APPLICATION OF GIS IN WATERSHED MANAGEMENT A CASE STUDY OF GANDHESWARI RIVER BASIN.

A thesis submitted towards partial fulfilment of the requirements for the degree of

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This is to certify that the thesis entitled "**Application of GIS in Watershed Management, A Case Study of Gandheswari River Basin"** is bonafide work carried out by **ABDUL HALIM** under our supervision and guidance for partial fulfilment of the requirement for Post Graduate Degree of Master of Engineering (Water Resources & Hydraulic Engineering) in School of Water Resources Engineering, during the academic session 2019-2022

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

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I hereby declare that this thesis contains a literature survey and original research work by the undersigned candidate as part of my **Master of Engineering in Water Resources & Hydraulic Engineering degree (6th Semester)** under the Faculty Council of Interdisciplinary Studies, Law and management in Jadavpur University during the academic session 2019-2022.

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Date :

Place : ____________________

ABSTRACT

Management of natural resources and to promote overall economic conditions are the major approach of watershed management. The main aspects of river basin management are to higher agricultural productivity and conserving natural resources and to improve rural livelihood. Morphometric analysis of a river catchment or basin provides a quantitative description of drainage system and relief characteristics. In the present study, morphometric parameters like basin geometry, drainage network, drainage texture have been analyzed through Remote Sensing (RS) and GIS techniques in Gandheswari river basin of Bankura district. Different types of thematic maps have been prepared through GIS techniques. The river basin covers an area of 364.9 Sq.km. The basin is in elongated in shape and is structurally controlled. Digital Elevation Model (DEM) has been prepared for the analysis of slope of the river basin.

Objective to enhance agricultural production of small and marginal farmers of West Bengal residing within the project area. The key purpose of the programme is to reach the farmers with assured irrigation water along with institutional as well as agriculture and allied support services and focused intervention was made to uplift the socio-economic conditions of underprivileged sections of Red andlaterite zone whose bread earnings are from primary sectors. In these districts attempt has been made to create need based and agro-climatic zone wise minor irrigation models, strengthening of institutions comprising beneficiary farmers to upkeep and maintain the structure created and to enhance income through focused guidance and support under agriculture, horticulture and fisheries. in these districts target to create need based and agro-climatic zone wise minor irrigation models, strengthening of institutions comprising beneficiary farmers to upkeep and maintain the structure created and to enhance income through focused guidance and support under agriculture, horticulture and fisheries.

Watershed Management development programmes results to recognise of watershed on unit basis for improvement and proper use of lands by following the land capability classification & control of floods by constructing the reservoirs like multi-purpose reservoirs like Check dams at head water of streams and in problem areas of adequate water supply for agriculture and proper source of water for drinking purpose and supply sufficient amount of water for industrial needs and management of various agricultural pollutions, environmental pollution and abatement of organic and inorganic pollutions.

KEYWORDS: Engineering measures, Watershed management techniques, surface water storage, *Arc* Geographic information system, Gandheswari River Basin.

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CHAPTER-1: INTRODUCTION

1.1 GENERAL BACKGROUND

Watershed is the drainage area on the land surface from which runoff or excess water from rainfall reach at a special point known as common outlet. It is the common point from which the excess amounts of water collected and distribute through a outlet to the connecting sources. Or you can say that it is the common method to collect the runoff water. As we know that the agricultural system is totally depends upon the water sources, without proper source of irrigation water agriculture is not possible in any situation. Watershed is the boundary to collect the runoff water coming from various sources like point sources and non-point sources.

Sustainable development and increased food production in agricultural based developing countries requires availability of sufficient water and fertile land. Water especially affects greatly the prosperity of people and their development potential and health. The availability of this vital resource is not guaranteed for large sections of the world's population. Over 40% of the extra food required to meet the growing food demands by 2025 will have to come from intensified rain fed farming in sub-Saharan Africa region. In contrast almost quarter of Sub-Saharan Africa (SSA) population lives in water-stressed areas. (World Bank, 2005; UNDP, 2006). Ethiopia is relatively well endowed with water resources, having an estimated annual surface runoff close to 122 billion m3. However these water resources are unevenly distributed both spatially and temporally. Between 80-90% of the country's surface water resources are found.

Average annual rainfall in the State ranges from 1234 mm to 4136 mm. The Himalayan region receives the maximum rainfall. As of April 2015, the country's water resource potential or annual water availability in terms of natural runoff (flow) in rivers is about 1,869 Billion Cubic Meter (BCM)/year. However, the usable water resources of the country have been estimated as 1,123 BCM/year. This is due to topography constraints and uneven distribution of the aid in various river basins, making it difficult to extract the entire available 1,869 BCM/year. Out of the 1,123 BCM/year, surface water and groundwater share is 690 BCM/year and 433 BCM/year, respectively. Setting aside 35 BCM for natural discharge, the net annual groundwater availability for the entire country is 398 BCM. Identifying potential groundwater zones is very important for the optimum utilization and conservation of this precious resource (Hutti&Nijagunappa, 2011). Test drilling and stratigraphy analysis are the conventional and reliable methods for determining the location of aquifers, but this method is very costly and time-consuming.

Water is, beyond any doubt, the most widespread liquid inside the earth's crust. An estimated eight to ten million cubic kilometres (km3) of fresh groundwater represents the lion's share of all liquid fresh water on Earth, or to be more precise: about 98 to 99% of it. In comparison, the global volume of fresh water in lakes is less than 1% of the total new groundwater volume. However, the importance of freshwater stored in the Earth's crust represents only one percent of the total volume of water in the hydrosphere, including the oceans. Groundwater flow in an aquifer is governed by the aquifer's intrinsic characteristics (size, permeability, etc.) and its recharge, which – on a global level – is mainly produced by infiltration of precipitation. Most of the groundwater flow eventually ends up in springs and streams. Though a vast reserve of groundwater resources is available, every drop of groundwater needs proper management. In view of the above fact, an attempt has been made to depict the hydro geological framework by synthesizing all the available data related to the hydro geological condition to assess the state's ground water development prospect.

Groundwater renewability as part of the total water cycle is the principal difference from other mineral resources. According to calculations on a global model Water GAP-2 (Döll et al., 2003), an average perennial amount of groundwater recharge is about 14,000 km3/year for land or, in other words, about 36% of the river runoff is forming by groundwater. Groundwater availability as of April 2015, the water resource potential or annual water availability of the country in terms of natural runoff (flow) in rivers is about 1,869 Billion Cubic Meter (BCM)/year. However, the usable water resources of the country have been estimated as 1,123 BCM/year. Due to topography constraints and uneven distribution of the aid in various river basins, which makes it is difficult to extract the entire available 1,869 BCM/year. Out of the 1,123 BCM/year, surface water and groundwater share is 690 BCM/year and 433 BCM/year, respectively. Setting aside 35 BCM for natural discharge, the net annual groundwater availability for the entire country is 398 BCM. (Jha & Sinha, 2009).Total cultivable area of this state is about 56 lakh hectares and having 62% irrigation area of net cropped area. Gross cropped area is 94,58,675 hectares.

The State is broadly divided into six Agro-climatic Zones namely i) Northern Hill Zone, ii)Teesta-Tarai Alluvial Zone, iii) Gangetic Alluvial Zone, iv) Vindhyan Alluvial Zone, v) Coastal Saline Zone and vi) Red & Laterite Zone. Annual rainfall data indicates that the "undulating Red and laterite zone" comprising Purulia, Part of Burdwan, Birbhum, Bankura, Jhargram& Paschim Medinipur district, receives significantly less rainwater then all other zones. Soil related data indicates that the soil of this zone is also infertile. Soils are coarse in texture, erosion prone; acidic in nature, nutrients are less in soil. Various ground water study indicates that availability of ground water is a challenge and water table is sinking due to multifarious reasons.

The planning and designing of soil and water conservation structures likewise water harvesting structure overflow structure, bunds, water ways etc. Thus it is essential to development of various programmes related to watershed basis in conjunction with fundamentals of soil and water conservation practices. The watershed development programme needs to be taken up from ridge line to outlet point. The main purpose of watershed management programme in dry land areas is to optimum and collective use of agricultural lands, water, vegetation in a particular area for providing facility to reduce the drought impacts, moderate floods, reduce soil erosion, increasing availability of water and increase food, fuel, fodder and fibre on sustainability basis.

1.2 SCENARIO

Low access to water supply, sanitation and in sufficient food production increasing scarcity of renewal and accessible water resources and diminishing water quality further narrow the resources and diminishing water quality further narrow the resources base of healthy ecosystems. At best this leads to chronic problems, this catastrophes may trigger regional and even global crises. Watershed management is the study of the relevant characteristics of a watershed aimed at the sustainable distribution of its resources and the process of creating and implementing plans, programs and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within the.

Groundwater renewability as part of the total water cycle is the principal difference from other mineral resources. According to calculations on a global model Water GAP-2 (Döll et al., 2003), an average perennial amount of groundwater recharge is about 14,000 km3/year for land or, in other words, about 36% of the river runoff is forming by groundwater. Groundwater availability as of April 2015, the water resource potential or annual water availability of the country in terms of natural runoff (flow) in rivers is about 1,869 Billion Cubic Meter (BCM)/year. However, the usable water resources of the country have been estimated as 1,123 BCM/year. Due to topography constraints and uneven distribution of the aid in various river basins, which makes it is difficult to extract the entire available 1,869 BCM/year. Out of the 1,123 BCM/year, surface water and groundwater share is 690 BCM/year and 433 BCM/year, respectively. Setting aside 35 BCM for natural discharge, the net annual groundwater availability for the entire country is 398 BCM. (Jha & Sinha, 2009).

Rainfall is the primary source of groundwater recharge in India, supplemented by other sources such as recharge from canals, irrigated fields, and surface water bodies. A significant part of the groundwater withdrawal occurs from the upper unconfined aquifers, which are also the active recharge zones and hold the replenish able groundwater resource. The replenish able groundwater resource in the active recharge zone in the country has been assessed by Central Ground Water Board jointly with the concerned State Government authorities. The assessment was carried out with Block/Mandal/Taluka/Watershed as the unit and as per norms recommended by the Ground Water Estimation Committee (GEC)-1997. As per the latest assessment, the annual replenish able groundwater resource in this zone has been estimated as 432 billion cubic meters (BCM). 399 BCM is considered to be available for development for various uses after keeping 34 BCM for natural discharge during the non-monsoon period for maintaining flows in springs, rivers, and streams (Central Ground Water Board, 2006)

Chronically water-scarce area in the western part and the hilly tract in the northern part of the State: The districts of, the west part of Bankura, Purulia,Birbhum, Burdwan, Paschim Midnapur face acute scarcity of water, mainly during the lean period due to the limited yield potential of available aquifers.

Arsenic contamination in groundwater occurs in isolated patches spreading over 79 blocks in eight districts, namely, Malda, Murshidabad, Nadia, North 24 Parganas, South 24- Parganas to the east, and Haora, Hoogly, and Burdwan to the west of Bhagirathi/ Hoogly river. The Eastern part of the Bhagirathi/ Hoogly river is much more affected than the western part. Deeper aquifers (> 100 mbgl) in the same area are generally free from arsenic. Groundwater in the arsenic affected area is characterized by high iron, calcium, magnesium, bicarbonate with low chloride, sulfate, and fluoride.

The Task Force on Fluoride Contamination had recommended rapid assessment of fluoride concentration in groundwater in 105 blocks of 12 districts of West Bengal. After the evaluation, the final scenario regarding the high fluoride concentration in the ground water of West Bengal has been observed in 43 blocks of 7 districts, namely Bankura, Birbhum, Puruliya, Malda, Uttar Dinajpur, Dakshin Dinajpur, and South 24 Parganas. However, this problem is most serious in Bankura, Birbhum, Puruliya, and Dakshin Dinajpur districts. CGWB has found fluoride contamination above the permissible limit in Nadia and Burdwan district as well. In the state highest concentration of fluoride in groundwater has been reported from the Khyarasol block (15.9mg/lit) and Rampurhat-I block (17.9mg/lit) of Birbhum district.

Based on the geophysical surveys and groundwater exploration, Brackish to saline and fresh water-bearing aquifers have been deciphered in the different depth zones in the Kolkata Municipal Corporation area, South 24 Parganas parts of North 24 Parganas, Haora, and East Midnapur districts.

Investigate three scenarios of water use and one scenario of water availability.

• Thewater use scenarios include assumptions about the trend in driving forces of water usein domestic, industrial, and agricultural sectors (Table 3.1): Scenario M (medium) this is a "best guess scenario" in which intermediate estimatesare made for changes in water use.Scenario L (low): This contains a set of assumptions that lead to a lower estimate of water use than Scenario M.Scenario H (high): This contains a set of assumptions that lead to a higher estimate of water use than Scenario M.

•The water availability scenario assumes that average surface temperature and precipitation will change in the future because of climate change. For this paper we use a climate changesscenario based on the trend of greenhouse gas emissions given by the IS92a scenario of theIntergovernmental Panel on Climate Change (IPCC).

As input to our model, we usetemperature and precipitation values computed with the general circulation models of theMax-Planck-Institute and the Geophysical Fluid Dynamics Laboratory.AlthoughWater GAP computes changes in water use and availability for the period 1990 to2100, in this paper we only report calculations for two "time slices" 2025 and 2075.

Table 1.1: Distinguishing assumptions of water use scenarios.

Scenarios.	Domestic	Industry	Agriculture
L	Water intensity increases withincome up to $15,000/cap-yr.Then rapidly declines by 50%and then further to a stringent water conservation targetvalue for domestic water use.	Water intensity is constant withincome up to either $5,000 or$15,000/cap-yr. Then rapidlydeclines by 50% and thenfurther to a stringent waterconservation target value forindustrial water us	Irrigated area constant. Wateruse efficiency improves.
M	Water intensity increases withincome up to $15,000/cap-yr.Then declines by 50% andRemains constant afterwards	Water intensity is constant withincome up to either $5,000 or$15,000/cap-yr. Then declinesby 50% and remains constant afterward	New irrigation areas in mostdeveloping countries. Water useefficiency improves.
H	Water intensity increases withincome up to $15,000/cap-yr.Afterwards, remains constant	Water intensity increases withincome up to either $5,000 or$15,000/cap-yr. Afterwards, remains constant	New irrigation areas in mostdeveloping countries. Water useefficiency does not improve

*
Scenario L = Low, Scenario M = Medium, Scenario H = High

1.3. STUDY AREA

The study area considered includes parts of Bankura district of West Bengal covering an area of about 20 sq. km area shown in Fig.2 consists of districts, boundaries, blocks and villages. The blocks included in the study area Gandheswari river, a tributary of Darakeswar, is a major river in Bankura District (Figure

No. 1). Geomorphologically, the landscape of Bankura may be described as a connecting link between the plains of Bengal and the Chhotanagpur plateau. Gandheswari River flows North- Western part of the district through four blocks viz. Bankura, Saltora, Chatna, and Gangajalghati. It has originated at Saltora (BM-162m.) and flows towards South-East and meets with river Darakeswar near Bankura town (BM-76m.). Maximum and minimum elevation of the river basin is 440 meter and 76 meter. The total length of Gandheswari River is 49 km and is a 5th order stream. The latitudinal extension of the river basin is 23º13'28"N to 23º30'25"N and the longitudinal extension is 86º53'13"E to 87º07'30"E.

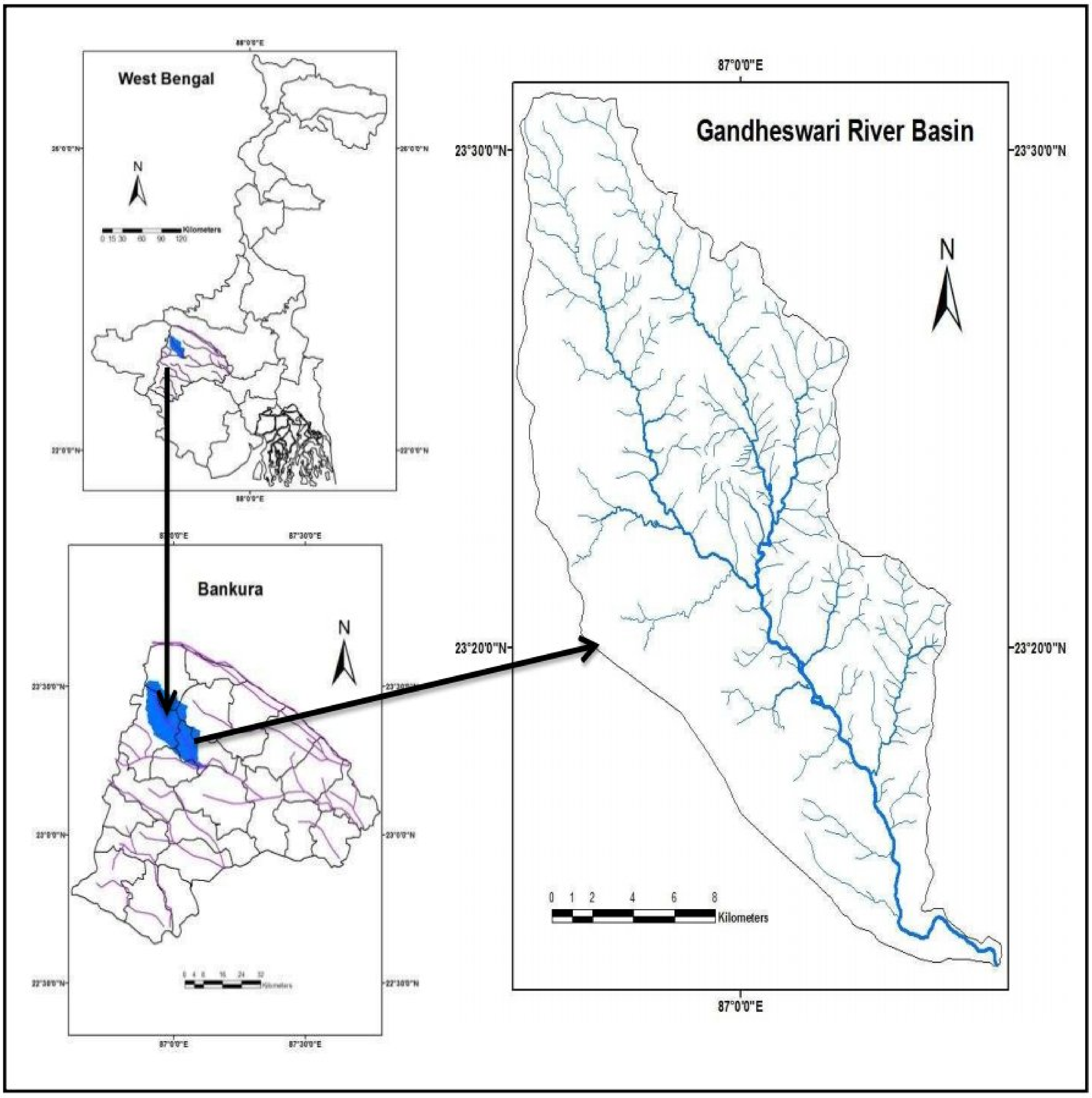


Fig: 1.1 Location Map of Study Area

Table: 1.2 Attributes of Gandeshwari River.

Name of River	Gandeshwari
River System	Tributary of Dwarekeshwar River (upto 5th order of stream) (A.N.Strahler, 1964)
Length of River	49 km
Basin Area	339km² (approx) (It covers Chhatna Block, Bankura I and II Blocks)
Originating Point	Near Purulia and Bankura District Boundary at extreme north
Remarkable point	Shushunia Hill (Bankura District, Chhatna Block)
End Point	Meets Dwarekeshwar River Near Bhujsahar Village
Predominant Fact about River	Lineament guided rivulet (mainly the lower confluence)

Table: 1.3 Ph Level of Gandeshwari River and Spring Water of Shushunia Hill

Location Ph Value (Month of November	**December) PRE MONSOON Ph Value (Month of July – August) POST MONSOON**	**Ph Value (Month of July – August) POST MONSOON**
Satighat (Bankura I Block)	6.2	5.8
Butsahar (Bankura II Block)	6.3	5.9
Kelabola (Bankura Block)	6.0	5.0
Banki	6.0	5.0
Shshunia	6.0	5.8
Purendrapur (Bankura Block I)	6.5	5.2

Table:1.4 Level of Turbidity in River Water (2015-16 Pre and Post Monsoon)

	Depth (from the surface layer of water to 10 cm depth)	Pre Monsoon	Post Monsoon
Turbidity (NTU) Nephelometer Turbidity Units	Near Satighats and Banki Village	65-73	89-110

1.4RESEARCH OBJECTIVE

The main objective of the study is to estimate catchment areas as well as for identification of potential areas for construction of minor irrigation structures with help GIS application and to develop a system for assessing potentials of schemes could be constructed in a given areas.

1.5 SCOPE OF STUDY

Despite threats from polluting activities, watershed is often surprisingly resilient, and water quality over large areas of the world generally remains good. Watershed management must be interrelated with and integrated into master plans to support the planning, policy, and strategy of groundwater resources protection and quality conservation. Watershed management strategies may apply, from home garden development to river basin based integrated programme level. The activities spread out in a wide range including forest cover development, chena stabilizing, conservation farming, tank and stream ecosystem development, irrigation water management, groundwater management, and participatory planning and development. Minimizing the land degradation, maintaining the stream base flow, ensuring a better sustainable production system

1.6 IMPORTANCE OF STUDY

The main importance of watershed development programmes are to control of floods by constructing the reservoirs like multi-purpose reservoirs. Proper source water for drinking purpose, management of various agricultural pollutions. Recognision of watershed on unit basis for improvement and proper use of lands by following the land capability classification and Check dams at head water of streams and in problem areas with reducing the environmental pollution.

1.7 OVER ALL METHODOLOGY

The overall research methodology is mainly divided into five components: Literature Review for Identification of goal and objective, Collection of the information of the present situation by primary survey and secondary survey, Data Presentation and Organisation of data analysis, Development of watershed in the study area and lastly output and result in analysis for Identifying strategies for scientific and sustainable management watershed. Scientific studies revealed that the study area selected is chronically water-scarce. Hydro geological parameters were considered for mapping the vulnerability of the area. Arc-GIS software was used for mapping Soil media, Aquifer media, topography, recharge, Vadose zone, ground water depth, and Hydraulic conductivity to identify the potential pollution zones of my study area. SCS runoff method was used for calculating runoff to determine the net recharge of the study area.

1.8 THESIS OUTLINE

The thesis consists of six chapters. Chapter 2 contains a literature review. Chapter 3 describes the study area and its characteristics. Chapter 4 conceptualization of catchment area Chapter 5 illustrates the research methodology and concept behind the study. Chapter 6 describes the results and discussions. The conclusion has been given in Chapter 7. References are given at the end of the dissertation.

CHAPTER-2: LITERATURE REVIEW

Watershed management uses a holistic approach to focus on multiple problems simultaneously, including water supply strategy, food management, water quality and ecosystem and economic values. It is an iterative process of integrated decision making regarding uses of modifications of land and water resources within a watershed. The process provides an opportunity for stake holders to balance diverse goals and uses for environmental resources.

2.1 Research Review of International and National scale on Watershed management.

Horton, R. (1945). Geographic Information System (GIS). These parameters describe the basin drainage network, geometry, texture, and relief characteristics. The hypsometric curve, hypsometric integral and clinographic curve were also prepared using topographic maps. Fluvial erosion associated with successive phases of rejuvenation plays a significant role in drainage basin development, whereas structure and tectonics, lithology and relief dictate the drainage pattern and morphological setting of the catchment. The drainage pattern, and the semi-linear alignment of main and branching drainage indicate the prominent influence of the Kerak-Al-fiha fault system on the drainage network.

Gutierrez, M. et. al. (1990). The shifting of population from urban to rural areas and water management changes to use more surface water created an opportunity for groundwater levels to recover. However, in 2002 private well owners reported low levels and water problems, which prompted mapping the new cone of depression. To this purpose, well data measured from private wells and data available elsewhere were mapped using GIS mapping tools. The results show a cone of depression extending towards the recently developed areas south of Springfield while the potentiometric levels of some areas within the city had recovered.

