Kangsabati River, which runs through West Bengal and Jharkhand in India, plays a crucial role in the region's agriculture. The river's alluvial deposits have enriched the soil, making it ideal for farming. Local farmers mainly grow crops like rice, vegetables, and pulses in this fertile land. Agriculture along the Kangsabati River is essential, providing livelihoods to the surrounding communities and making a significant contribution to the area's food supply

Area	Crops 2017	Area	Crops 2023	Change detection	Change variation	Change	Percent
2275.243	Others	2725.122	Others	Others - Others	No Change Others	2108.871	77.38632
2275.243	Others	4048.523	Crops	Others - Crops	Increase Crop_Area	166.2785	4.10714
4498.415	Crops	2725.122	Others	Crops - Others	Decrease Crops Area	616.1314	22.60932
4498.415	Crops	4048.523	Crops	Crops - Crops	No Chjange_Crops	3882.197	95.89168

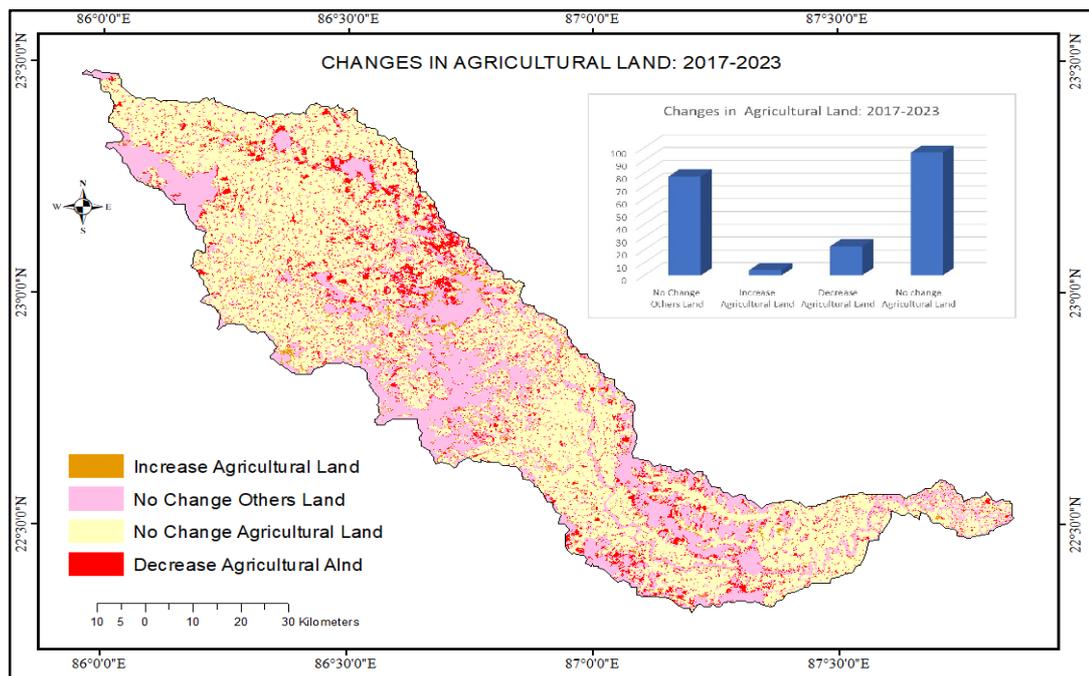


Fig:11 Change detection of agricultural.

One of the key features of agriculture along the Kangsabati River is the use of traditional farming methods. Due to the lack of modern infrastructure and technology in the region, farmers rely on age-old techniques for cultivation. Despite the challenges, farmers along the Kangsabati River have been able to sustain the productivity of their land and produce a variety of crops. The traditional farming methods also contribute to the unique flavor and quality of the produce, making it highly sought after in the market.

Threats or Challenges:

However, agriculture along the Kangsabati River also faces challenges due to factors such as lack of irrigation facilities, unpredictable weather patterns, and limited access to markets. The dependence on monsoon rains for irrigation poses a risk to the crops, and farmers often struggle to make ends meet during the dry spells. Additionally, the lack of proper infrastructure for transportation and marketing hinders the farmers' ability to reach wider markets and fetch better prices for their produce. Despite these challenges, the farmers along the Kangsabati River continue to work hard to make a living from the land, preserving the traditional farming practices and contributing to the rich agricultural heritage of the region.

The Kangsabati River is also an important habitat for a variety of aquatic species and serves as a lifeline for the ecosystem in the region. The river is home to a diverse range of flora and fauna, including several endangered species. It supports a rich biodiversity and provides a unique ecosystem that is crucial for the survival of many species. Efforts have been made to preserve and protect the Kangsabati River and its surrounding environment to ensure the sustainability of the ecosystem.

Conclusion:

However, the Kangsabati River also faces various challenges, including pollution and deforestation. The river is at risk due to industrial waste and pollution, which threatens the water quality and the health of the ecosystem. Additionally, deforestation and unsustainable agricultural practices have led to erosion and sedimentation in the river, further exacerbating the environmental threats. Authorities and local communities need to work together to address these issues and ensure the conservation of the Kangsabati River for future generations.

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