Talukdar et al. (1996). Watershed management is the management of the natural resources of a drainage basin primarily for the production and protection of water supplied and water based resources, including the control of erosion and floods and the protection of aesthetic values associated with water. It uses the knowledge of hydrology to control flood, prevent erosion, increase the yield of water from the watershed and thereby, provide an adequate supply of water for agriculture, drinking, and commercial purposes.

V.R.Desaiet al. (1999) (wb). The quantitative description of basin geometry i.e., morphometric analysis is determining by effectively used of Remote Sensing and Geographic Information System (GIS) techniques. Studied in terms of the morphometric parameters like stream length, bifurcation ratio, drainage density stream frequency, texture ratio, form factor, circularity ratio and elongation ratio and prioritised all the sub watersheds under study. The results suggest that the ratio between cumulative stream length and stream order is constant throughout the successive orders of a basin. The morphometric parameters bifurcation ratio and drainage density, confirm that the area is under dense vegetation cover and virtually the drainage has not been affected by structural disturbances. The form factor values indicate that the basin has moderately high and short duration peak flows.

V R Readdy et.al.(2000). Theimpacts of this watershed program on bio-physical, socio-economic, environmental and ecological parameters. It has also improved the environmental quality and ecological status in the watershed. The watershed interventions increased the vegetative index or greenery, reduced runoff, soil loss, and land degradations and improved the bio-diversity in fragile ecosystems. Theobjectives of Geospatial techniques are used for land and water management action planat present research work is to prepare the thematic maps of land use/ land cover, soil, slope and drainage using satellite imagery data. The study will be helpful in identification of sites for construction of different soil and water conservation structures like water harvesting structures, check dams, farm ponds, percolation tanks, nala bunds, nala widening and deepening of drainage network etc.

J.M.Read,et al year : (2002). FrLULC characterising for detecting land-cover changes using spatial methods is an area of research that has been attracting increasing attention recently. We compare performances of selected pattern recognition methods for characterising diverent land covers using unclassi ed Landsat Thematic Mapper (TM) data for a lowland site. Two spatial statistics (fractal dimension, using the isarithm and triangular prism surface area (TPSA) methods, and Moran's index of spatial autocorrelation) and selected landscape indices (Shannon's diversity index, contagion, and fractal dimension from perimeter/area) were investigated. Mean values of each metric for each cover type were calculated for subset areas representing forest, agriculture, pasture, and scrub, for all seven Landsat-TM bands, whereas the standard landscape indices were not. These results can be further applied locally using moving windows for change detection in global environmental change studies. Moreover, in this information era characterized by increasingly abundant imagery, these spatial statistics could serve as metadata for content-based data mining of imager.

John Kerr et. al. (2002). Rain fed agriculture in India's semi-arid tropics is characterized by low productivity de- graded natural resources, and widespread poverty. Most of the hundreds of millions of people livingin the Indian semi-arid tropics depend on agriculture and naturalre-source management for their livelihoods, so development planners are eager to implement productive, environmentally sustainable land and water management systems.

James R et. al. (2002). Throughout human history, water has played a central, defining role. It has sculpted the biological and physical landscape through erosion and disturbance. Watersheds are critical habitats for aquatic biodiversity of fishes, amphibians, crustaceans, and riparian plant biodiversity. Because of their climatic and topographic diversity, forested areas particularly in the mountains are hotspots of biodiversity. Water and forests have also played a key role in shaping the pattern and type of human occupancy; routes of travel and transportation, patterns of settlement, and the nature and scope of human land-use all owe their characteristics largely to water regimes. The national resources of forested watersheds have been used to develop and sustain lowland urban centers. Watersheds that have maintained hydrologic functions and processes, and those that support healthy populations of the species of interest or their specific habitats have been identified in the United States.

Vittala SS, et. al. (2004) Morphometric characterization were the variables of form factor, drainage density, coefficient of compactness, and maintenance coefficient, as well as the relief parameters found, including the hypsometry, slope, aspect and relief dissection (horizontal and vertical amplitude). The integrated analysis of the variables (morphometric and relief) concludes that the watershed has low susceptibility to flooding but that the morphology of the relief and litho logical structure favours the development of erosion processes in the watershed. The aim of this study is to characterize the morphometry of a watershed using radar data Shuttle Radar Topographic Mission (SRTM) and GIS techniques.

G.Gurjar et.al. (2007) Watershed management is primarily synonymous with the soil and water conservation with the basic concept is to reduce the floods and sediment control besides increasing. Watershed management is the most important practice in agriculture, especially in dryland agriculture. It plays a greater role in conserving the runoff water from various sources. Therain water harvesting is the major source of water in watershed. That harvested water is used to irrigate the crops under water stress condition in the dry areas agricultural food production.

Jaganathan, R.,et al.(2010). Geomatics is today widely used in land use change detection and management of water resources. The technology has found to be very effective in identification of land use changes occurred over a period of time with temporal data. Explosive growth of urbanisation, increasing demand of water for industries and IT parks have resulted in reduction of water bodies and land use in southern sub urban area. Detection of land use changes brings out aquifer hazards in the study area. The present paper summarizes the aggravating groundwater problem and gives solution through geomatics by integrating drainage, geology, geomorphology, lineament, soil, water level, rainfall and land use for the periods 1994, 2004 and 2008. By synthesizing the satellite data and hydro geological information, changes in land use category, uprising aquifer hazards, unaccountable groundwater extraction surpassing over unplanned growth of urbanization which have trigged the hydro geological imbalance, lowering of water level have been identified.

Sudhansu et. al. 2011. Geographical information sciences to measure and manage water resources are diverse. Satellite remote sensing provides essential data for mapping water resources, hydrology flux measurement, monitoring drought, and flood inundation. GIS-based systems for managing urban storm water; for flood and soil erosion management; for mapping groundwater zones; for crop production, including measuring soil moisture and aridity; for gauging the impact of climate change; for evaluating glacier change dynamics; for assessing the impact of urban growth on water resources; for measuring the degradation of rivers.

Scaria,R.et. al.(2012). Water Harvesting Structures (WHS) is one of the main responses to water scarcity and groundwater depletion within catchments. WHS are a major part of watershed development in India and are increasingly seen as essential for ensuring the sustainability of local groundwater use structures such as check dams,sfmis,wds infiltration tanks and contour bunds - all of which aim to slow down and capture runoff and increase groundwater recharge. The effectiveness of WHS in a catchment depends on three main factors: the efficiency of groundwater recharge; the storage capacity of the underlying aquifers; and the dynamic interactions between surface water and groundwater. Even in areas that have poor groundwater recharge efficiency and low aquifer storage capacity, WHS, are being used as the main interventions and for every WHS built within a catchment area.

Jajnaseni Rout et al. (2012). Watershed is an area of land and water bounded by a drainage divide within which the surface runoff collects and flows out of the watershed through a single outlet into a lager river (or) lake. Land and water are the two most valuable and essential resources which forms the basis of all the life and forms key resources in all economic activities ranging from agriculture to industry. Watershed management is no longer the exclusive domain of soil and water conservationists, it now needs equal contribution from social scientists, doctors and experts of other disciplines also.

Das Ajoy,et al. (2012). Watershed is the line separating neighbouring drainage basins (catchments). In hilly country, the divide lies along topographical peaks and ridges, but in flat country (especially where the ground is marshy) the divide may be invisible – just a more or less notional line on the ground on either side of which falling raindrops will start a journey to different rivers, and even to different sides of a region or continent. Drainage divides are important geographical. Bankura , Purulia drought prone district of the West Bengalin spite of considerableamountofrainfall, due to heavy runoff the main problem of this area is scarcity of water as well as soil erosion. It has been accepted that for sustainable rural livelihood water and soil consumption is must and most suitable way to achieve this is micro watershed management.

P. pathak, et al. (2013). Integrated watershed management is recognized as a potential approach for agriculture growth and rehabilitation of fragile and degraded lands. The agriculture in low rainfall areas of eastern Rajasthan, India is characterized by high risks from drought, degraded natural resources and pervasive poverty, food insecurity and malnutrition. In this region, water is the main limiting factor for upgrading rain fed agriculture.

P.D Jhankar. et.al.(2013). Watershed management is a planed to take such engineering and biological measures which will direct extra run off to ground water storage. The most significant feature of this work is that if technologies are developed and adopted in larger scale in rural areas. It will prevent thousand of villages of the country from water supply of the tankers. GIS an essential tool for watershed planning and management tasks. Forthe GIS mapping drainage network, topography, flow path of water are to be easily locate. Watershed management is not so much about managing natural resources, but about managing human activity as it affects these resources. The drainage area of the river provides the natural boundary for managing and mitigating human and environmental interactions. Because human activity includes actions by government, municipalities, industries, and landowners, watershed management must be a co-operative effort. Effective watershed management can prevent community water shortages, poor water quality, flooding and erosion.

MB Dongardive, et al. (2018). Land and water management action plan of micro level planning and usefulness of modern toolsofGeospatial techniques were usedand technology a study on water resource planning of water resources for micro watershed was conducted. The objectives of the present research work was to prepare the thematic maps of land use/ land cover, soil, slope and drainage using satellite imagery data and survey of India (SOI) top sheet of micro watershed and to integrate all the maps under GIS environment to prepare the water resource management plans for the study of micro watershed.

Mondal I., et al. (2019) use a GIS-based DRASTIC model for assessing groundwater vulnerability in the Jangalmahal area, West Bengal, India. Groundwater vulnerability assessment to delineate areas that are more susceptible to contamination from anthropogenic sources has become an important element for sensible natural resource management and land use and land cover planning of the Jangalmahal area. The study area reveals that about 43.5% of the watershed area is exposed to high-risk, 11.6% exposed to medium-risk, and 45.26% exposed to the watershed are dominated by high vulnerability classes while the north-western and middle portions are characterized by moderate vulnerability classes. The elevated northern and lower part of the study area shows the low aquifer vulnerability zone. The estimated DRASTIC index gives an indicator of the prevailing vulnerability in this Jangalmahal area.

Y.Arafat M.N et. al. (2020). Hydrograph is a way of predicting the amount of flood discharge plans in a watershed. Each watershed has different drainage characteristics due to the topographic shape of the watershed, land use, river typology (length, number, and slope), height and duration of rainfall. This research was conducted in Palu River Basin, with a basin area of 3. 060,388 km2,

Kassateka et. al. (2020). The study aimed at evaluating the impact of integrated watershed management on reducing soil erosion and changes in the livelihoods of rural farming households in Ethiopia. The changes in soil erosion for the years between 2002 and 2015 were estimated using the Revised Universal Soil Loss Equation model, while the impacts on livelihoods were assessed by household interviews. During the study period, the overall average annual soil loss was halved. Furthermore, crop productivity, water availability (irrigation and domestic) and fodder availability increased by 22, 33 and 10%, respectively, while an increase in household income (by 56%) was observed. Moreover, 72% of the sampled households were able to cover their 12-month annual expenditure demands in 2015, while only 50% of the households were able to cover these demands in 2002. It can be concluded that the implemented integrated watershed management activities seemingly resulted in reduced soil loss, enhanced vegetation cover, and additional household income. This paper also elaborates on the hurdles for integrated watershed management expansion.

CHAPTER-3 DESCRPTION OF STUDY ARE

3.1 INTRODUCTION

Bankura District is the western most district of West Bengal. The study area is situated The latitudinal extension of the river basin is 23°13'28"N to 23°30'25"N and the longitudinal extension is 86°53'13"E to 87°07'30"E.Geomorphologically, the landscape of Bankura may be described as a connecting link between the plains of Bengal and the Chhotanagpur plateau. Gandheswari River flows North- Western part of the district through four blocks viz. Bankura, Saltora, Chatna, and Gangajalghati. It has originated at Saltora (BM-162m.) and flows towards South-East and meets with river Darakeswar near Bankura town (BM-76m.). Maximum and minimum elevation of the river basin is 440 meter and 76 meter. The total length of Gandheswari River is 49 km and is a 5th order stream.

The area of interest is underlain by Pre-Cambrian Metamorphic rocks excepting a small area in the north eastern part where a sedimentary rock of Gondwana age predominates. Unconsolidated sediments of recent to sub recent age are restricted in narrow river channels and to the valleys. The area may be considered as pen plain with slight undulating surface configuration. Actually it is a part of the Ranchi peneplains. The general elevation ranges from 300m to 150m, the master slope being towards the east and south east. Most of the streams have easterly to south easterly course except the northern tributaries of Damodar river and western tributaries of Subarnarekha river.

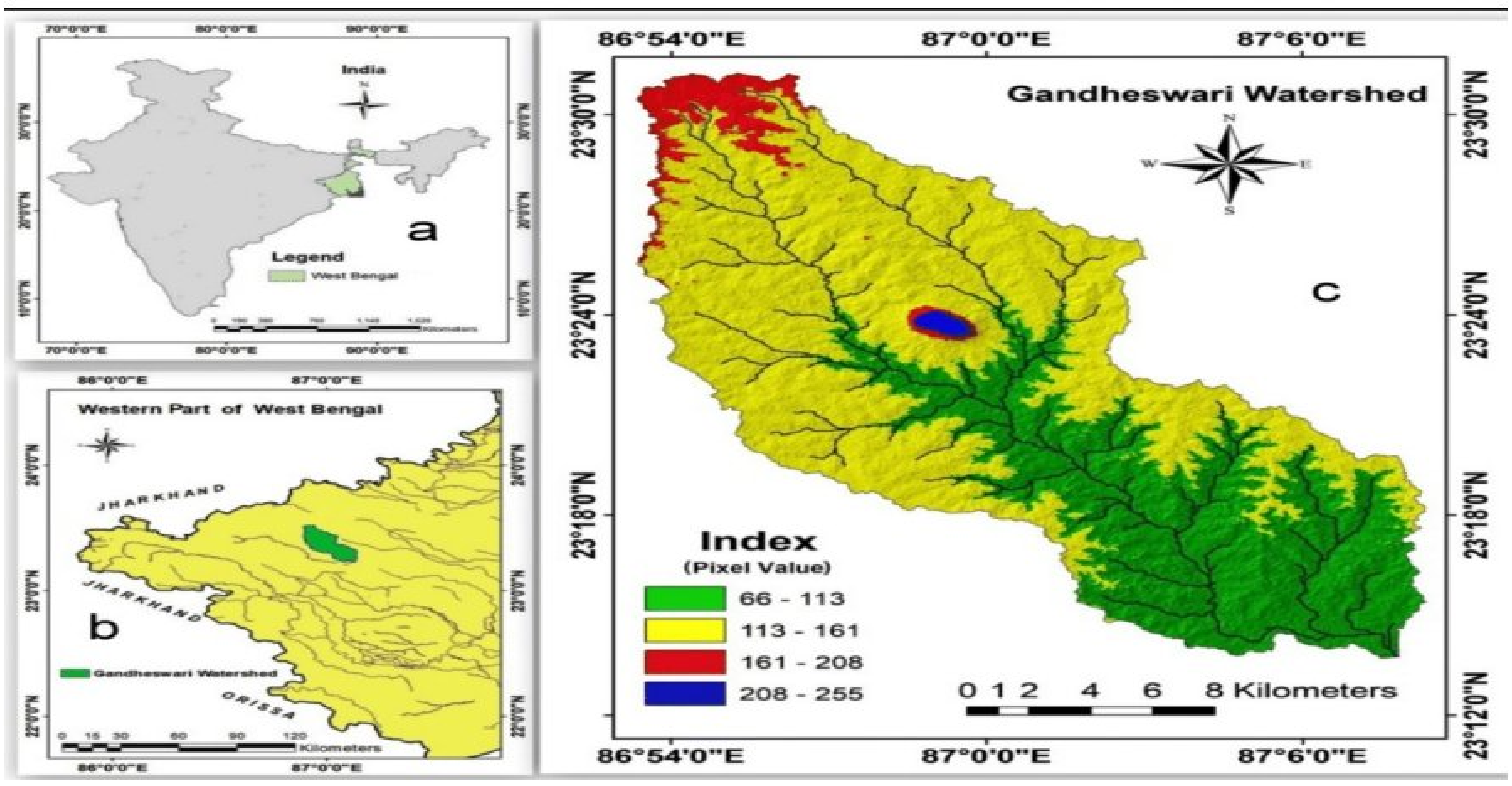


Fig.3.1: Study Area Map

3.1.1. GEOLOGY& TOPOGRAPHY:

Due to undulated topography nearly 50% of the rainfall flows away as runoff. The area is covered mostly by residual soil formed by weathering of bedrocks. The areas consist of numerous pediments, ridges and valley fills. This region receives significantly less rainwater. Soil related data indicates that the soil of this zone is also infertile. Soils are coarse in texture, erosion prone; acidic in nature, nutrients are less in soil.

The geological foundation of the study area is mainly Azoic (Archaean). This is the oldest formation with combination of granites, Chotonagpur gneisses and few ultra basic rocks. The dolerite, pegmatite, aplit, vein quartz, granite, gneiss, are most common rocks. This region is the combination of three principal types of formations;Gandowana super group, Chotonagpur Gneissic Complex and Tertiary alluvium. The upper layer of soil covers with sedimentary rock of stone and conglomerate. The Shushunia hill zone covers with gneiss which composed with sillimanite and kyanite bearing quartzite. It is metamorphosed form of peri-alluminaus sedimentary rock of Proterozoic formation. The Silurian (Paleozoic era) was the origin era river Gandeshwari when the warm and green house phase has started . The site and situation of the water flow was full of fallacies. Metamorphosed quartz-sand stone (rocky) covers the outer surface near the source region of river Gandeshwari. This study area is small container of vast geological history and this river depicts the palaeo-geological events by its diversified rock strata. Here the lineament is the most dominant factor which controls the river course. In spite of consequent nature of river course, the lower confluence is totally guided by the lineament (Fig.3). The typical meandering near the estuary of Gandeshwari River (near Banki Village) is simple reflection of under lying lineament.The latitudinal extension of the river basin is 23º13'28"N to 23º30'25"N and the longitudinal extension is 86º53'13"E to 87º07'30"E.

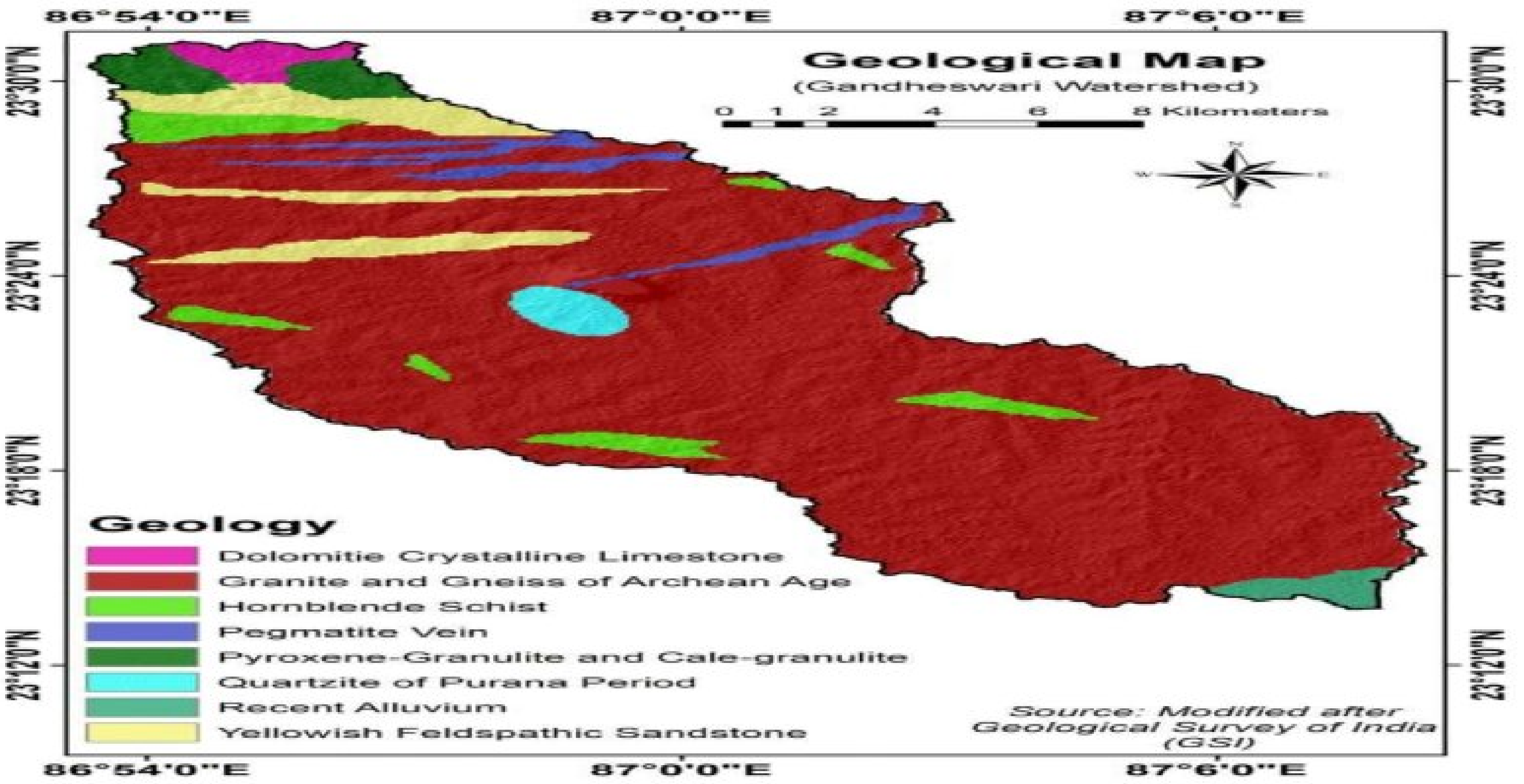


Fig.3.2: Geological Map

3.1.2 SOCIAL ECONOMIC PROFILE OF THE AREA

Socioeconomic status (SES) is one of the most widely studied constructs in the social sciences. Several ways of measuring SES have been proposed, but most 2 include some quantification of family income, parental education, and occupational status. Socioeconomic status (SES) indicates one's access to collectively desired resources, be they material goods, money, power, friendship networks, healthcare, leisure time, or educational opportunities. And it is access to such resources that enable individuals and/or groups to prosper in the social world. The prosperity of a region or district depends directly upon the socio economic development of the area which can be understand through the study socio-economic status of the concerning region. It includes the developments of agriculture, Industry, infrastructure, transport and communication, educational facilities, etc. All these facilities and services comprise collectively the infrastructure of an economy. The development and expansion of these facilities are an essential prerequisite for increasing agricultural and industrial production in a district as well as development of the region. Infrastructural facilities are directly related with population and area. Gdpis11,729.33 crore (equivalent to ₹280 billion or US$4.3 billion in 2017) as per data of 2013-14.

The prosperity of a region or district depends directly upon the socio economic development of the area which can be understand through the study socio-economic status of the concerning region. It includes the developments of agriculture, Industry, infrastructure, transport and communication, educational facilities, etc. All these facilities and services comprise collectively the infrastructure of an economy. The development and expansion of these facilities are an essential prerequisite for increasing agricultural and industrial production in a district as well as development of the region. Biotechnology, information technology, desalination and improve water management increase water productivity. Irrigated areas are expanded; storage in increased, human water use goes up considerably.

. Agriculture occupies an important placein the economy of Bankura. It not only provides food to the large and fast growingpeople but also raw materials to numerous agro-based industries. About more than75 per cent of the working population is directly or indirectly engaged in agriculture.

Table-3.1Production and Productivity of major crops n Bankura district.

Crops	Area(Thousandhect ares)	Production (Thousand Tons)	Productivity (Kg/hec)
Rice	198	507.5	2563.13

Wheat	3	6.8	2266.67
Maize	0.3	0.7	2333.33
OtherCereals	0.1	0.1	1000
Pulses	0.2	0.1	500
Oilseeds	26.7	20.9	782.77
bres (Jute, Mesta, Other Fibres)	0.10	0.7	7000
Potato	30.3	1190.4	39287.13
Chillies(dry)	1.5	1.7	1133.33
Ginger	0.3	0.4	1333.33

Landisanimportantcomponentonwhichphysical,economicandsocial development depends. Land provides food and variety of minerals and therefore it needs proper use. Land resource has very often been left in the past entirely ofprimitive methods. This has led to proper use of land resulting basic resource which has gradually deteriorated (Siddiqi, 1971). There is consequent need of system ofland utilization (Stamp, 1960) as the pressure of population is growing up on limited land resources. Natural scientists have defined land use in terms of syndromes ofhuman activities such as agriculture, forestry and building construction that alter surfaceprocessesincludingbiogeochemistry,hydrologyandbiodiversity. Social scientistsdefinedlandusemorebroadlytoincludethesocialandeconomic purposes within lands which are managed or left unmanaged such as subsistenceversus commercial agriculture, rented versus owned or private versus public land.

Gandheswari river is 49 kilometres (31.36 miles) long, flows in Bankura district, West Bengal India. It originates near the border zone of District Purulia and Bankura (West Bengal). It flows side by the Shushunia Hill (height 440 m, 23° 22' 30" N and 86°58'20" E) and occupies an area of 389 square km (approx) and north of Bankura and it meets the Dwarakeswar river near Bhujsahar . It is subject to sudden flooding during rains (flash flood).

3.1.3 POPULATION OF RURAL AND URBAN

Out of total population of Bankura, 3,992,309 in the district, 299,773 are in urban area and 3,296,901 are in rural area. 65,743 households are in urban, 701,159 are in rural area. 230,340 literate people are in urban, 2,002,652 are in rural area. The district has a total area of 6,882 sq km., 90.47 sq km is urban and 6791.53 sq km is rural.

TABLE3.2: POPULATION CENSUS DATA (2011)

Source: https://www.censusindia.co.in/subdistricts/blocks-bankura-district-west-bengal-339

BLOCKS	POPULATION 2011
Bankura	234,254
Bankura-I	107,685
Bankura-II	140,864
Barjora	202,049
Chattna	195,038
Gangajalhati	180,974
Hirbandh	83,834
Indpur	156,522
Indus	169,783
Jaypur	156,920
Khatra	117,030
kotulpur	188,775
Mejhia	86,188
Onda	252,984
Patrasayer	184,070
Raipur	171,377
Ranibundh	119,089
Saltora	135,980
Sarenga	106,808

Simlapal	143,038
Sonamukhi	158,697
Taldangra	147,893
Vishnupur	156,822

3.1.4 CLIMATE AND TEMPERATURE

The climate especially in the upland tracts to the West is much drier than in Eastern or Southern Bengal. Hot westerly winds blows from the beginning of March to early July. The cold season starts about the middle of November continues till the end of February, and the hot season extends up to May. The south western monsoon season continues at the end of September, October and the first day of November constitutes the past monsoon season. The temperature rises rapidly about from early March. May is the hottest month with a mean delay temp.45°C on the exceptional day of May and the June day temp rises up to 45°c. January is the coldest month a maximum temp of 25.3°c and a minimum 12.4oc. During the assuage of western distribution areas in north India, cold weather is experienced with a minimum temperature of 5°to 6°c. at night.Changes in the climate regime can influence natural processes of a watershed ecosystem. Climate-induced increase in surface temperatures can impact hydrologic processes of a watershed system. This study uses a continuous simulation model to evaluate potential implications of increasing temperature on water quantity and quality at a regional scale in the River Watershed. It was predicted that climate change can have a significant affects on stream flow, sediment loading, and nutrient (nitrogen and phosphorus) loading in a watershed. Climate change also influences the timing and magnitude of runoff and sediment yield. Changes in variability of flows and pollutant loading that are induced by climate change have important implications on water supplies, water quality, and aquatic ecosystems of a watershed. Potential impacts of these changes include deficit supplies during peak seasons of water demand.

3.1.5 RAINFALL

The average annual rainfall 1400mm the cold and hot weather raise are very light. Yearly rain about 85% of Rainfall occurs from June to September constitute. August is the wettest month of the year. The days are pretty pleasant from November to mid-February, but the nights are cold an extreme temperature is found. South-west monsoon is the primary source of rainfall. Bankura often suffers drought conditions due to shortage of rainfall. A rainfall map has been collected from the Central Ground Water Board. The southern part of the district receives maximum rainfall, whereas eastern and central part gets minimum rain. But this slight variation in precipitation has no significant influence on the occurrences and availability of groundwater because most of the water goes away as surface runoff due to the hard rocky terrain.

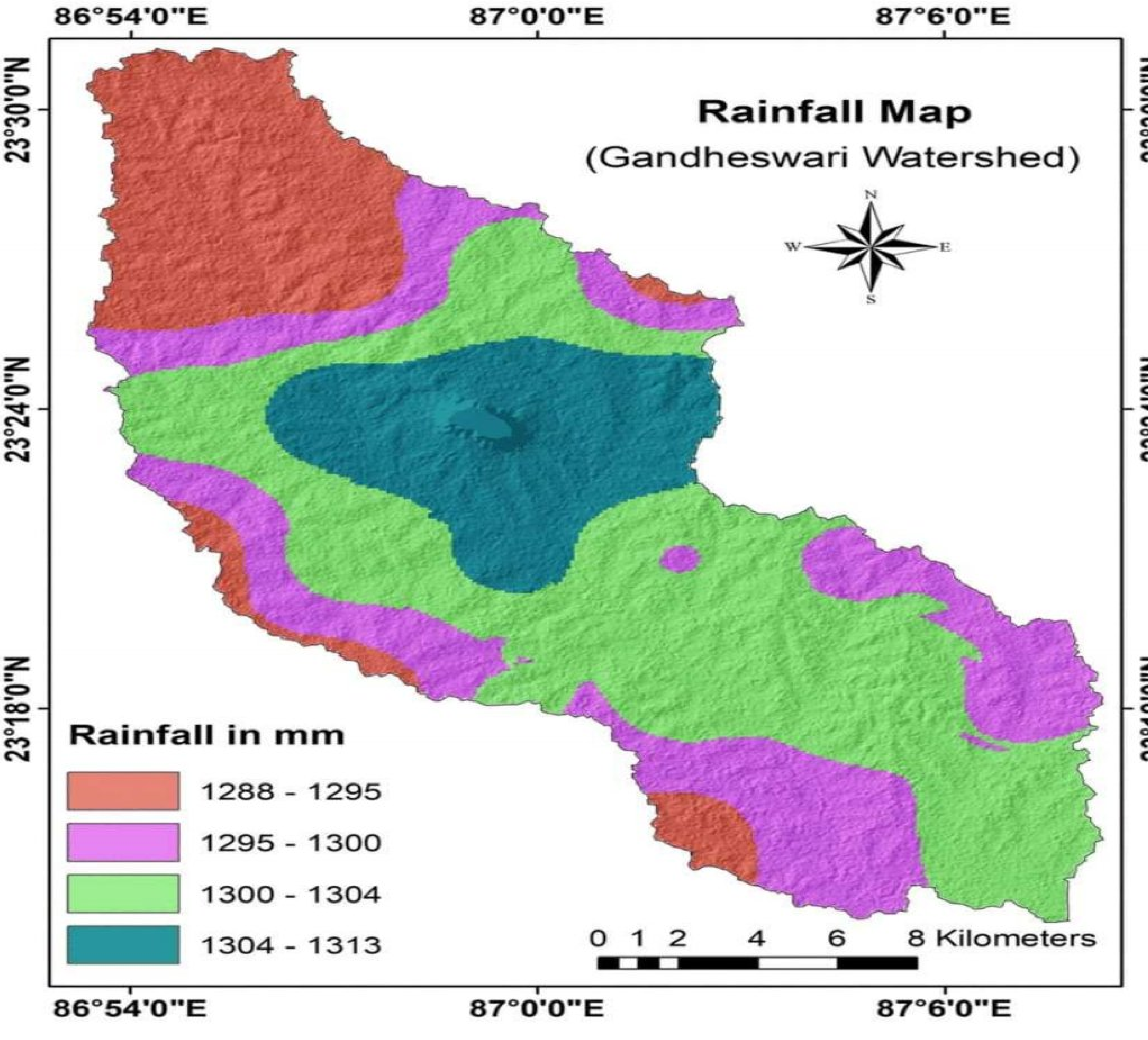


FIGURE 3.3: RAINFALL MAP

A general rainfall-temperature graph has been given below (Figure No. 3.4).

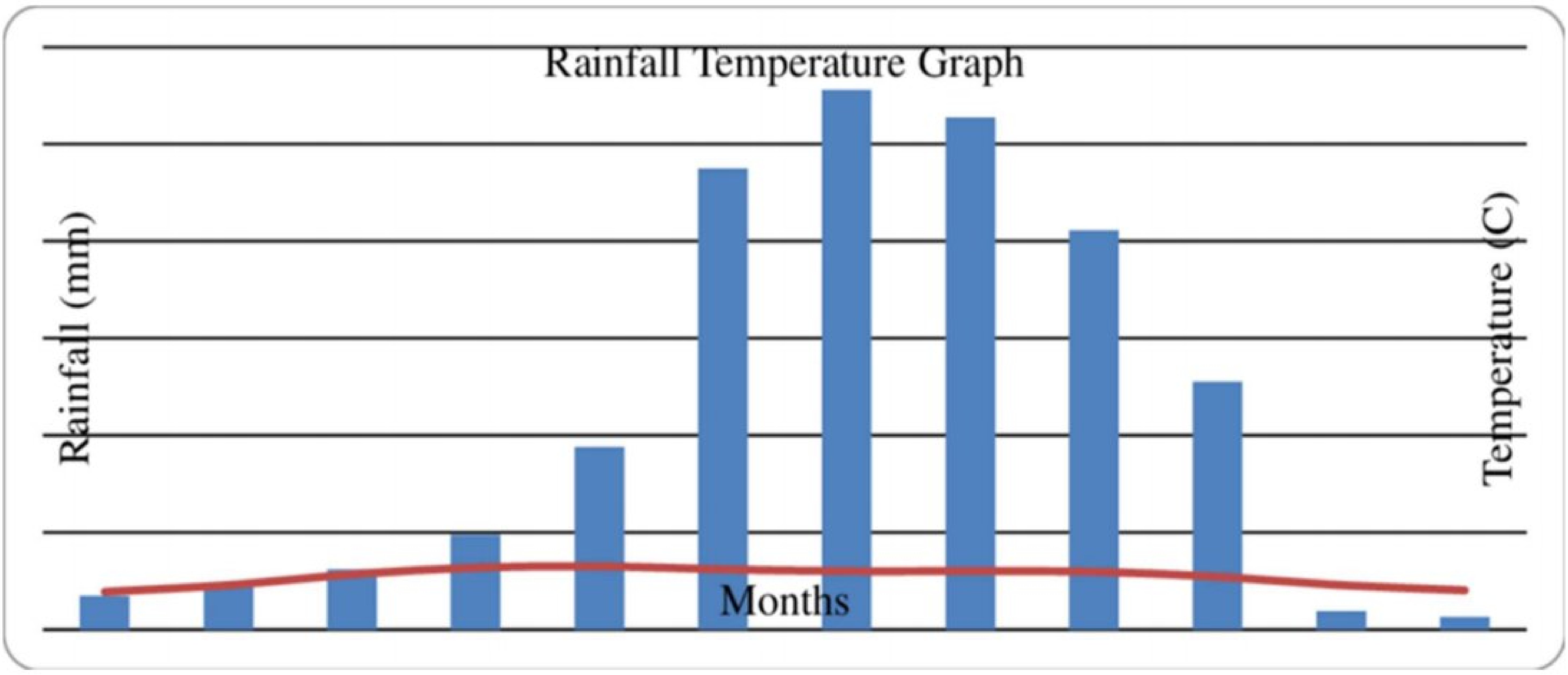


Figure No.3.4 Rainfall and Temperature of Gandheswari River Basin.

TableNo.3.3 Temperature and Rainfall Scenario of Catchment Area

Months	Average Monthly Rainfall in mm	Average Monthly Temperature in^{0}C
January	17.2	19.3
February	22.1	22.8
March	30.9	28.3
April	48.7	31.8
May	94.0	32.5
June	237.5	30.9
July	278.0	30.0
August	263.7	30.0
September	205.7	29.7
October	127.6	27.1

November	9.3	22.8
December	6.4	20.1
Total	1341.1	

Source: Agricultural Meteorologist, Directorateof Agriculture, Government of West Bengal

3.1.6 SLOPE

The slope map of study area (Figure 3.4) is created from the DEM image of Bankura district. The 0-2 degree of the slope demonstrates the flat zone, which is good land for developing agriculture. 5-11 degrees of the slope has some Steepness and is respectably reasonable for growing crops.

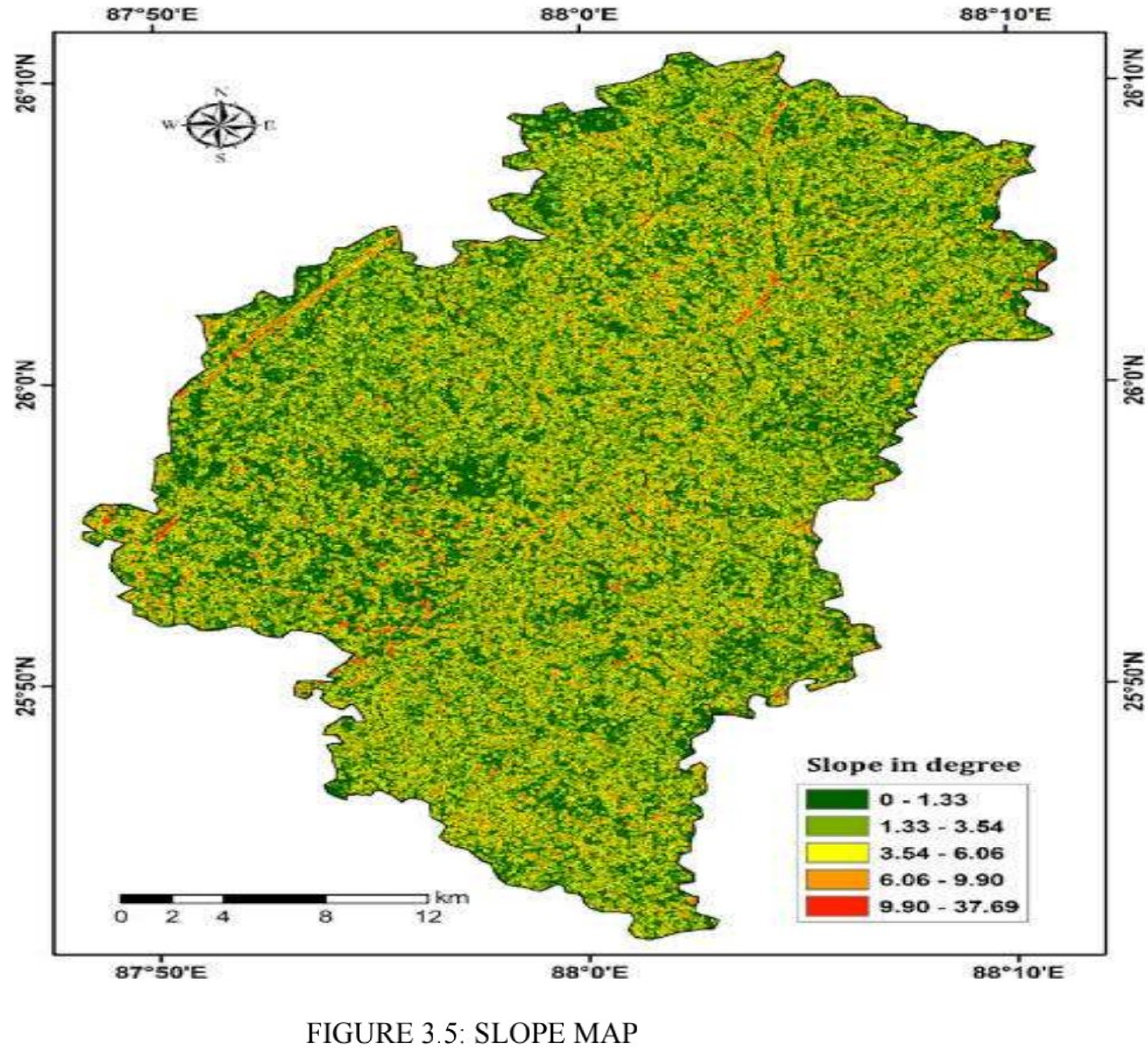


FIGURE 3.5: SLOPE MAP

3.1.7 VEGETATION& FOREST COVER

Bankura district forest is pre dominantly Sal and its associated species and plantation forest of Eucalyptus and Akashmoni. Bankura holds one of the best quality of Sal forest in West Bengal particularly at Radhanagar, Sonamukhi and Patrasayer and the entire Bishnpur sub-divisional jurisdiction. The large gregarious Sal is the mast predominant forest tree. There are two realities of sal the most prevalent, having dark brown heartwood while that the Dom sal, of the lower hills so white, slightly tinged with red. Besides Sal Muchkunda, a tall evergreen tree, the tall and shady Shimul and Palash are also found. Mauha is also an essential tree of this region. In the woodland, there is a thick cover of greens and a layer of shrubs beneath the level of the forest foliage, depending on the subtle variation. There is also a protected forest called Joypur forest that covers with another Beliatoreforest cover has, however, being cleared and degraded or replaced by shrubs, bushes, and cultivated fields at the foothill plains. It was indeed a part of the jungle mahal, a land of tropical deciduas forest due to biotic interference such as shifting cultivation, fire, graze ring, and unscientific forest management. Such interference has affected the flora of the district. Either by checking the progress of vegetation to the higher succession stage or by bringing about a hetrognention.

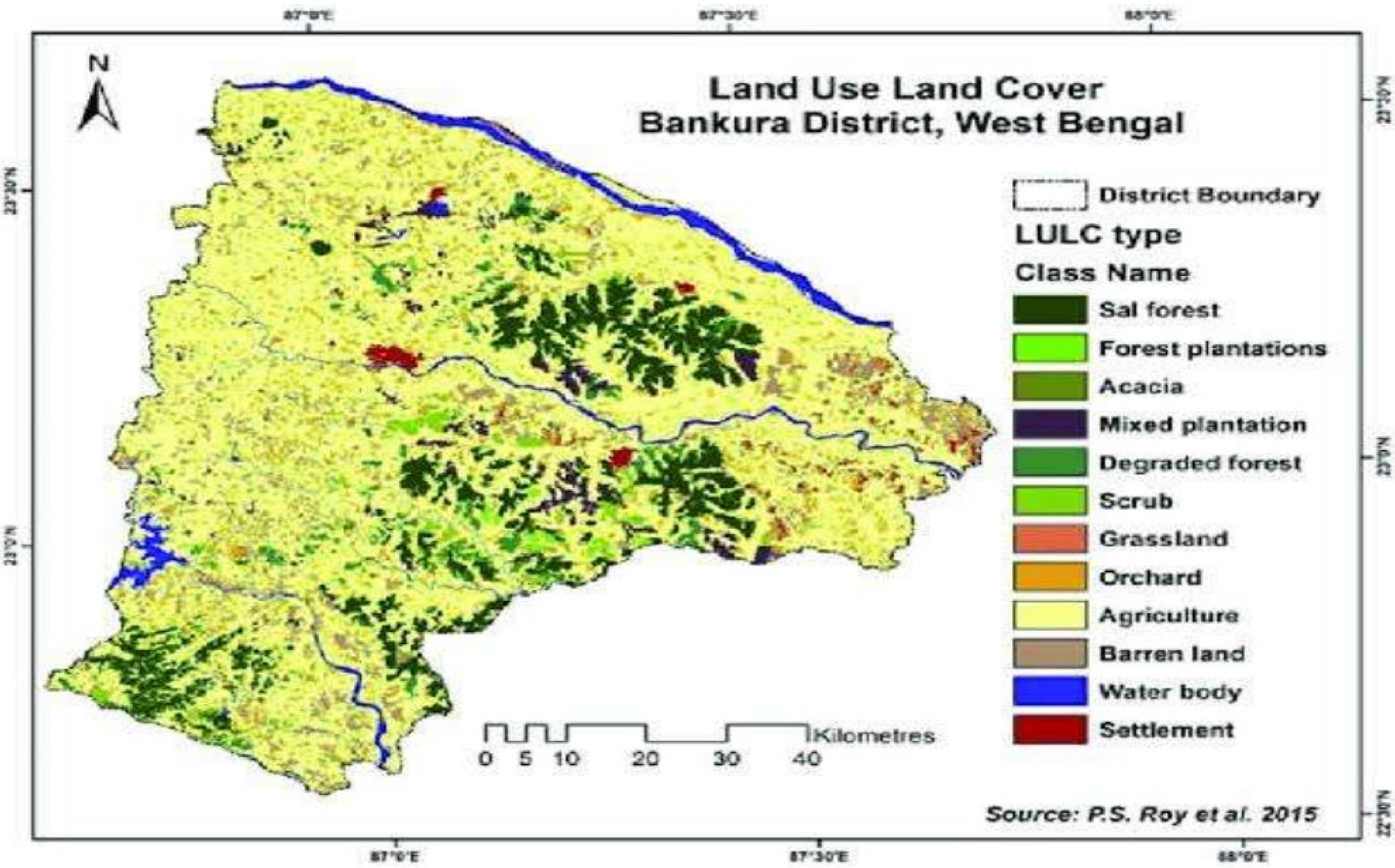


FIG. 3.6 LAND USE LAND COVER MAP

3.1.8 SOIL TYPE:

According to the textural types, soils of the district can be classified under the following types: (1) Sandy (2) Sandy Loam (3) Loam (4) Sandy Clay Loam (5) Clay Loam (6) Clay, clay dominated loam and loamy soils are mostly confident to the flood plains of the Damodar and the Dwarkeswar rivers through sporadic occurrences. This type of occurrences is also seen in other small river valleys. The district as a whole is covered generally by sandy loam. Typical red soil has limited distribution in the south central, south-eastern and south western parts of the district around Bishnupur, Kotulpur and Raipur blocks respectively. They are the red coloured sedentary soil (i.e. those formed from residual parent materials) found mainly on laterites supporting Sal vegetation. They are also found along the margins of small hills bare of vegetation. They are free from CACO3, low in Base Exchange capacity and have a highly unsaturated base. They may be derived from laterites by a process of resilicification by ascending ground water but cannot be grouped either as laterites or laterite soil.

Brown soils from a group within this class which are also sedentary in nature, mainly derived from rocks like sandstone, granite gneiss and schists. The alluvial soils, which have wide distribution in the east-central and southeastern parts of the district, are grouped according to soil association as Damodar-Rajmahal riverine, Damodar flatlands, Damodar highlands etc.The laterite soils have wide distribution in the south-central to the south western part of the district. Such soils are distinguished from the red soils by the occurrence of ferruginous concretions in a definite layer, whereas in the red soils they are distributed throughout the profile.

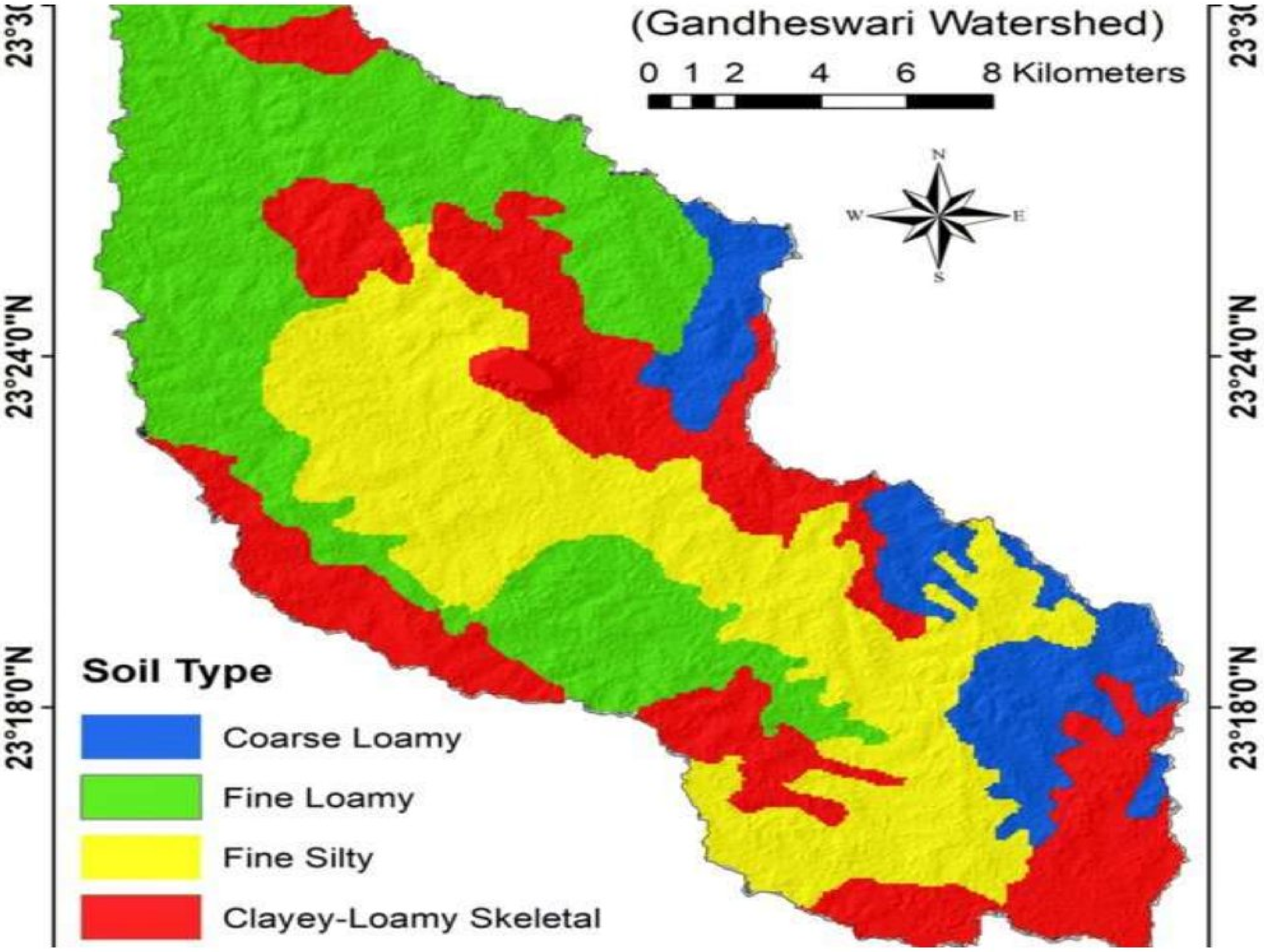
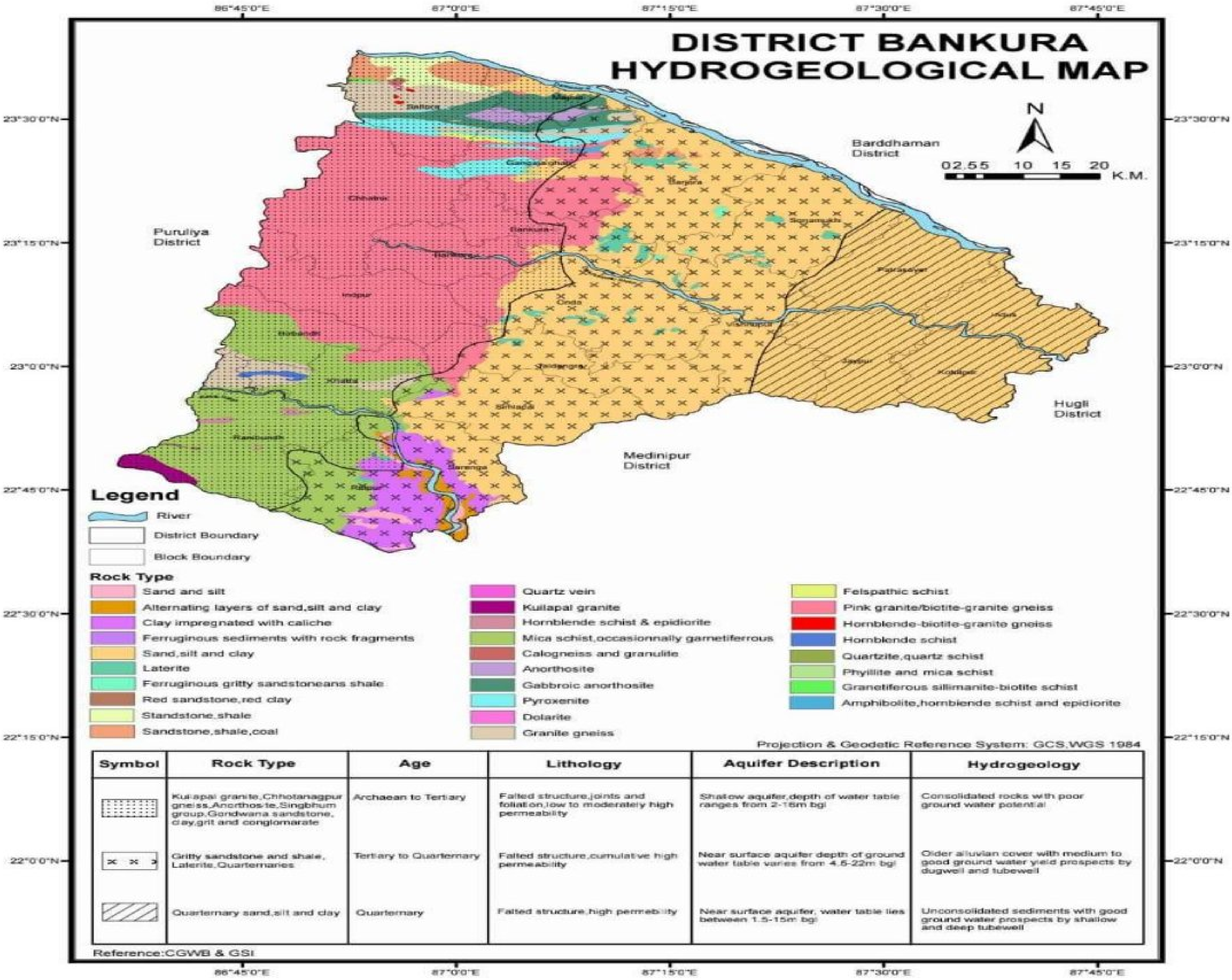


FIG. 3.7 SOIL MAP

3.1.9 GEOMORPHOLOGY AND HYDROGEOLOGY

The study area is slightly elevated near level to moderately sloping tracts of uplands and shallow valleys alternating in space throughout the area and it is the northern part of bankura district and south west of study area is Susunia hills. Geo-morphologically, the study area represents moderately undulating terrain. The depth of the water table varies from 3m to 12m. Rainfall is the prime source of groundwater recharge. The central part of the district is represented by pen plain with widely scattered residual hills produced by denudation processes.



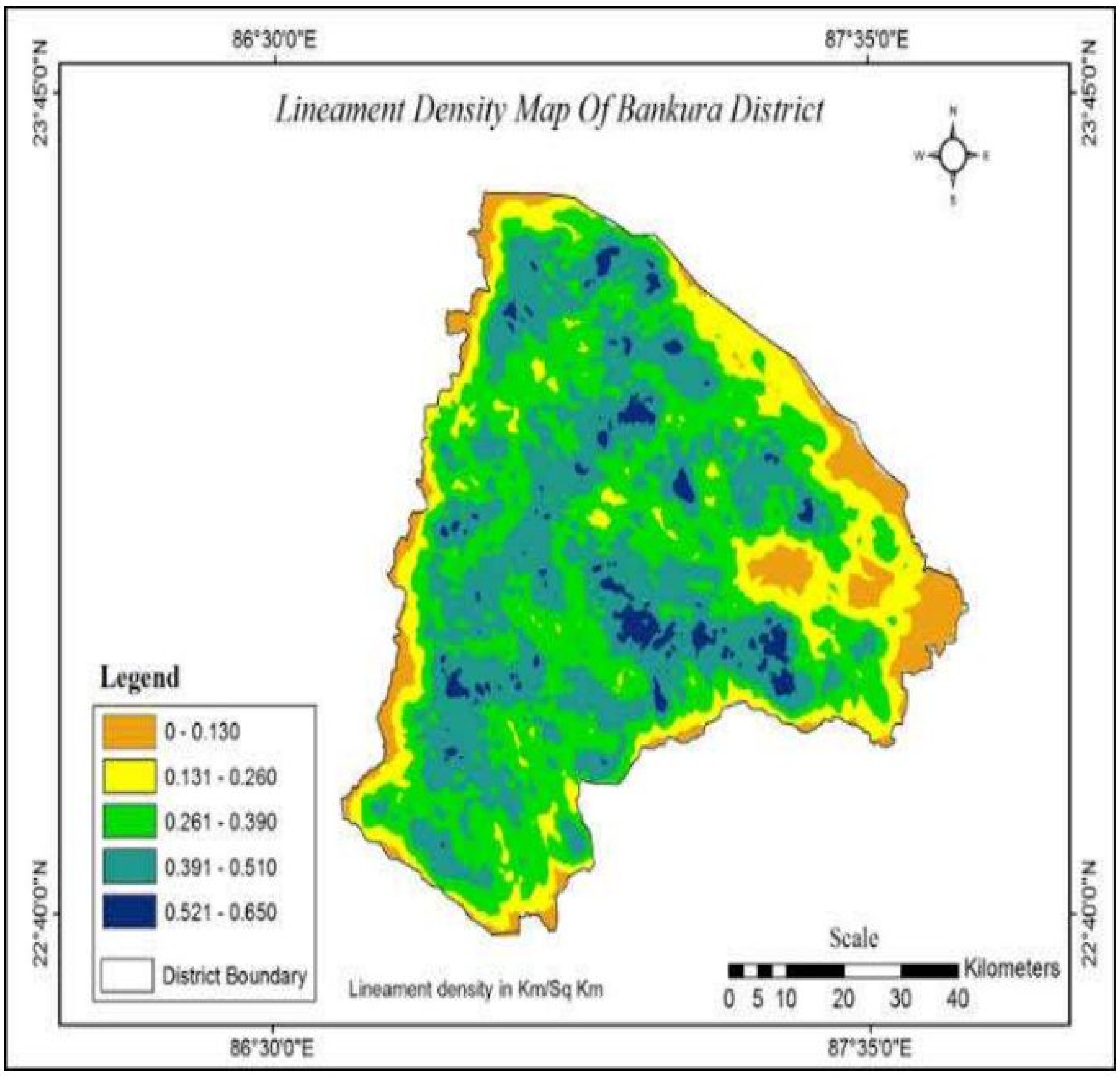
Symbol	Rock Type	Age	Lithology	Aquifer Description	Hydrogeology
	Kuilapal granite,Chhotanagpur gneiss,Anorthosite,Singbhum group,Gondwana sandstone, clay,grit and conglomarate	Archaean to Tertiary	Falted structure,joints and foliation,low to moderately high permeability	Shallow aquifer,depth of water table ranges from 2-16m bgl	Consolidated rocks with poor ground water potential
× ×	Gritty sandstone and shale, Laterite,Quarternaries	Tertiary to Quarternary	Falted structure,cumulative high permeability	Near surface aquifer depth of ground water table varies from 4.5-22m bgl	Older alluvian cover with medium to good ground water yield prospects by dugwell and tubewell
	Quarternary sand,silt and clay	Quarternary	Falted structure,high permebility	Near surface aquifer, water table lies between 1.5-15m bgl	Unconsolidated sediments with good ground water prospects by shallow and deep tubewell

FIGURE 3.8: HYDROGEOLOGY MAP

The soil cover is fragile and composed of loose, gritty, sandy, reddish material. There are sparse in-filled valleys and depressions which are narrow and shallow in character. The groundwater is mainly controlled by secondary porosity, interconnected fracture, joints, bedding plains, and fissures within-country rocks. The area, in general, does not hold good potential for the development of groundwater. However, the narrow alluvial tract of the main drainage and small in-filled valleys have moderate to good groundwater potential.

3.1.10 LINEAMENT DENSITY

Lineaments are linear and curvilinear structural features that play a significant role in groundwater occurrences and movements in the hard rocky areas like Bankura. Ground occurrences depend on secondary porosity and permeability (Acharya & Nag, 2013). Lineaments like joints and fractures help to infiltrate the surface run-off to the subsurface. Lineaments are considered to be good potentials for groundwater.



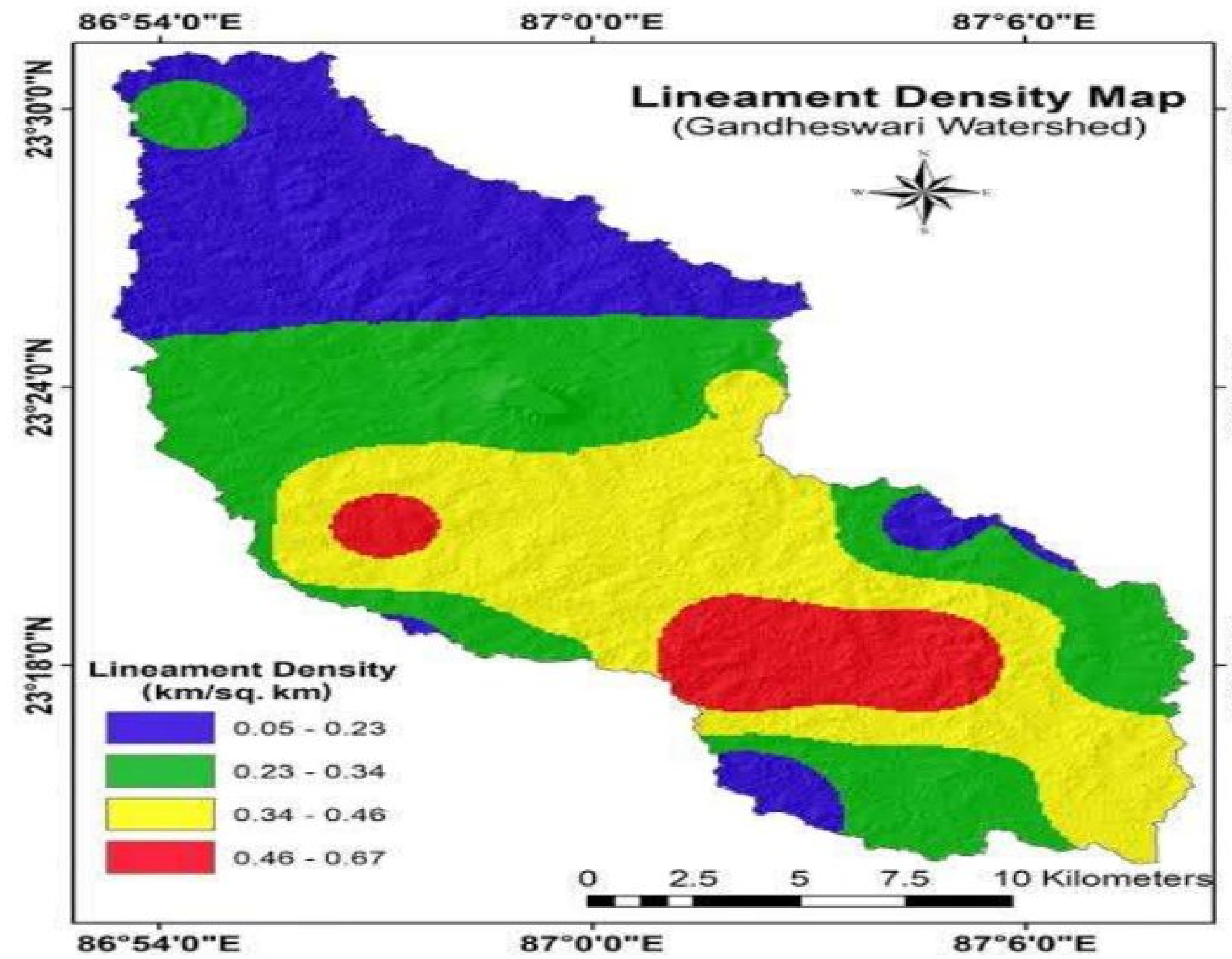


FIGURE 3.9: LINEAMENT DENSITY MAP

3.1.11 WATER QUALITY SCENARIO OF STUDY AREA

Water quality is poorly understood due to the variety in the interactions between water and soluble minerals, sparingly soluble minerals, and salts, both natural and anthropogenic. Despite the complex hydro and biogeochemical factors, the number of dissolved constituents in groundwater is limited. In addition to the trace constituents in water, the significant components are Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-} (as acid and salts), Cl^-, HCO_3^-, etc., and the secondary constituents are Fe^{2+}, Sr^{2+}, K^+, CO_3^{2-}, NO_3^-, and F^- (fluoride). Fluoride (F) becomes toxic when drinking water beyond the maximum permissible limit of 1.5 ppm.

Table 3.4: Effect of fluoride in water on human health

Fluoride Concentration (mg/L)	Effects
<1.0	Safe limit
1.0-3.0	Dental fluorosis (discoloration, mottling and pitting of teeth)
3.0-4.0	Stiffened and brittle bones and joints
4.0-6.0 and above	Deformities in knee and hip bones and finally paralysis making the person unable to walk or stand in straight posture, crippling fluorosis

Fluorine is a fairly common element that does not occur in the elemental state in nature because of its high reactivity. It accounts for about 0.3 gm/kg of the earth‟ crust and exists in fluorides in several minerals. Fluoride is found almost everywhere in the environment. It is available in air, water, and virtually all foodstuffs. In seawater, a total concentration of 1.3mg/litre has been reported. In areas rich in fluoride-containing minerals, well-waters may contain up to 10mg or more fluoride per litre. The level of daily fluoride exposure depends mainly on the geographical area. Chronic exposure to the fluoridated ground or drinking water creates a health problem in human beings and diverse species of domestic animals in the form of Osteo-dental fluorosis. Only fluoride concentration in water less than 1.0 mg/l is considered safe for human consumption; however, the maximum permissible limit is 1.5 mg/l. (WHO 2011)

3.2. CHRACTERISTIC OF STUDY AREA

The Gandeshwari river basin is uniclinal and gentle slopping river basin except the Shushunia hill zone (Fig 1 and 2). The average height of this basin area varies from 90 m to 437 m. This river flows over the extended part of Chatonagpur plateau and it lies in the extreme eastern end of Purulia Bankura ductile shear zone. This is the ancient land mass and the land is older than Pleistocene. During the Silurian, earth underwent considerable changes. Here the tectonic activity continued to shift the continents during the Silurian. The zone has experienced a long warm greenhouse phase during early Permian .This region was in southern hemisphere (40° S) and marked by the aridity during the Silurian era (Table 2). This study area comprises with undulating Plane (Below 120metre), eroded plateau (120-220 metre) and ShushiniaHill Zone (220-437 metre). The undulating plane is just like a pene-plane (Davician concept) and the inclination of land is unidirectional too.

The main drainage pattern of this river is dendritic or sub dendrictic. This drainage pattern indicates that surface layer of basin is homogeneous in nature and it maintains uniformity in erosion and weathering processes. The dendritic and sub dendritic pattern of Gandeshwari rivulet signifies the following geomorphic facts: (i) Uniform sub surface and Sub surface layer (rocks and mineral composition) (ii) Uniform rate of erosion (obviously by uniform erosion agents) (iii)The principal gradient is toward the main surface runoff (Fig.2) (iv) The surface runoff is mainly subsequent and consequent types (v) Uniformity in surface elevation.

3.2.1 BASINGEOMETRY

BasinArea(A)andBasin Perimeter(*P*)

Basin area, basin perimeter and channel length are significant morphometric variables whichdeterminetheshape,sizeandgenetic aspect of relief, drainagenetwork and characteristics ofdrainage basin. The drainage area is probably the single most important watershed characteristic tohydrological design and reflects the volume of water that can be generated from rainfall (Pal &Debnath, 2012). In the present study shows that the area of the basin is 364.9 sq.km and perimeter oftheriveris 101.54 km(Table No. 3.9).

BasinLength(Lb)

Generally the basin length can be measure of main axis of flow on which the basin is divided. In thatcasethetotallength of Gandheswaririver basin is39.4km.

Formfactor(Rf)

According to Horton (Horton, 1932) form factor is the ratio of the area of the basin to square of thebasin length. In the present study, the value of form factor is 0.2351 (Table No. 3.9) which indicatesthe basin is elongated and will have a flatter peak of flow for a longer duration and are easier tomanage the floodsthanthecircularformof a basin.

Shapefactor(Sf)

The shape factor can be defined as the ratio of the square of the basin length to area of the basin(Horton, 1932) and is inverse proportion with form factor. Shape factor of the river basin is 4.25, whichindicatestheelongated shape of the basin.

CirculatoryRatio(Rc)

Circulatory ratio is the total drainage basin area divided by the area of a circle having the sameperimeter as the basin (Summerfield, 1991). Circulatory ratio of the river is 0.44. It has highlightedtheelongationshapeof basin.

$$R_c = \frac{12.57A}{{P_r}^2}$$

ElongationRatio (Re)

Elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to themaximum basin length (Schumm, 1956). In the present study, this value is 0.55 hence the basin iselongatedshape(Strahler,1952).

$$R_e = \frac{2}{Lb}\sqrt{\frac{A}{\pi}}$$

TextureRatio(T)

Schumm (Schumm, 1956) defined, texture ratio is an important factor in the drainage morphometricanalysis which is depending on the underlying lithology, infiltration capacity and relief aspect of theterrain. The texture ratio can be defined as the ratio of total number of streams of first order to theperimeterof the basin.Texture ratio of thebasinis2.85.

$$T = \frac{N_1}{P_r}$$

Drainagetexture(Dt)

An important geomorphic concept is drainage texture by which we mean the relative spacing ofdrainage lines (Smith, 1939) while Horton (Horton, 1945) defined Drainage texture on the basis ofstreamfrequency (numberofstreamperunitarea). Drainage textureoftheriverbasinis1.38.

CompactnessCoefficient(Cc)

It can be represented as basin perimeter divided by the circumference of a circle to the same area ofthe basin (Horton, 1945). This are indirectly related with elongation of the basin area. Lower valuesofthisparameterindicatethemoreelongationofthebasinandlesserosion,whilehighervaluesindicatetheesselongationandhigherosion.Inthisstudy,thevalueofcompactnesscoefficients 0.16 (TableNo.3.9).

$$C_c = 0.2821 \frac{P^{0.5}}{A}$$

Fitnessratio(F)

It is the ratio of main channel length to the length of the watershed perimeter is fitness ratio (Melton, 1957), which is a measure of topographic fitness. Fitness ratio of the river basin is 0.48

3.2.2 DRAINAGE NETWORK

6 **Stream Ordering (Su) and Numberof Stream (Nu)**

7 Stream order expresses the hierarchical arrangement between streams. It is a fundamental property of stream networks since it is related to the relative discharge of a channel segment (Summerfield,1991). Gandheswari river basin is a 5th order stream (Figure No. 3.10). Total number of stream of the river basin is290. Stream segments in different order have been given in Table No 3.6.

StreamLength(Lu)andMainChannel Length(L)

Leopold et al., (1964) defined stream length as 'the distance along a stream channel'. The calculated total stream length of the river basin is 399.25 km (Table No. 3.7) and the main channel length of the river basin is 49 km.

Stream Length Ratio(Lur)

Miller (1964) defined stream length ratio as 'average ratio of average length of streams of a givenorder to average length of streams of next lower order'. Stream length ratio of the river basin is 2.61(TableNo. 3.7).

$$R_l = \frac{L^{\bar{u}}}{L^{\bar{u}} - 1}$$

Table No.3.5 StreamLength, StreamLength Ratio

Su	Nu	Lu	Lu/Nu	Lur	Lur-r	Lur×Lur-r	Lurm
1st orderstreams	221	213.44	0.9658				
2ndorderstreams	54	92.81	1.7187	1.78	306.25	545.12	
3rdorderstreams	11	48.66	4.4236	2.5738	141.47	364.12	
4thorderstreams	3	17.02	5.6733	1.2825	65.68	84.23	2.16
5thorderstreams	1	27.32	27.32	4.8155	44.39	213.76	
Total	290	399.25	40.1014	10.4518	557.79	1207.23	
Mean				2.6126			

Source:*Author'sCalculatio*

BifurcationRatio(Rb)

Bifurcation ratio (R_b) which is related to the branching pattern of the drainage network, is defined asa ratio of the number of streams of a given order ((Nu) to the number of streams of the next higherorder (N_u+1) and is expressed in terms of the following equation-

$$R_b = Nu / Nu+1$$

Where, Nu= number of streams of a given orderNu+1=number of streams of the next higher order] Mean bifurcation ratio varies from 2.0 for lat or rolling basins to 3.0-4.0 for mountainous, hilly dissected basins (Horton,1945). Bifurcation ratio of Gandheswari river basin has been calculated as 3.91. Thus the results suggest that the basin is situated in a dissected or hilly tract.

Rho coefficient(R)

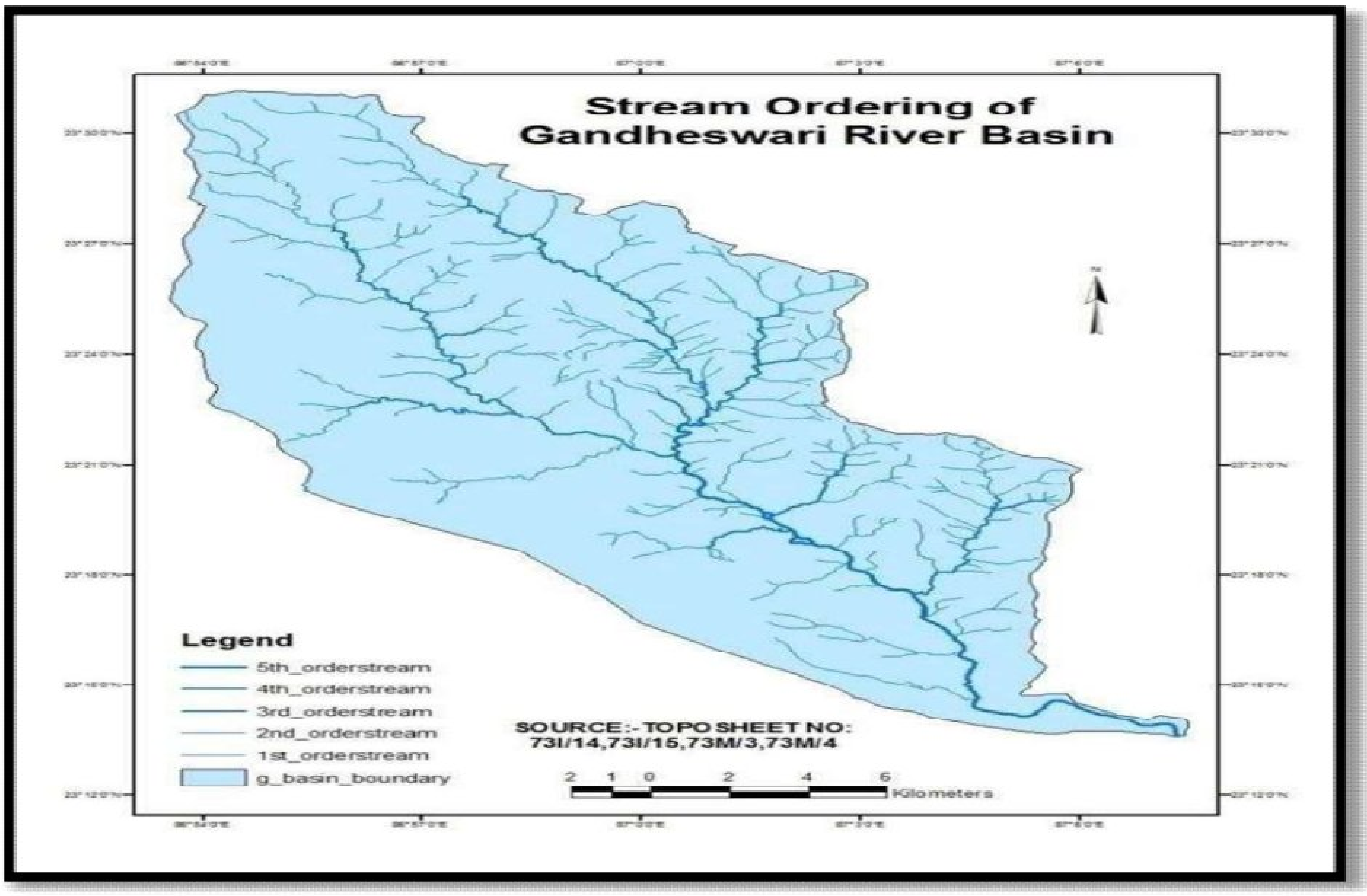
The Rho coefficient is an important parameter relating drainage density physiographic development of a watershed which facilitate evaluation of storage capacity of drainage network and hence, a determinant of ultimate degree of drainage development in a given watershed (Horton,1945).Rho values of the Gandheswari river basins 0.52.

Weighted Mean BifurcationRatio(Rbwm)

Strahler (1952) used a weighted mean bifurcation ratio obtained by multiplying the bifurcation ratio for each successive pair of orders by the total numbers of streams involved in the ratio and taking the mean of the sum of these values. The Weighted Mean Bifurcation Ratio of the river basin is 4.21

TableNo.3.6 Stream Order,Number,Bifurcation Ratio, Weighted Mean Bifurcation Ratio

Su	Nu	Rb	Nur	Rb×Nur	Rbwm
1st orderstreams	221				4.21
Numberof2nd orderstreams	54	4.09	275	1124.75	
Numberof3rd orderstreams	11	4.91	65	319.15	
Numberof4th orderstreams	3	3.67	14	51.38	
Numberof5th orderstreams	1	3	4	12	
Total	290	15.67	358		
Mean		3.9175			



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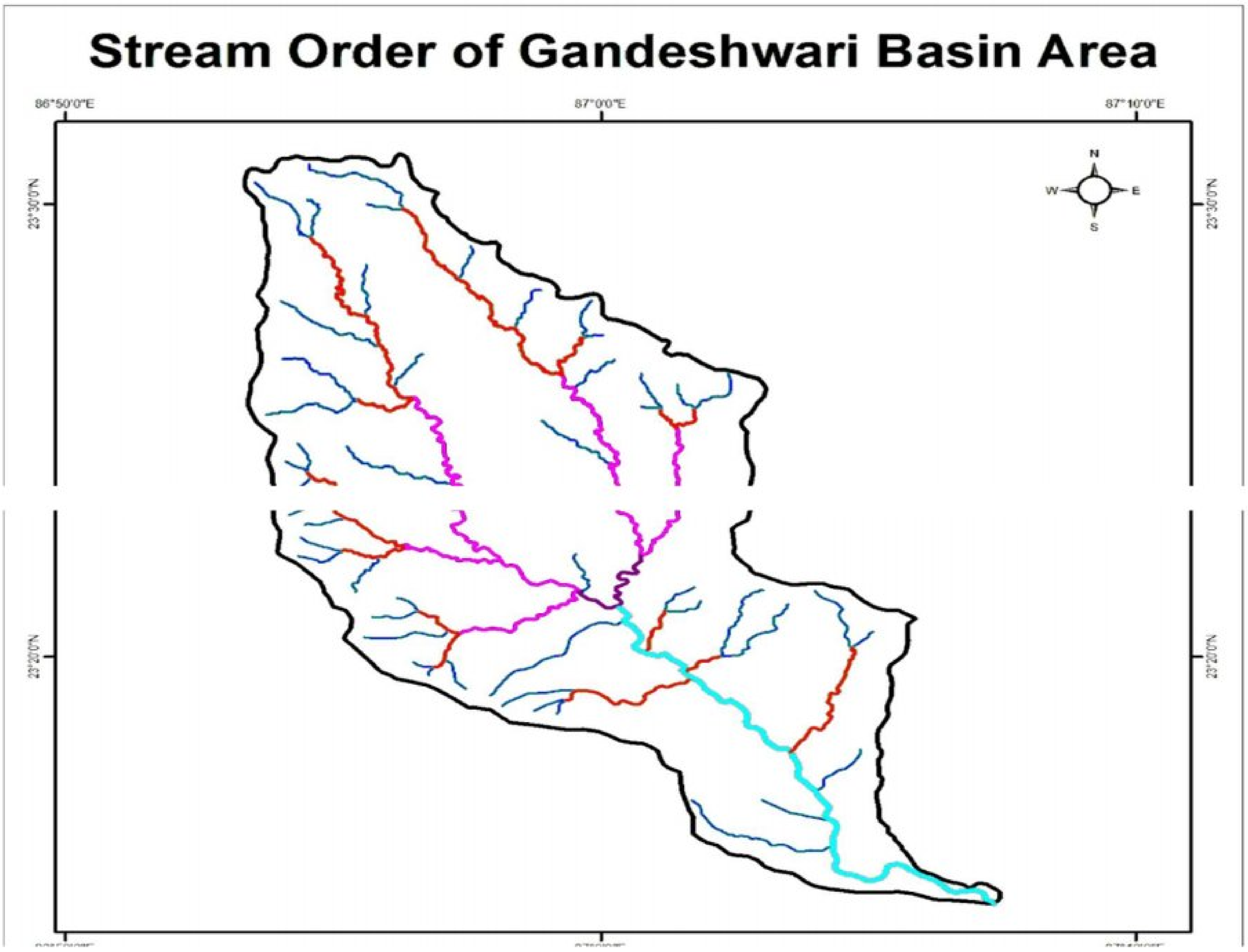

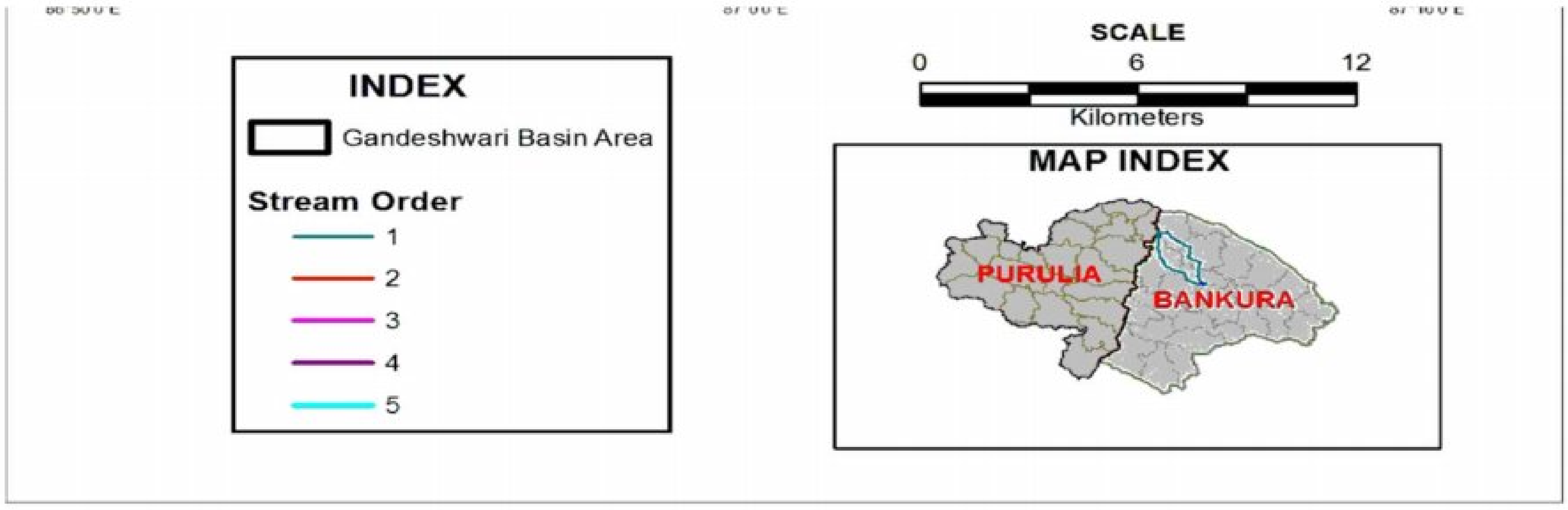

Figure N 3.10 Stream order Map of Gandheswari River Basin

3.2.3 DRAINAGE TEXTURE ANALYSIS

StreamFrequency(F)

Stream Frequency defined as the Number (Summerfield,1991). Stream frequency of the basin is 0.79 (TableNo.3.8).

$$F_s = \frac{N_u}{A}$$

Drainage Density(Dd)

Drainage density is defined as the mean length of stream channel per unit area. The drainage density (Horton,1932, 1945) is the average length of stream channel per unit areas :D=ΣL/A, Where the drainage density per unit areaΣ1is the summation of the length of Channels within the area A. Drainage density of the river basin is 1.094km perSq.km.

$$D_d = \frac{L_u}{A}$$

DrainageIntensity

It is the ratio of the stream frequency to the drainage density (Faniran, 1968). Drainage intensity of the river basin is 0.722 (Table No. 3.9).

Constant of Channel Maintenance

Strahler (1952) stated that'the constant of channel maintenance indicates the relative size of land form units in a drainage basin and has a specific genetic connotation'. Channel maintenance constant of the watershed is0.91

Infiltration Number

The infiltration number of a watershed is defined as the product of drainage density and stream frequency and given an idea about the infiltration characteristics of the watershed. The higher the infiltration number, the lower will be the infiltration and the higher ran-off (Pareta&Pareta, 2011).Infiltration number as calculated as 0.864 of the basin.

Length of Overland Flow (Lo)

The distance covered from the water divide to the nearest channel represents the length of over land flow, an important variable on which runoff and flood processes depend(On the other hand, according to Leopoldetal,(1964),length of overland flow is 'mean distance from channel sup maximum valley-side slope to drainage divide'. The length of overland flow of the river basin is 0.457(sq./km).

3.2.4 RELIEF PARAMETER

AbsoluteRelief (Ra)

It is actual height of a place with respect to mean sea level. The highest elevation zone was found in northern and southern part of the province while, lowest elevation observed in the north-central and coastal part of the study area.

RelativeRelief(Rr)

Relative Relief is defined as the differences in height the highest and the lowest points in a unit area.It is an important morphometric parameter which is used for the overall assessment of morphological characteristics of terrain. The relative relief of the basin is 366m.Becauseofitsclose association with slope, the relative relief is more expressive and useful in different fields including relief dissection and surface ruggedness. When the amplitude of regional relief is greater, the surface roughness will be seen to vary significantly from unit to unit under the over thrusting natural set of hydromorphic condition. Thus the more is the local relative relief, the more is the roughness and there manifold decrease is the effective value of terrain for arable farming (Singh &Dhillion,1984).

Dissection Index(Di)

The concept of relative is not entirely satisfactory as a criterion of the nature of relief. Dissection index indicates the intensity of effectiveness of relief intensity in achieving an apparent usability of an area unit. The dissection index gives clue to the development of land forms under the purview offluvial geomorphic cycle of erosion" (Prasad, 1985). The dissection value of the river basin (Tableno.4) indicates the basin situated in a hilly tract. Susunia hill (Height 440m.) is the highest elevation zones of the basin and except this hill other region is more or less little undulating surface.

RuggednessNumber(Rn)

Goudie (2004) described the ruggedness of terrain as property of the landscape which describes the complexity of the topography and the roughness of the terrain. More rugged landscapes tend to exhibit a greater amount of complexity, having rough and uneven surfaces. According to Leopold etal., (1964) Ruggedness number is 'basin relief multiplied by drainage density'. The ruggedness number in Gandheswari river basin is 0.40 which indicates the basin is less soil erosion prone and has inherent structural complexity in association wither life and drainage density.

Reliefratio(Rh)

Schumm (1956) stated the relief ratio may be defined as the ratio between the total relief of a basinand the longest dimension of the basin parallel to the main drainage line. The total relief is the differences of highest elevation and lowest elevation of valley floor in the basin. The relief ratio of the river basin is 0.007.

Watershed Slope (SW)

Watershed slope is the ration between the total basin reliefs (H) divided by basin length (Lb). The calculated value of watershed slope is 0.009

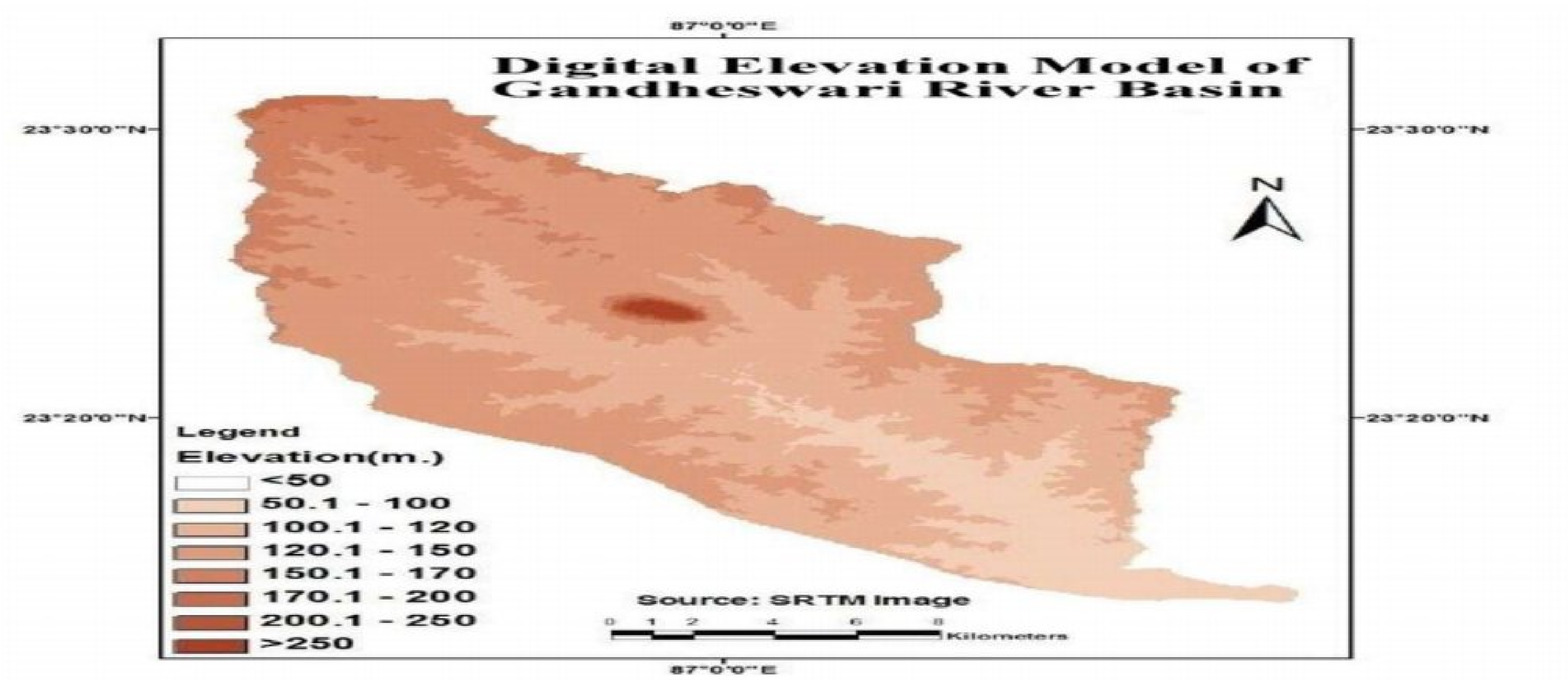

Figure No.3.12 Digital Elevation Map (DEM) of Gandheswari River Basin

3.3 HYDRAULIC CHARACTERIZATIONS OF GANDHESWARI RIVER BASIN:

The morphometric parameters like drainage density, bifurcation ratio, stream frequency, elongation ratio, form factor can be termed as erosion risk assessment parameters which can be used to prioritize watershed (Biswas,1999).Different studies on the issue of morphometric analysis and watershed management has suggested that there is positive relation between watershed development and conservation of natural resources.Thakuiah et al., (2012) suggested that the quantitative analysis and morphmetric parameter are found to be of immense unity in river basin evaluation watershed prioritization for soil and water conservation and natural resource management at watershed level. Drainage morphometry is like a tool to understand the process of land form, soil and erosion characteristics.

Bifurcation ratio of the river basin (3.91) indicates that the basin situated in a dissected region and the higher value of bifurcation ratio indicates the basin is structurally controlled. Rho value also indicates the nature of hydrologic storage during flood and it is effect on soil erosion. Field observations have suggested that during rainy season shallow river bed frequently overflow and causes flood. Low value of Stream frequency, Drainage density, Drainage intensity implies that surface runoff is not fast and makes it to susceptible to soil erosion, gully erosion, flooding.

Drainage density, Stream frequency, bifurcation ratio, drainage intensity are directly related to soil erosion. Higher value of those parameters indicates more susceptible for soil erosion and vice-versa. In case of the study the Drainage density, Stream frequency, bifurcation ratio, drainage intensity has indicated low to moderate nature of soil erosion.

The general slope of Gandheswari river basin is from North–West to South East. Circulatory ratio, elongation ratio, form factor, shape factor indicate the river basin in an elongated in shape. Lower value of form factor indicate that basin have a flatter peak of flow for a longer duration. Low ruggedness index indicates less soil erosion.

TableNo.3.7 Morphometric analysis of Gandheswari River Basin.

Sl. No.	MorphometricParameters	Formula	Reference	Result
	BasinGeometry			
1	BasinArea(A)	GISsoftwareanalysis	Schumm(1956)	364.9
2	BasinPerimeter(P)	GISsoftwareanalysis	Schumm1956)	101.54
3	Formfactor(Rf)	Rf= A/L2	Horton(1945)	0.2351
4	ElongationRatio(Re)	Re=2√(A/π)/L	Schumm(1956)	0.55
5	TextureRatio(T)	T=Nu/P	Horton(1945)	2.85
6	CirculatoryRatio(Rc)	Rc=4πA/P2	Miller(1953)	0.44
7	Drainagetexture(Dt)	Dt= Dd×F	Smith(1950)	1.38
8	Compactnesscoefficient(Cc)	Cc=0.2821P/A0.5	Horton(1945)	0.16
9	BasinLength(Lb)kms	GISsoftwareanalysis	Schumm1956)	39.4
10	ShapeFactor (Sf)	Sf=Lb2/A	Horton(1945)	4.25
11	FitnessRatio	F=L/P	Melton(1957)	0.48
	DrainageNetwork			
12	StreamOrder(Su)	Hierarchicalrank	Strahler(1952)	5
13	StreamNumber(Nu)	Nu=S1+S2+S3…Ln	Horton(1945)	290
14	StreamLength(Lu)	Lu=S1+S2+S3…Ln	Strahler (1964)	399.25
15	BifurcationRatio(Rb)	Rb=Nu/Nu+1	Schumm1956)	3.9171
16	MainChannel Length(L)	GISsoftwareanalysis		49
17	StreamLengthRatio(Lurm)	See table no.2	Strahler(1964)	2.61
18	WeightedMeanBifurcation Ratio(Rbwm)	See table no.3	Strahler(1964)	4.21
19	Rhocoefficient(R)	R=Lur/ Rb	Horton(1945)	0.67
	DrainageTextureAnalysis			
20	StreamFrequency(F)	F=Nu/A	Horton(1945)	0.79
21	Drainagedensity(Dd)	Dd= Lu/A	Strahler(1964)	1.094
	Constant ofChannel			

22	Maintenance(C)	C=1/Dd	Schumm1956)	0.914
23	Drainageintensity(Di)	Di=F/Dd	Faniran(1958)	0.722
24	InfiltrationNumber(If)	If=F ×Dd	Faniran(1958)	0.86
25	Lengthofoverlandflow(Lo)	Lo=1/Dd×2	Horton(1945)	0.457
	Reliefcharecteristics			
26	Height ofthebasinmouthm. (z)	GISsoftwareanalysis	-	74
27	TotalContourLengths(Ctl)in kms	GISsoftwareanalysis	-	451.1685
28	Maximumheightofthebasin m.(Z)	GISsoftwareanalysis	-	440
29	Totalbasinrelief(H)	H=Z –z	Strahler(1952)	366
30	ReliefRatio(Rh)	Rh= H/Lb	Schumm(1956)	0.00928
31	AbsoluteRatio(Ra)	GISsoftwareanalysis		440
32	DissectionIndex(Di)	Di=H/Ra	Singh and Dubey(1994)	0.83/0.52
33	RuggednessNumber(Rn)	Rn=Dd×(H/1000)	Baker (1976)	0.4
34	WatershedSlope(Sw)	Sw=H/Lb	-	0.009

Source: Author'sCalculation

CHAPTER-4 CONCEPTUAL WATER OF CATCHMENT AREA

4.1 GROUNDWATER FLUCTUATION OF THE STUDY AREA

Groundwater level of pre-monsoon and post-monsoon reflects the actual groundwater condition of the area. Groundwater level data of different observatory wells for the period of 2010–2021 has been collected from the State Water Investigation Directorate (SWID). Locations of groundwater observatory wells, with a majority of the area having a mean pre-monsoon groundwater depth of 5 to 9 m. On the other hand, the mean post-monsoon groundwater level varies from 1 to 6 m. Groundwater level for the pre-monsoon is very low in Chatna,Saltora, Indpur blocks. Higher groundwater fluctuation indicates excellent recharge capacity, and in turn, it reflects the excellent potentiality zones of groundwater. The fluctuation rate is high in Indpur blocks.

Table 4.1: Yearly Ground Water trends for ChatnaBlock of Bankura District near study area from pre & post Monsoon years 2010 to 2021.

Source: State Water Investigation Directorate (SWID).

Year	Blocks	Last 10 Year Pre MonsoonAverage (m bgl)	Last 10 Year Post Monsoon Average (m bgl))
2010	Chatna	8.27	5.34
2011	Chatna	7.83	3.91
2012	Chatna	7.29	3.05
2013	Chatna	6.37	1.52
2014	Chatna	6.02	3.93
2015	Chatna	6.48	4.47
2016	Chatna	6.94	3.11
2017	Chatna	5.98	2.49
2018	Chatna	5.89	4.22
2019	Chatna	7.02	3.77
2020	Chatna	**5.77**	**3.80**
2021	Chatna	**5.78**	**3.24**

The latitudinal extension of the Chattna Block is 23º18'30"N and the longitudinal extension is 86º57'53"E.

Table 4.2: Yearly Ground Water trends for SaltoraBlock of Bankura District near study area from pre & post Monsoon years 2010 to 2021.

Year	Blocks	Last 10 Year Pre MonsoonAverage (m bgl)	Last 10 Year Post Monsoon Average (m bgl))
2010	Saltora	7.04	7.98
2011	Saltora	8.15	4.04
2012	Saltora	6.55	2.99
2013	Saltora	6.12	2.20
2014	Saltora	5.61	5.57
2015	Saltora	7.84	3.63
2016	Saltora	8.39	2.90
2017	Saltora	5.55	3.12
2018	Saltora	5.68	3.96
2019	Saltora	5.87	3.02
2020	Saltora	5.37	3.19
2021	Saltora	5.58	2.42

The latitudinal extension of the Saltora Block is 23º31'39"N and the longitudinal extension is 86º55'56"E

Table 4.3: Yearly Ground Water trends for Indpur Block of Bankura District near study area from pre & post Monsoon years 2010 to 2021.

Year	Blocks	Last 10 Year Pre MonsoonAverage (m bgl)	Last 10 Year Post Monsoon Average (m bgl))
2010	Indpur	7.32	7.98

2011	Indpur	8.93	4.04
2012	Indpur	6.76	2.99
2013	Indpur	7.18	2.20
2014	Indpur	6.02	5.57
2015	Indpur	7.01	3.63
2016	Indpur	9.36	2.90
2017	Indpur	8.02	3.12
2018	Indpur	6.68	3.96
2019	Indpur	8.54	3.02
2020	Indpur	7.62	4.89
2021	Indpur	7.86	3.24

The latitudinal extension of the Indpur Block is 23º09'25"N and the longitudinal extension is 86º55'43"E.

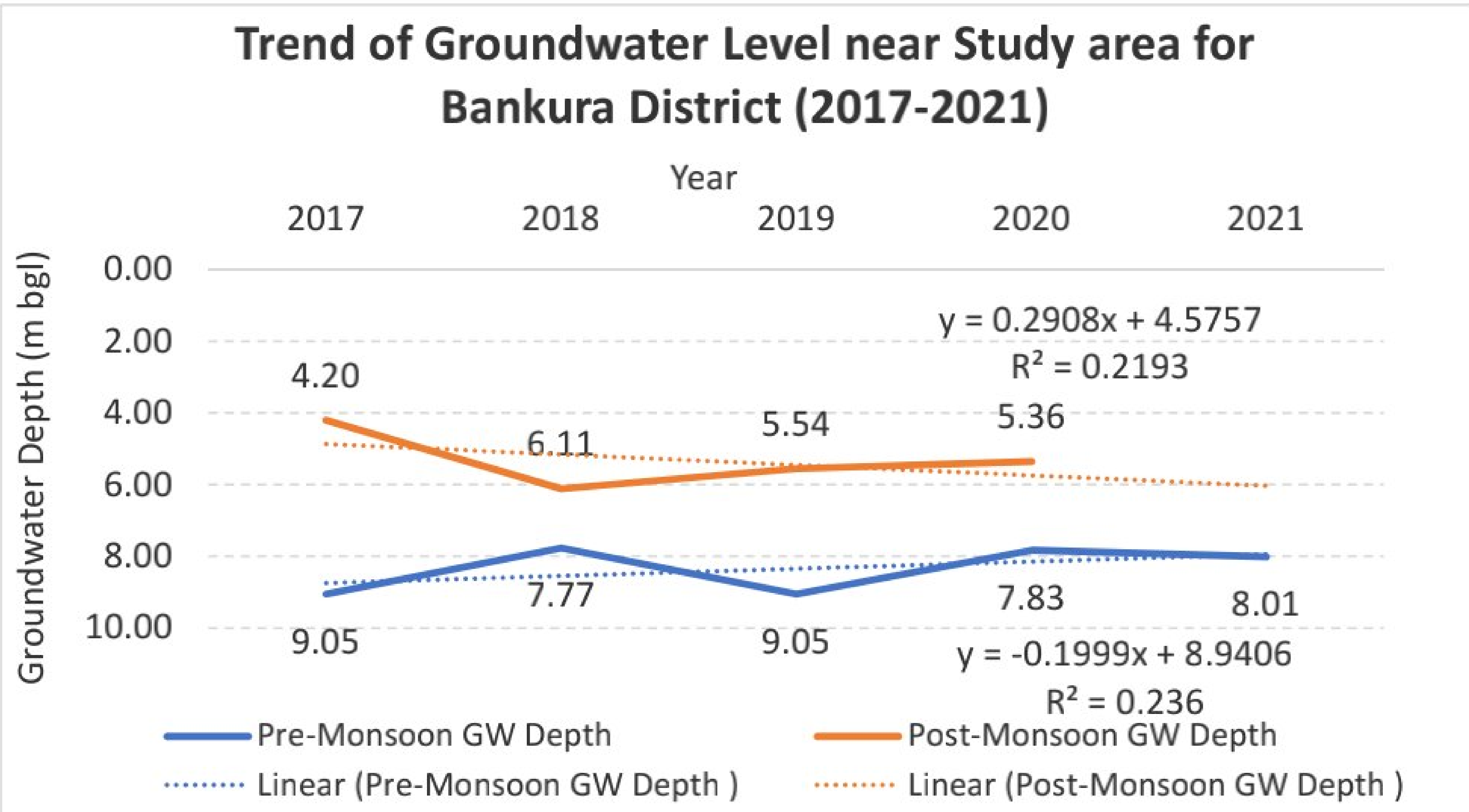

Fig. 4.1 Ground water trend near Study area

4.2 WATER RESOURCES PROBLEM OF THE STUDY AREA

Bankura has a long history of water scarcity. It has worsened with the growing population. According to geologists, the primary reason is the lack of geologically controlled aquifers in the area. Bankura has underlain hard crystalline rocks that constrain water percolation, restricting water table formation Groundwater is the primary source of drinking water in Bankura district, West Bengal, India. Because of the known health and economic impacts associated with groundwater contamination, steps to assess the vulnerability of groundwater must be taken for sustainable groundwater protection and management planning. Vulnerability of groundwater refers to the intrinsic characteristics that determine the sensitivity of the water to being adversely affected by an imposed contaminant load. The DRASTIC method (Aller et al., 1987), developed by the U.S. Environmental Protection Agency, is the most widely used method for identifying the areas where groundwater supplies are most susceptible to contamination. It is a relatively quick and simple to use process for assessing susceptibility to a large extent. Vulnerability to contamination is a dimensionless index function of hydro geological factors, anthropogenic influences, and sources of contamination in any given area (Plymale and Angle 2002). The index consists of seven parameters with different weighting factors. The DRASTIC parameters are weighted from one to five according to their relative importance in contributing to the contamination potential (Aller et al., 1987). The resulting index is a comparable measure of vulnerability to contamination; higher index values are more vulnerable than those with a lower index.

4.3 ESTIMATION OF DIRECT RUNOFF FROM RAINFALL

In this method of runoff estimation, the effects of the surface conditions of a watershed area are evaluated using land use and treatment classes. Land use is the watershed cover. It includes every kind of vegetation, litter, and mulch, and fallow and non- agricultural uses such as water surfaces (lakes, swamps, etc) and impervious surfaces (roads, roofs, roofs, etc.). Land treatment applies mainly to agricultural land uses and includes mechanical practices such as contouring or terracing and management practices such as grazing control or rotation of crops. The classes consist of use and treatment combinations actually to be found on watersheds. Land use and treatment classes are readily obtained either by observation or by measuring plant and litter density and extent on sample areas.

4.4 HYDROLOGICAL SOIL GROUPS:

There are four soil groups used in determining the hydrological soil cover complexes, which are used to estimate the runoff from rainfall. A generalized soil map of India, giving the broad classification of all the significant soils in India, is shown in Figure 4.1. Major characteristics of these groups are described in Table. The variety is vast, but the groups can be divided into sub-groups whenever such a refinement is justified. The infiltration rates and permeability of soils in different groups are shown in Table 4.1 respectively. In these tables, the infiltration rate is when water enters the soil at the surface and is controlled by surface conditions. Permeability rate is the rate at which water moves in the soil, influenced by the nature and characteristics of soil horizons.

TABLE 4.4: HYDROLOGICAL SOIL GROUPS

SOIL GROUP	DESCRIPTION
A	Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material.

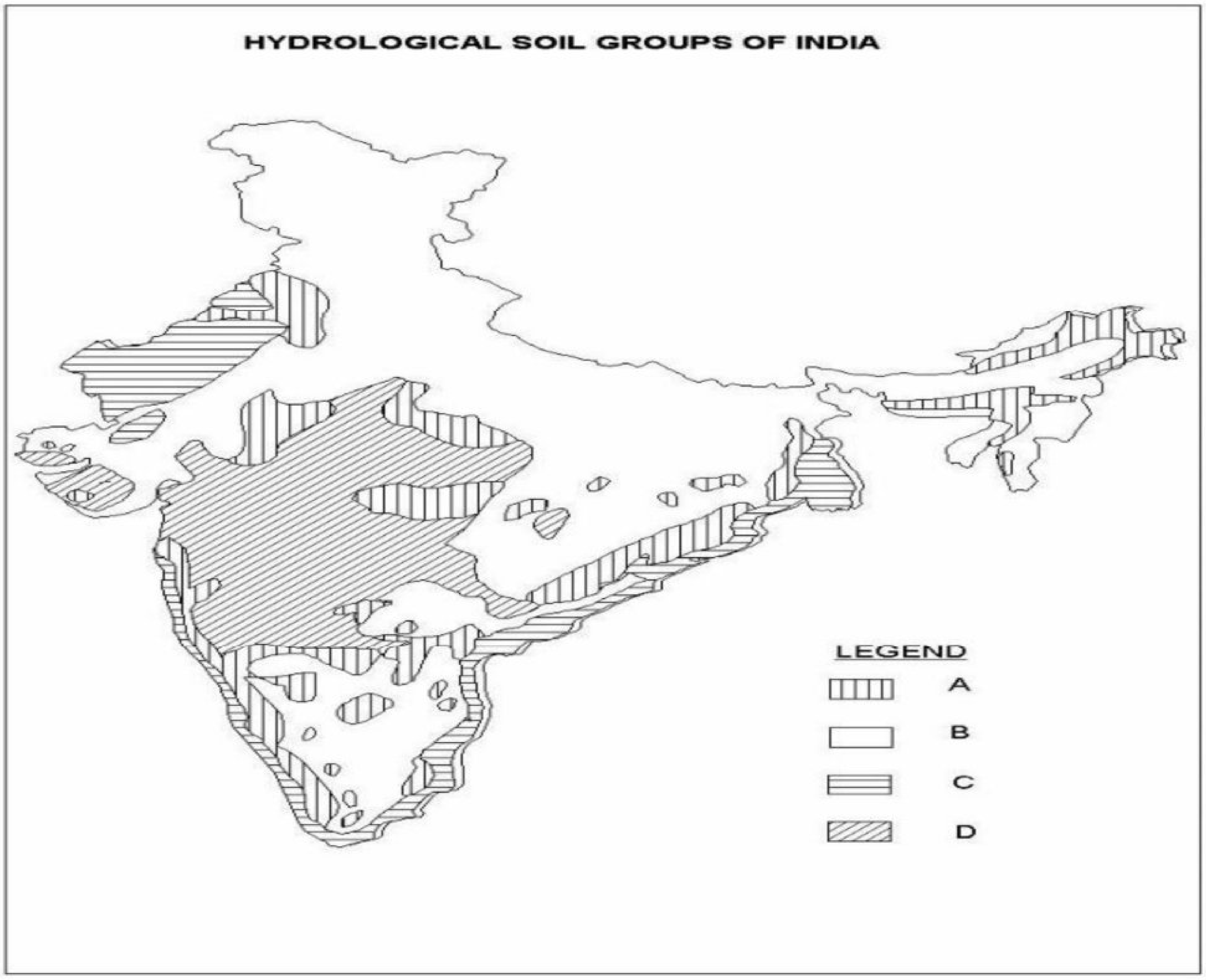

Fig.4.2: HYDROLOGICAL SOIL GROUPS OF INDIA

4.5 LAND USE AND TREATMENT.

The commonly used land use and treatment classes are briefly described below.

These classes are used in determining hydrologic soil-cover complexes, which are used in one of the methods for estimating runoff from rainfall.

➢Cultivated lands: These include all field crops such as maize, sugarcane, paddy, and wheat.

➢ Fallow lands: These are lands taken up for cultivation but are temporarily out of cultivation for not less than one year and not more than five years. Current fallow lands are cropped areas kept fallow during the current year.

➢ Uncultivated lands include:

• Permanent pastures and other grazing lands.

• Cultivable waste, which islands are available for cultivation, is taken up for cultivation or abandoned after a few years for one reason or another. Land once cultivated but uncultivated for 5 years in succession shall also be included in this category.

Forest area includes all lands classed as forest under any legal enactment dealing with forest or administered as forest, whether State-owned or private and whether wooded or maintained as potential forest land.

➢ Tree crops include woody perennial plants that reach a mature height of at least 8 feet and have well-defined stems and a definite crown shape.

➢ Lands put to non-agricultural uses are areas occupied by buildings, roads, railroads etc.

➢ Barren and uncultivable lands include areas covered by mountains, deserts etc.

4.6 RAINFALL – RUNOFF EQUATIONS:

The data generally available in India comprise rainfall measured by non-recording rain gauge stations. Rainfall-runoff relation developed for such data is given below

Q = [(P-Ia)2] / [(P-Ia) +S] --------------------(Eq.1)

Where Q is the actual runoff in mm, S, the potential maximum retention in mm, and Ia, initial abstraction during the period between the beginning of rainfall and runoff in equivalent depth over the catchment in mm. In areas covered by black soils having Antecedent Moisture Conditions (AMC) II and III, Ia in the equation is equal to 0.1S, whereas in all other regions, including those with black soils of AMC I, Ia is equal to 0.3S. To show this relationship graphically, 'S' values are transformed into 'Curve

Numbers (CN)' using the following equation CN = 25400 / (254 + S)

Using the above equation, the following equations have been developed:

Q = [(P-0.3S)2] / [(P+0.7S)] --------------------- (Eq.2)

Q = [(P-0.1S)2] / [(P+0.9S)] -----------------------(Eq.3)

Equation 2 applies to all soil regions of India except black soil areas referred to in the section on 'Hydrological Soil Groups'. Equation 3 applies to black soil regions. This equation should be used with the assumption that cracks, which are typical of these soils when dry, have been filled. Therefore, equation 3 should be used where AMC falls into groups II and III. In cases where the AMC falls in group I, equation 1 should be used. The rainfall limits for AMC conditions are shown in Table 4.5.

Table 4.5: Rainfall Limits for Antecedent Moisture Condition

AMC	5 – day Total Antecedent Rainfall (cm)	
	Dormant Season	**Growing Season**
I	< 1.25	< 3.5
II	1.25 to 2.75	3.50 to 5.25
III	> 2.75	> 5.25

4.7 EXISTINGSCENERIO

Arid and Semi-arid climatic regions cover 30% of earth's land surface, a larger land area than any other climate .this climate are characterized by harsh environmental condition such as low and erratic rainfall intense solar radiation ,high wind velocity and high evapo-transpiration .During most part of the year evapotranspiration remains always more than annual rainfall .Besides, the productivity and production is lower and sometimes crop production fails due to deficient irrigation of erratic rainfall .The soil of arid zone are coarse structure –less with low water holding capacity .This soil is poor because of poor organic carbon status and poor physical characteristic .

Water is one of the essential natural resource for every survival of life on the planet Earth. Demand for water is increasing day by day, with the ever increasing population, resulted severe water crisis. We need water for agriculture, industry, human & cattle consumption. The available water is also affected by problem of pollution and contamination. Therefore it is very important to manage this very essential resource in a sustainable manner. Hence we need proper management and development plan to conserve, restore or recharge water where soil loss is very high due to various topographical conditions. The study area considered includes parts of Bankura districts of West Bengal covering an area of about 364.9 sq. km area. Water resource management and catchment delineation has been done in the respective micro watershed using Python, GIS and Remote Sensing techniques.

CHAPTER-5: METHODOLOGY

5.1 INTRODUCTION

The basic method of this study is empirical and the review of literatures. The geomorphic information has taken using by a descriptive approach including a geomorphologic survey of the river bed, the stratigraphic study of river basin and morphological analysis of water flow. A relation has been established in-between geological references and field observations. To present, geomorphic and geological information a few maps have been prepared. From the topographical sheets (73M, 73N, R.F.1:250,000) of Survey of India, few geo information (such as average slope, surface elevation) have been collected. The sand withdrawal sites have been identified by GPS and those have plotted in map. A few geomorphic features like monadonack and bornhardt have been identified and which may be act as an example in Indian context. Here the basic concept of Hutton's uniform it a rianism; 'present is the key of past' has taken as key to study the past climatic and geomorphic information. On the basis of paleontological and geological information, the palaeo-geomorphic situations as well as identification of monadonack and bornhardt have been specified.

In this chapter, methodologies to achieve various activities of the study objectives are discussed. The various activities carried out in the study is shown through the flow chart in (Figure 5.1)

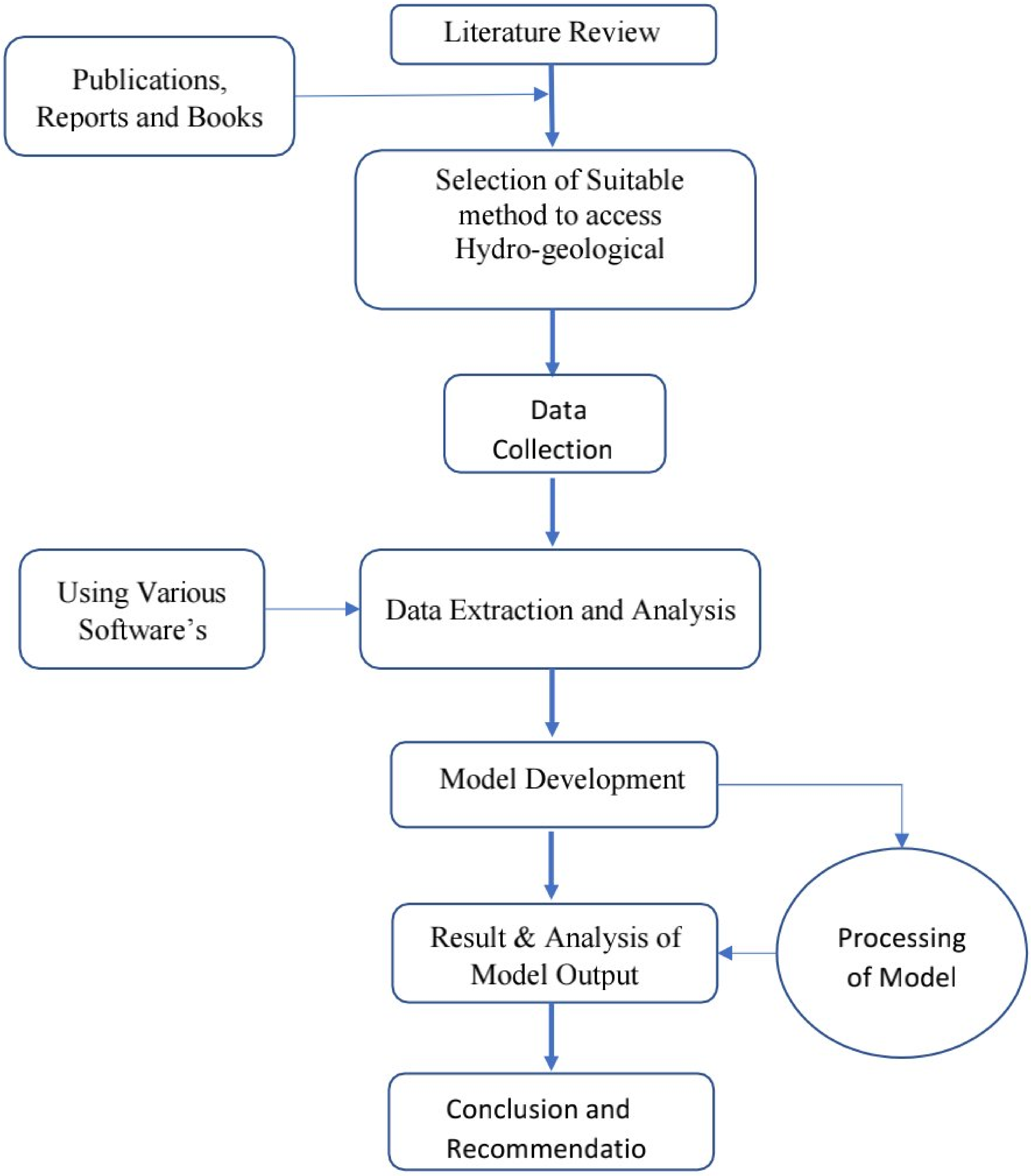

FIGURE 5.1: FLOWCHART OF METHODOLOGY

The district is suffering from acute water shortages for a long time, and water scarcity is a significant issue for the socio-economic development of Bankura. The district is in the rocky zone with a high slope and altitude. Thus, this portion of West Bengal has a less infiltration rate and less recharge. In present days' aquifer depth get even lower than in previous years. Along with this, the lowest rainfall and over-exploitation of groundwater has made the condition even worse.

Most of the block of Bankura District is affected by fluoride contamination. Surface water bodies dry up every year during the summer season. People depend on groundwater for domestic, irrigation, and other various purposes during this time, but excessive use of groundwater has worsened the situation. Therefore, proper evaluation, planning, and management of groundwater are essential for this region.

5.2 LITERATURE REVIEW

A literature review was carried out to select the method for development of watershed management and mapping groundwater vulnerability. Based on the literature review, scientific and secondary data were collected for better knowledge of the survey field. Many of the reviewed studies were organized worldwide. These reviewed studies have helped to watershed management and estimate groundwater pollution potential zones of the aquifer in different zones of the world. These studies were helpful by providing a general outline of how to improve the catchment area and mapping of different groundwater zones and widen the disciplines of the research and analysis.

5.3 DATA COLLECTION

The data relating to the depth of water were collected from the State Water Investigation Directorate (SWID) ,Govt. of West Bengal and discharge and hfl data were collected from Irrigation & Waterways DepartmentGovt. of West Bengal, from which net recharge is calculated by The Soil Conservation Service Curve Number (SCS-CN) method. The map relating to aquifer media and soil media has been collected from the Geological Survey of India, Kolkata, and National Bureau of Soil Survey and Land Use Planning, 2010. Hydraulic conductivity data were collected from the (PHED Bankura Division, Govt. of West Bengal). The topography of the study area was prepared based on processing both SRTM 90 DEM and ASTER DEM data. The impact of the vadose zone was prepared based on the map collected from the Geological Survey of India, Kolkata. Satellite Image (Landsat-8 OLI) download from USGS website. Toposheet of Bankura district, scale 1:50000 collected from Survey of India (SOI). Soil map of Bankura district collected from (NBSS). Geology map of Bankura district collected from (GSI). DEM (Digital Elevation Model) downloads from Bhuvan (http://bhuvan.nrsc.gov.in/). The LULC map for the study area has been extracted using the Extraction tool of the ArcGIS Spatial Analyst module

5.4 DATA ANALYSIS

The data collected were converted into digital format to insert into the Geographical Information System (GIS) environment. The ArcGIS 10.5 was used to manipulate the data, and the weight age of each parameter was assigned as per Aller et al. (1987). The technique of "inverse distance weighted" (IDW) interpolation in GIS was used to prepare. The DRASTIC formula was used in the ArcGIS raster calculator to find out the vulnerability of groundwater. The 100 meters' spatial pixel resolution (raster Grid) raster layer was used for all raster manipulations.

5.5 BRIEF DESCRIPTION OF ARCGIS SOFTWARE:

ArcGIS is a geographic information system (GIS) for working with maps and geographic information maintained by the Environmental Systems Research Institute (ESRI). It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database. The system provides an infrastructure for making maps and geographic information available throughout an organization, community, and openly on the Web. In the study, ArcMap, ArcCatalog, and Arc Toolbox applications of ArcGIS 10.5 have been used. ArcMap is the application used to view, edit and query geospatial data, and create maps. The ArcMap interface has two main sections, including a table of contents on the left and the data frames which display the map. Items in the table of contents correspond with layers on the map. ArcCatalog is a data management application used to browse datasets and files on one's computer, database, or other sources. In addition to showing what data is available, ArcCatalog also allows users to preview the data on a map. ArcCatalog also provides the ability to view and manage metadata for spatial datasets. Arc Toolbox contains geoprocessing, data conversion, and analysis tools, along with much of the functionality in Arc Info.

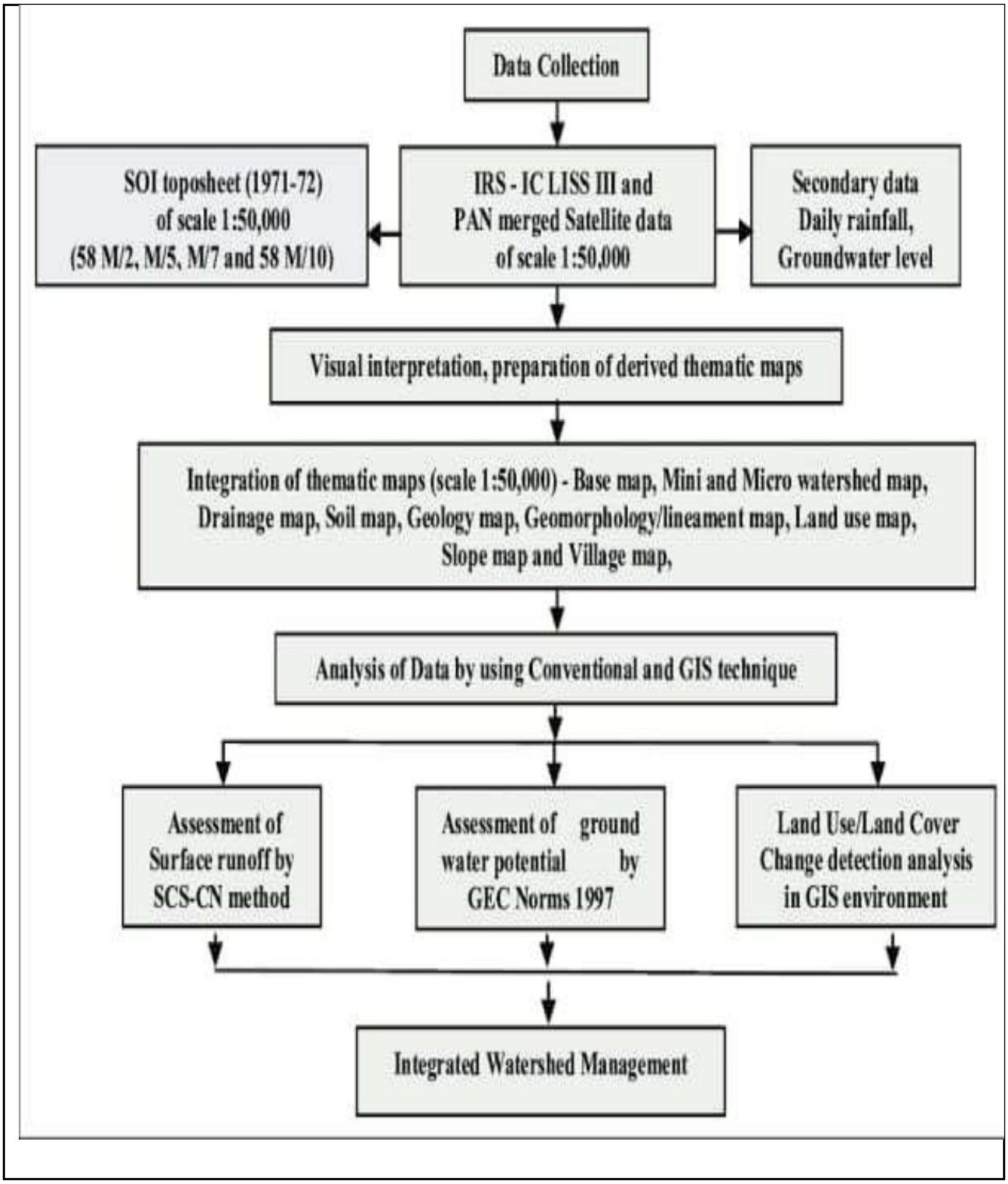

FIGURE 5.2: FLOW DIAGRAM OF RESEARCH METHODOLOGY

5.6 DATA PROCESSING

A) SPATIAL DATA:

It isalso known as geospatial data, is information about a physical object that can be represented by numerical values in a geographic coordinate system.Generally speaking, spatial data represents the location, size and shape of an object on planet Earth such as a building, lake, mountain or township. Spatial data may also include attributes that provide more information about the entity that is being represented Geographic Information System (GIS) or other specialized software applications can be used to access visualize, manipulate and analyse geospatial data.

B) NON SPATIAL DATA:

It describes the characteristics of the features and is also known as attributes data. It is that information which is independent of all geometric considerations. The combination of spatial and non spatial data is known as geospatial data.

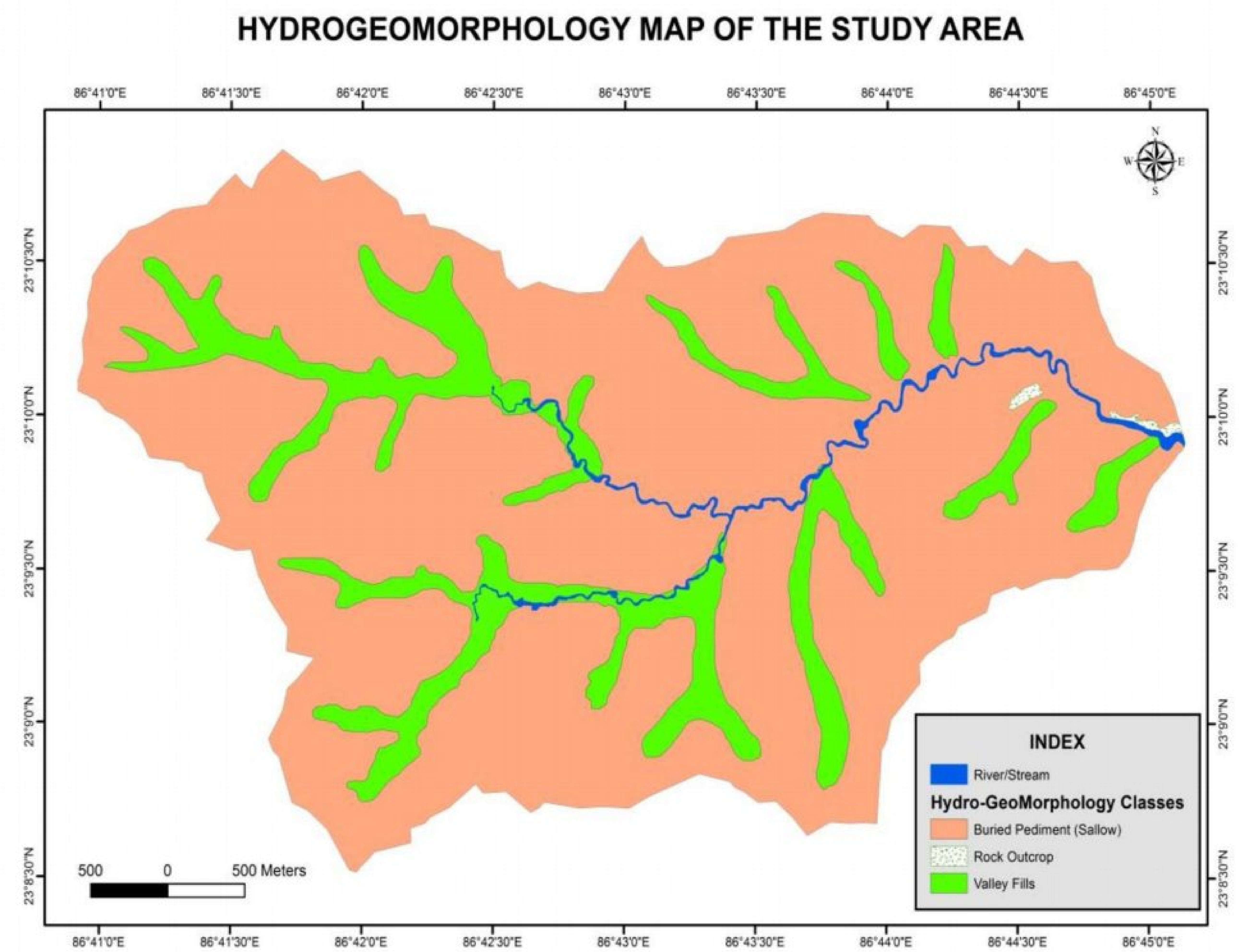

Fig.5.3: Hydrogeomorphological Map of study area

A) Water requirement based on LULC. The following data is obtained from the LULC map (Fig.6) as shown in Table 5.1

Table-5.1

LULC CLASS	AREA (Ha)
Built up	120.90
Double Crop	6.93
Forest	31.54
Single Crop	1396.91
Wastelands	290.50
Water bodies	78.80

Water requirement is calculated by considering the single crop area. It is calculated and found to be 1396.91 x 0.2 = **279.22 Ha-m.**

B) Finding out suitable site for the various minor irrigation structures

Though the area considered has adequate amounts of rainfall, the poor soil quality, presence of rock outcrops and the undulated terrain fails to meet the water requirements. For this reason, the existing micro irrigation structures are not sufficient to store the water due to heavy drain off and inefficient water bearing capacity of the soil. Hence we need to provide some more micro irrigation structures in the form of Water Detention Structures (WDS), Check dams, Pump Dug Well (PDW) etc. For this we have to look for the low lying areas from the contours of the study area for establishing WDS. It has to be made sure that the structures have no proximity to the river channels, roads, forests or habitation areas. There should be atleast a minimum distance of 200m between two WDS. Reference is taken from the LULC, contours, existing waterbodies, flow accumulation and Google maps. Check dams are providing throughout the course of the main river at an interval of atleast 500m.

PDW are also provided for water requirements in rural areas and other purposes in water management.

The micro watershed wise scheme proposal map is shown in Fig.5.4

A) Water Budget based on existing micro-irrigation structures.

Table 5.2

MI structures	Area (Ha)	Number	Total Volume of water (Ha-m)
Water ponds (SFMIS)	69.746	203	209.238
Check Dams	1.20	2	7.20

For water ponds, the depth taken is approximately 3m. So the total volume is calculated for total number of water ponds present in Ha-m.

For check dams, the depth taken is approximately 1.5m. So the total volume is calculated for one dam. The volume is doubled as annual rainfall occurs twice throughout the year. The total volume is thus calculated for total numbers of check dams present in Ha-m.

The Water Budget calculated on the existing micro irrigation structures is found to be **216.438 Ha-m.**

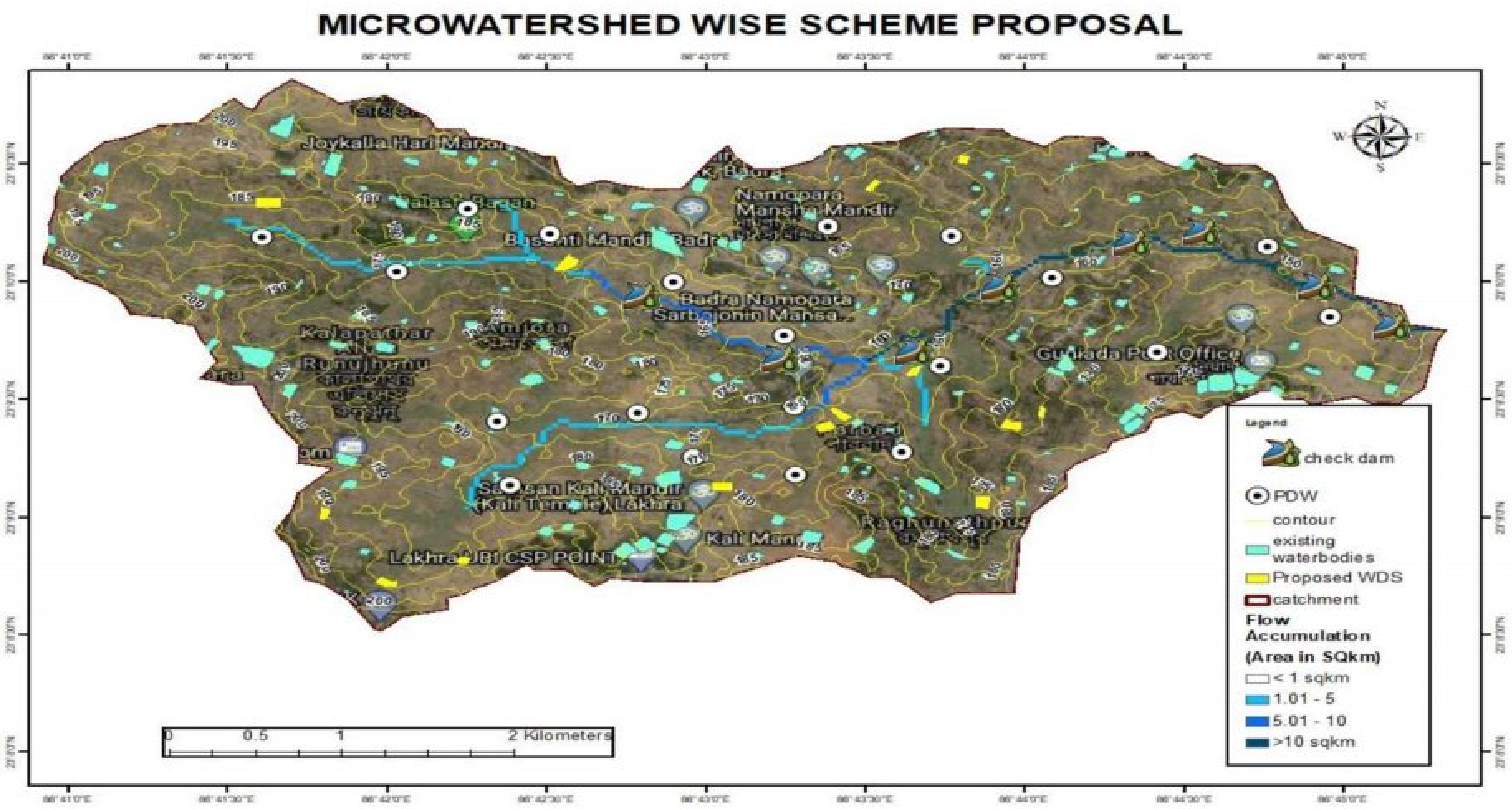

Fig.5.4: Proposed minor irrigation structures

A) <u>Calculation of tentative irrigated area based on proposed structures</u>

Table 5.3:

MIstructuresproposed	Command area (Ha)	Number	Total command area for irrigation (Ha)
WDS	9.28 (total)	14	9.28 x 3=27.84
Check Dams	8.00 (per structure)	8	64.00
PDW	1.50 (per structure)	20	30.00

The tentative irrigated area based on the proposed micro irrigation structures is found to be **121.84 Ha**.

5.7 OVERLAY/INDEX ANALYSIS BY ARC GIS SOFTWARE:

Overlay/Index analysis is a multi-criteria analysis wherein analysis can be carried out with complex things to find out specific themes with the help of the assignment of rank to the individual class of feature and then assign weight age to the particular feature considering its influence over theme. All the thematic maps were converted into raster format and superimposed by the weighted method, which consists of rank and weight age wise thematic maps and integration of them through GIS. Integration of thematic maps for carrying out multi-criteria or overlay analysis in a GIS environment was done using ArcGIS software.

5.8 PROCEDURE OF CREATING COUNTER OF GIS

BASIC PRINCIPLES OF REMOTE SENSING: Remote Sensing (RS) is generally defined as the science of collecting and interpreting information about a target without being in physical contact with the object under study. There are various categories of remote sensing starting from observation by naked eyes, photography by camera, photography from aircraft, and sensing by sensors from space satellite. Depending on its physical features and chemical properties, different objects on the earth's surface reflect, reradiate or emit different amounts of electromagnetic energy in various wavelengths.

The measurement of reflected or reradiated or emitted electromagnetic radiation forms the basis for understanding the characteristic of earth's surface features. Three typical responses are used to distinguish the objects from one another. Only selected portions of the electromagnetic spectrum which can pass through the earth's atmosphere with relatively little attenuation are used for remote sensing purpose. The selected region of the electromagnetic.

Spectrum which are employed in remote sensing include: 0.4 to 0.7 pm, 0.7 to 3.0 pm (IR band), 3 to 5 pm, and 8 to 14 pm (TIR) and 0.1 to 30 cm (microwave).
An active remote sensing system supplies its own source of energy to illuminate the objects and measures the reflected energy returned to the system (similar to photography in night with flash.

In passive remote sensing, the naturally radiated or reflected energy from the earth's surface features is measured by the sensors operating in different selected spectral bands on board (similar to photography in daytime without flash).
Remote Sensing principle has been shown in Fig.5.1 using a schematic diagram given below.

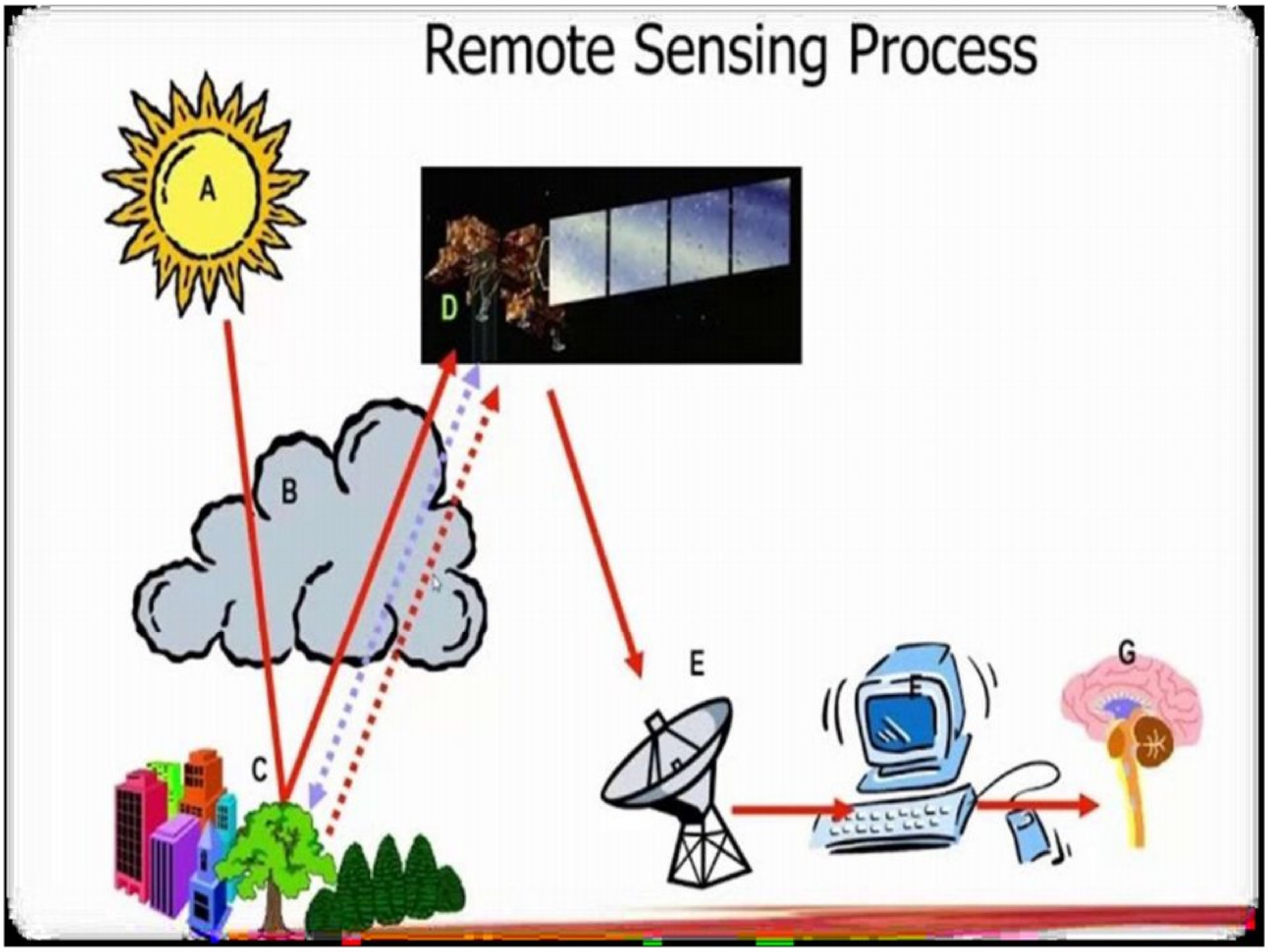

Fig 5.5 Basic Principle of Remote Sensing

5.9APPLICATION OF REMOTE SENSING OF GIS:

Technicians are charged with locating data that is collected by others and need to know how to acquire and manipulate the data as well asproduce maps that are useful. It is a co-operative system limited only by the technology of the day. GIS has widespread applications like that of in transport, civic planning, crime statistics, archaeology , disaster & health managementtechnicians are charged with locating data that is collected by others and need to know how to acquire and manipulate the data as well as produce maps that are useful. It is a co-operative system limited only by the technology of the day. GIS has widespread applications like that of in transport, civic planning, crime statistics, archaeology, disaster & health management.

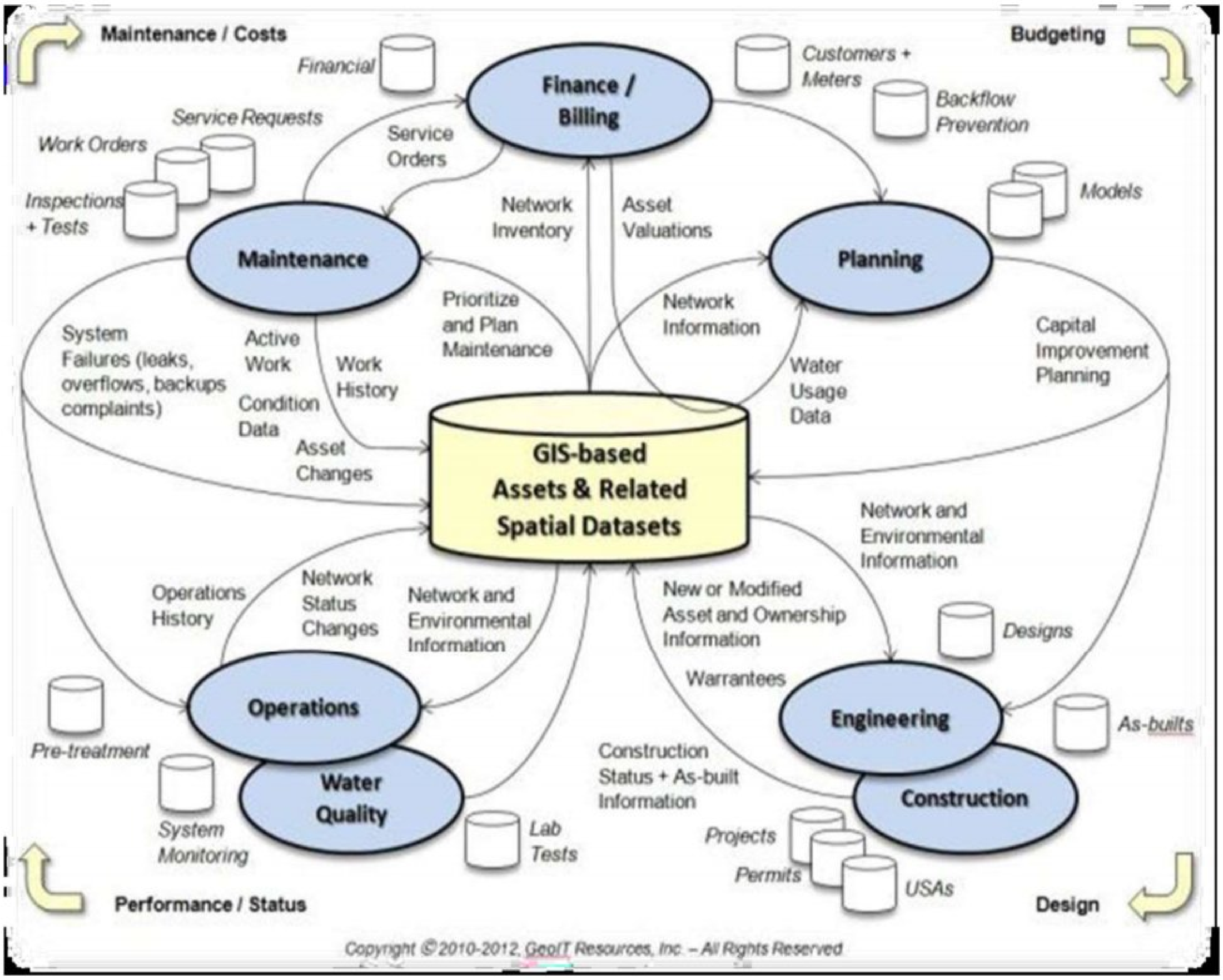

Fig.5.6: GIS based Datasets

CHAPTER-6 RESULTS AND DISCUSSION:

6.1 DISCHARGE AND HFL CALCULATION OF GANDHESWARI RIVER BASIN.

Monsoon and Post Monsoon High flood level (H.F.L) and Discharge (Q) calculation of 10 years at Gandheswari river basin at Bankura District are given table no-6.1. Graphical Representation also shows the water depth and discharge relation of monsoon and post monsoon season of basin area of Gandheswari river. Graphical representations are shows fig.no-6.1 and 6.2 are given below.

Table 6.1

	MONSOON		POST MONSOON	
YEARS	AVG. WATER LEVEL (in Metre)	AVG. DISCHARGE (Cumec)	AVG. WATER LEVEL (in Metre)	AVG. DISCHARGE (Cumec)
2012	28.48	16.6	8.29	5.32
2013	36.22	23.25	40.53	25.47
2014	6.51	2.61	0	0
2015	17.22	10.48	0	0
2016	36.72	23.6	34.2	19.4
2017	51.53	33.76	36.78	23.97
2018	72.06	47	36.57	22.57
2019	69.5	40.25	71.1	44.6
2020	72.05	47.49	36.51	23.18
2021	71.65	45.96	36.62	21.58

Logarithm form of Monsoon data are given table no-6.2

Table: 6.2

LOG (D)	LOG (Q)
1.45454	1.220108
1.558948	1.366423
0.813581	0.416641
1.236033	1.020361
1.564903	1.372912
1.71206	1.528402
1.857694	1.672098
1.841985	1.604766
1.857634	1.676602
1.855216	1.66238

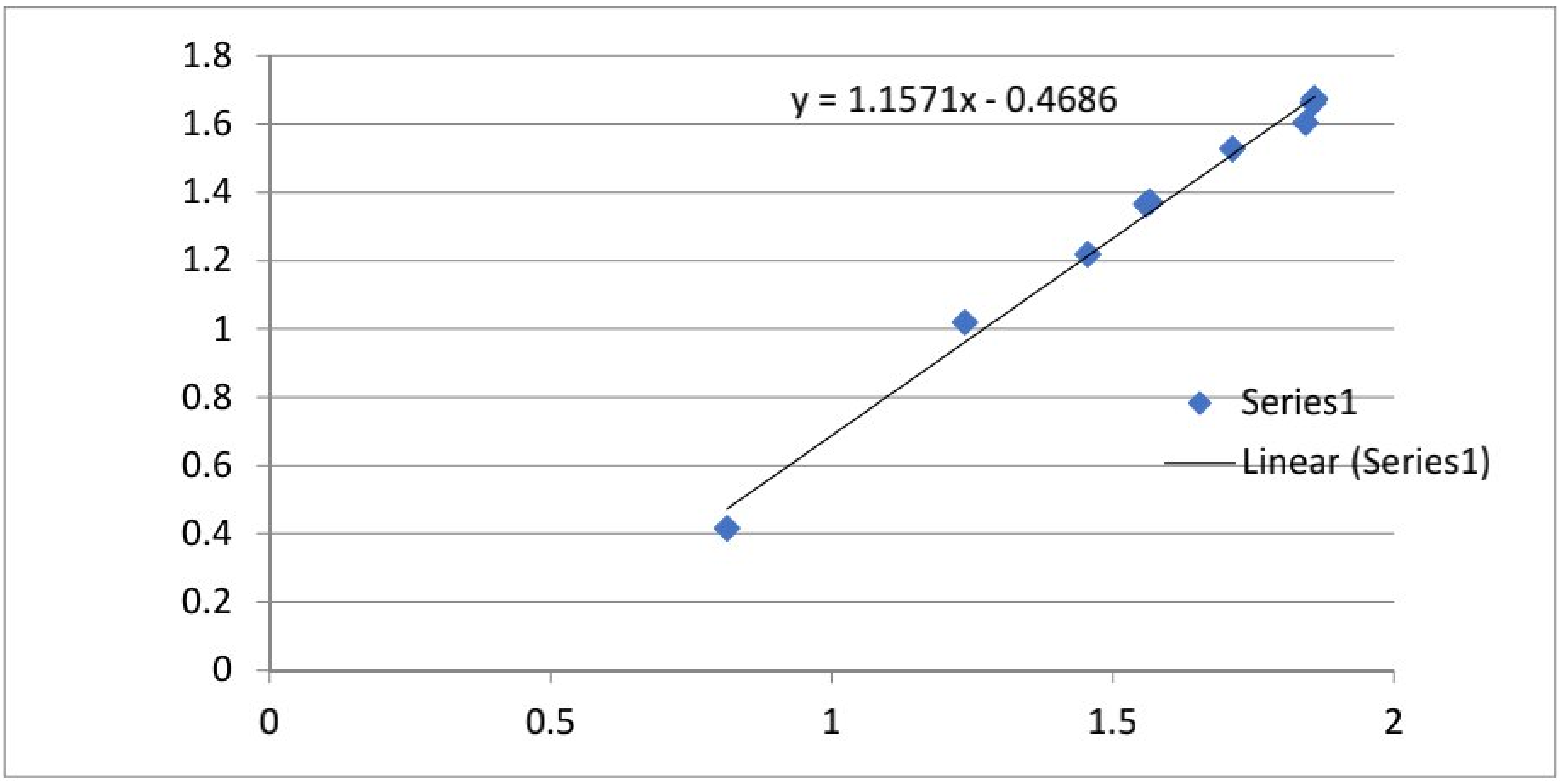

Fig. No-6.1 Graphical Representation of Water depth (D) X axis to Discharge (Q) Y axis (Monsoon)

Logarithm form of Monsoon data are given table no-6.3

Table: 6.3

LOG (D)	LOG (Q)
0.918555	0.725912
1.607777	1.406029
0	0
0	0
1.534026	1.287802
1.565612	1.379668
1.563125	1.353532
1.85187	1.649335
1.562412	1.365113
1.563718	1.334051

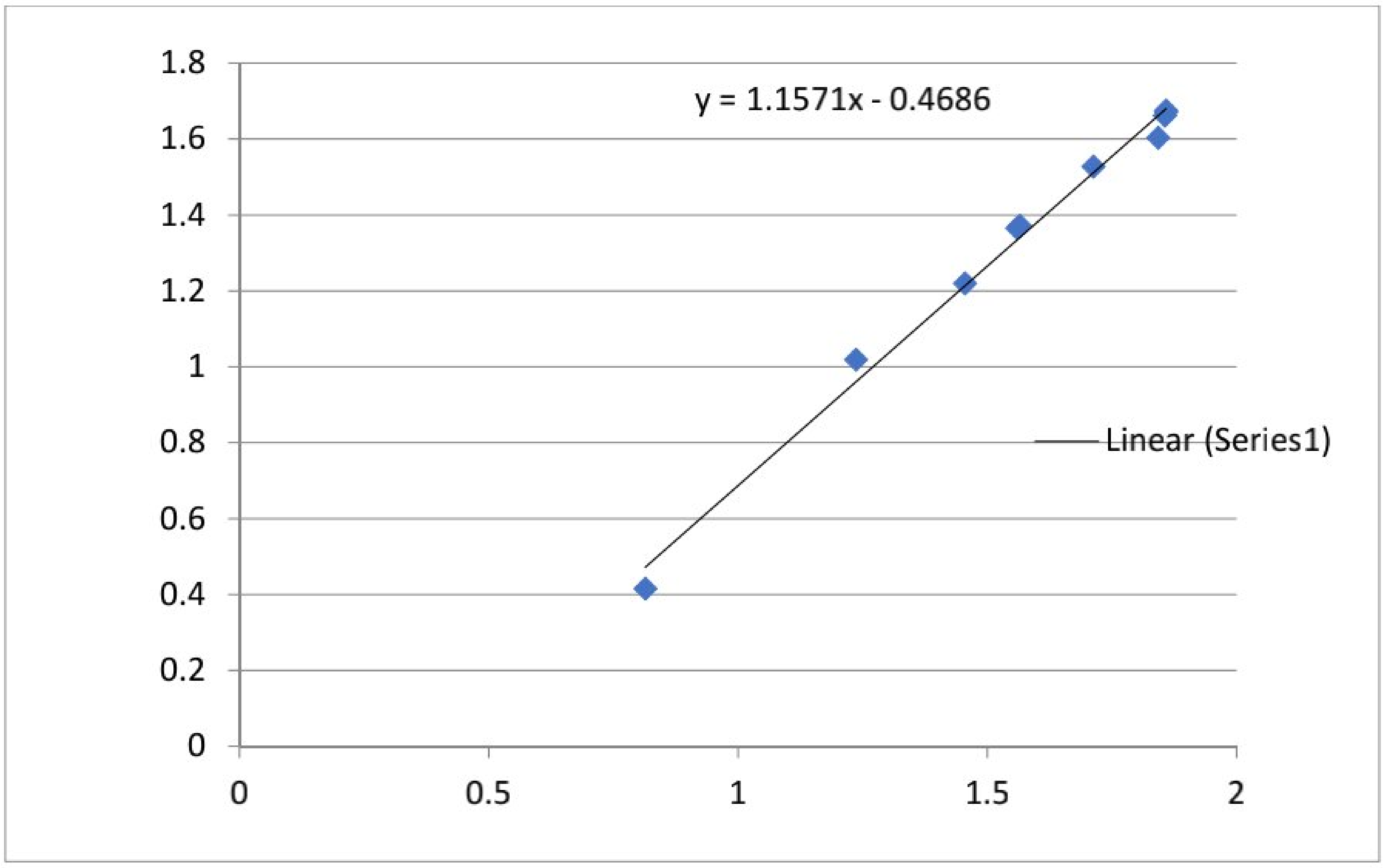

Fig. No-6.2 Graphical Representation of Water depth (D) X axis to Discharge (Q) Y axis (Post Monsoon)

There is an attempt here to understand how the WDPs (Water Development Programme) have helped improving land use pattern and agricultural productivity across different watershed regions. In order to give a general picture of the scenario, the central government schemes of IWDP, DPAP and DDP evaluated by the established organizations are taken into consideration for review and analysis.

6.2 CHANGE IN LAND USE PATTERN

Better land use pattern is one of the important objectives of watershed management. With increase in surface water conservation and increase in availability of water in the watershed regions, it is expected that there will be more positive change in land use pattern. The change in land use is in a positive direction due to watershed development programme. The report indicates about 35% to 70% changes in land use in all the districts of the state. This is especially due to initiation of vegetable cultivation especially in fields close to development of irrigation structures. There is also decrease in cultivable wastelands due to WDP in the state. On an average about 60% of the cultivable wastelands especially that are nearby the newly developed irrigation structures are put into use i.e. cultivation started in these wastelands due to WDPs.

6.3 CROPPING PATTERN AND AGRICULTURAL PRODUCTIVITY

Since water is essential for agricultural production, the provision of adequate water by means of increasing ground water level and conservation of surface water are instrumental. With available water harvesting structure farmers are inclined to new cropping pattern and agricultural diversification. Both agricultural diversification and intensification lead to increase in agricultural productivity in the regions where watershed programmes are effective.

6.4 CROP DIVERSIFICATION:

Crop diversification is also an important outcome of the watershed programme. The study area of Bankura district covered under better adoption to commercial crops especially among the small and medium farmers. The farmers are moving towards growing fruits and vegetables. Vegetable cultivation is popular where there is adequate water or irrigation facility available. However, very less people are interested so far to take up micro enterprises initiatives. By and large crop diversification is possible due to WDPs. In some states there is more preference to commercial crops with better water harvesting structures and in irrigated areas. In some other states, vegetables crops are well adopted. This not necessarily means that the area under cereal crops is declining

6.5 FINDING OUT THE PROBABLE CHANGE IN CROP INTENSITY

The change in cropping intensity is one of the major indicators to assess impact of the watershed development programmes

It is observed to be found that the proposed micro irrigation structures would provide a better water detention capacity in the micro watershed. The total volume of water obtained from the existing as well as newly proposed micro irrigation structures when used judiciously along with a proper cropping pattern based on the agro-climatic conditions prevailing in the area, the single crop areas can be converted into double crop areas thereby increasing the cropping intensity of that watershed.

This project can therefore be implemented at a larger scale for more effective water resource management and also to irrigate non-cultivable areas thereby increasing the culturable command areas (CCA).

Increase in residual moisture content due to contour bunding helping in crop growth and yield. Loosening the hard strata, thus increase in infiltration of water and easy penetration of roots due to land development activities like levelling and tillage. Decrease in soil erosion and hence protection of fertile top soil due to contour bunding. Increase of ground water and supplemental irrigation due to water harvesting structures.

6.6 INCREASES IN AGRICULTURAL PRODUCTIVITY

Rice is the main crop of the Bankura district. Though the district is prone to drought, but the help of WDPs (Water Development Programme) it can raise surplus food production. Besides rice, the major crops are Potato, wheat, Vegetables, Mustard, Summer Til etc. Like rice, the district is also surplus in Potato & Vegetable production. The district is lagging behind in the production of Pulses & Oilseeds. We are to give special emphasis in production of Oilseeds & Pulses by introducing new varieties of Pulse Crops like.Arhar, Lentil, Gram,Khesari,Kalai,Moong etc. Ground Nut and Sunflower have been introduced in Rabi season to meet up the gap between demand and production of Oilseed crops. Broccoli and Capsicum are also cultivated by farmers of this district to meet up the demand of the local people.

Efforts should be made to increase the yield of common cultivated crops by adopting the following measures:

- High yielding / Hybrid variety of seeds.
- Judicious use of irrigation water
- Short duration and with low requirement of moisture level crops
- Proper use of manures and fertilizers

6.7 POVERTY ALLEVIATION.

The data with respect to poverty alleviation as directly observed from the field was only made available in the district of Bankura where reduction of poverty level and income generating activities carried out under the project helped in providing some regular income and also observed that the impact of these projects on poverty alleviation and the long-term sustainability was however less clear. Even though the results indicate that successful projects have in fact reduced rainwater runoff and recharged ground and surface water aquifers, improved drinking water supply, increased the irrigated area, changed cropping patterns, crop intensity and agricultural productivity, increased availability of fuel and fodder, improved soil fertility and changed the composition of livestock.

6.8 IMPROVEMENT IN STANDARD OF LIVING.

Successful implementation of the watershed programme is realized in the fact that it brings more lands under cultivation, improve the quality of the land thereby the productivity. All the positive impacts of WSD are expected to culminate in improved standard of living at the household level. People are 43 able to get some regular income perhaps some additional income which leads to additional expenditure. Raised income enables a better life in terms of better food, clothes, education, health, more spending at the time of festivals and marriages, physical assets and amenities acquired.

6.9 PREPARATION OF FINAL MAP BASED ON THE PROPOSED SCHEMES AND COMMAND AREAS.

The final output map is prepared using GIS and Remote sensing techniques as shown in Fig.6.3

MAP SHOWING PROPOSED SCHEMES AND COMMAND AREA WITHIN STUDY AREA

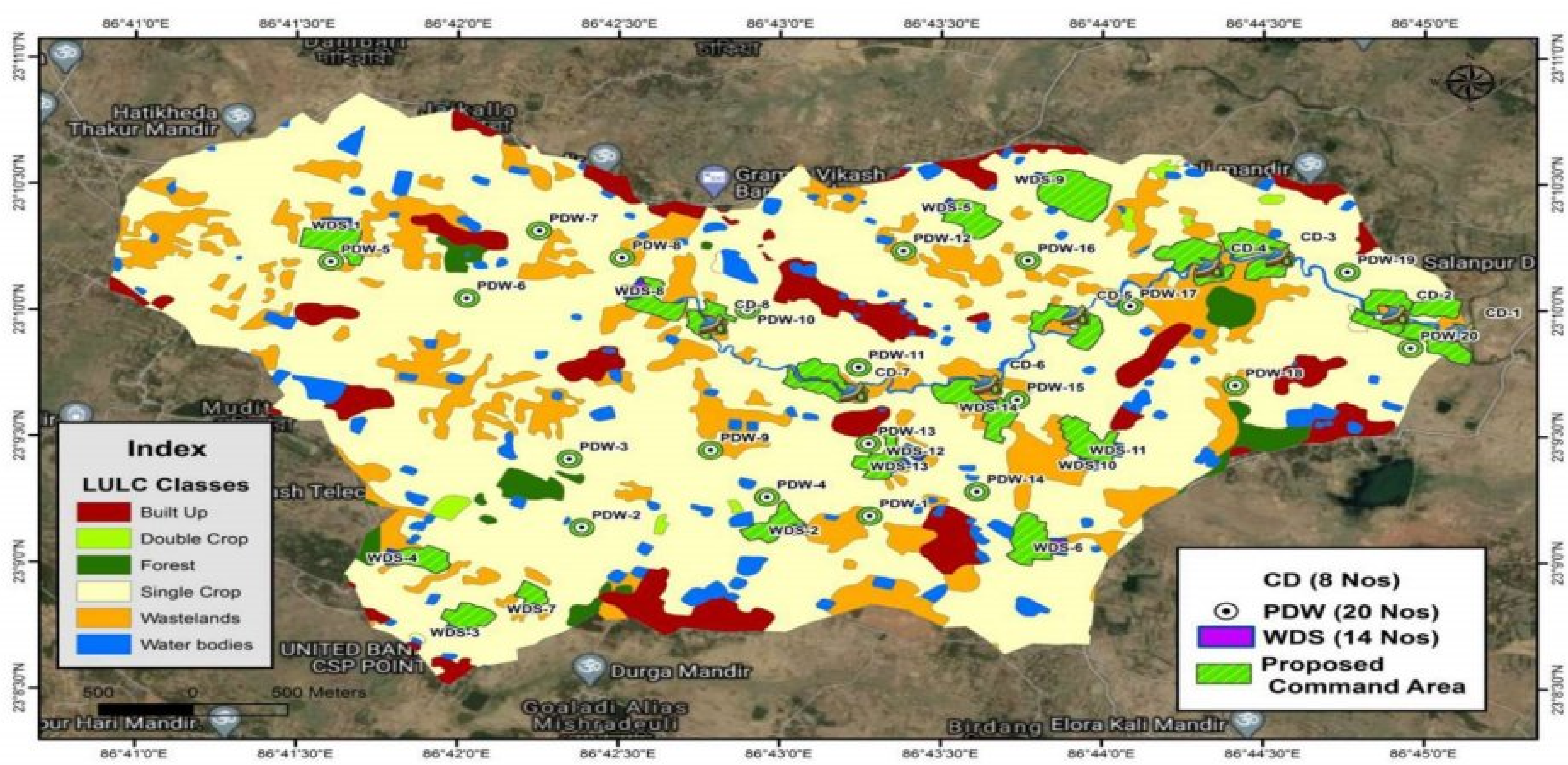

Fig.6.3: Proposed schemes and command areas final map

CHAPTER-7CONCLUSION:

7.1 LIMITATION OF STUDY

On the basis of above studies flowing conclusion have emerged that there is fairly good correction between the rainfall data and runoff data of the water shed and thereby making the generated runoff data suitable for the study.

The satellite imagery for identifying correct land use pattern of the watershed by visual interpretation technique of remote sensing is found to be an appropriate technique for estimation for peak rate of runoff and run off volume of the watershed by using land use curve number from Satellite data in the Hydrologic Soil cover Complex Number Method.

The Present study has highlighted the emerging state of watershed of the region and underscored the need for appropriate and timely measure for watershed management which have been spelt out in the study

It is observed that remote sensing can provide data on surface water bodies, estimate meteorological variables like temperature and precipitation, estimate hydrological state variables like soil moisture and land surface characteristics, and to estimate fluxes such as evapotranspiration, etc. When these data is organised in a Geographical Information System (GIS) along with other parameters, they become an important tool that helps in making decisions about delineating catchment areas, provide precision on crop selection and defining market based agricultural strategies. One way, it may say the process provides effective ways to observe surface water dynamics, compared to traditional in situ measurements.

Outcomes of this pilot in part of Bankura district develop a system using python language that can delineate catchment areas of any geographical locations within a fraction of time. Besides, it could map the existing water resources available in those locations and can give analternative intelligence on potential schemes to be constructed based on calculation of catchment as well as other parameters like soil, terrain information, etc. That knowledge would help reducing human efforts towards identification of appropriate scheme locations as well as facilitates to implement saturation mode approach in an given area in the perspective of ensuring irrigated water to all targeted beneficiaries. Besides, the process would help mapping of availability of total water volume in a given areas that may help benefitting farmers to make appropriate plans for agriculture and allied sectors in any seasons.

This system could be tagged with weather forecast information, soil moisture mapping data, etc for more precision agriculture.

7.2 FUTURE SCOPE OF STUDY

In future these results can be used to prepare a proper exploration plan for groundwater resources of the study area for having a long-term sustainability of this limited resource. Detailed application GIS with integration of Artificial intelligence (AI) also useful for accurate estimation and artificial recharge planning and other environmental studies related to the groundwater availability in the study area. The final map obtained in this study can be utilized by planners and administrators to look for the groundwater resources in the study area. This method can also improve with application of modern software like Mik-she other parts of the exploring groundwater and sustainable watershed management.

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