River & Research

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Editors

SAIARD

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EDITORIAL NOTE

It is with immense pride and anticipation that we present "River & Research," an extraordinary testament to the profound interplay between human exploration and the vibrant ecosystems of rivers. Published by the South Asian Institute for Advanced Research & Development (SAIARD), this book stands as a pinnacle of scholarly dedication and environmental advocacy.

"River & Research" is a collaborative endeavor, showcasing the collective wisdom and tireless efforts of esteemed researchers, ecologists, and scholars from around the globe. SAIARD's commitment to fostering interdisciplinary dialogue and promoting innovative research shines brightly within these pages.

This comprehensive volume serves as a captivating chronicle, delving into the multifaceted relationships between rivers and the progress of human civilization. Through meticulous research, compelling narratives, and cutting-edge insights, the book illuminates the pivotal role that rivers have played throughout history — as cradles of civilization, sources of inspiration, and conduits for scientific discovery.

As you journey through the chapters, you'll traverse continents and eras, uncovering the intricate connections between scientific inquiry and the preservation of these precious waterways. "River & Research" doesn't merely dwell on historical anecdotes; it grapples with contemporary challenges, urging proactive measures to protect and sustain these vital ecosystems.

SAIARD's commitment to excellence is vividly displayed through the book's rich visual content, scholarly rigor, and thought-provoking analyses. Every page invites contemplation, urging readers to reflect on the symbiotic relationship between rigorous scientific investigation and the conservation of our planet's natural resources.

"River & Research," a cornerstone of SAIARD's dedication to advancing knowledge and fostering environmental stewardship, stands as a beacon of hope and a catalyst for positive change. We extend our gratitude to the authors, researchers, and contributors whose dedication has brought this remarkable work to fruition.

With great enthusiasm, we invite you to embark on an enlightening and transformative journey through the captivating pages of "River & Research."

PREFACE

In the vast tapestry of our world, rivers flow as the lifeblood of civilizations, sustaining ecosystems, nurturing cultures, and inspiring human ingenuity. It is with immense pleasure and deep reverence for these vital waterways that the South Asian Institute for Advanced Research & Development (SAIARD) proudly presents "River & Research."

This book stands as a tribute to the enduring relationship between humanity's quest for knowledge and the majestic presence of rivers. As an institute committed to the advancement of knowledge and the promotion of sustainable development, SAIARD recognizes the pivotal role of rivers in shaping our past, influencing our present, and charting the course for our future.

"River & Research" is the culmination of collaborative efforts, a collective endeavor involving dedicated researchers, scholars, and experts in diverse fields. Through their unwavering commitment and expertise, this book embarks on a profound exploration of the intricate connections between scientific inquiry and the preservation of rivers. Within these pages, readers will embark on a captivating journey across continents and epochs, traversing the currents of history, culture, and scientific discovery. The book eloquently portrays how rivers have been at the forefront of human civilization, fostering trade, nourishing agriculture, and providing inspiration for artistic expression.

Moreover, "River & Research" confronts the pressing challenges faced by these invaluable waterways in the modern era. From pollution to overexploitation, from the impacts of climate change to the loss of biodiversity, the book calls for a united global effort to safeguard these precious ecosystems for generations to come. As we navigate the pages of this remarkable volume, let us heed the call to action embedded within its narrative. Let us recognize the symbiotic relationship between our quest for knowledge and our responsibility to protect and preserve the natural world.

We extend our heartfelt gratitude to the authors, researchers, and contributors whose dedication and expertise have brought forth this illuminating work. May "River & Research" serve as a catalyst for dialogue, action, and a renewed commitment to the stewardship of our planet's rivers. With great anticipation, we invite you to delve into the pages of "River & Research" and embark on a journey that celebrates the profound interplay between rivers and the relentless pursuit of knowledge.

CONTENTS

MICRO-EXAMINATION OF FISHES IN THE RAMGANGA RIVER SYSTEM

Prof. Neelima Gupta

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Abstract

India is rich in riverine aquatic resources and fish has a special importance as a supplement to ill- balanced cereal. In India, water resources themselves have potentialities of aquatic food approximating to 7.5 millions hectares. However, the reckless use of natural resources and dangerous chemicals concomitant with industrialization and population explosion has added substantial dimensions to the problem of pollution which has acquired the status of a global problem. Much concern has recently been generated over adverse health effects arising from effluent polluted waters. Under extreme conditions, there have been cases of mass mortality of fishes.

Ramganga is the first major tributary joining Ganga originating from Doodhatoli ranges of Kumaun Himalayas in the district of Pauri Garhwal, Uttarakhand and flows south west. It originates from the high altitude zone of 800m-900m. The length of the river from the source to the confluence with the Ganga is 596 km. and the catchment area of the basin is about 32,493 sq. km. During its course of flow, it traverses through Kalagarh, Moradabad, Bareilly, Jalalabad (Shahjehanpur) and finally merges with river Ramganga at Kannauj. Five experimental stations (I Kalagarh, II Moradabad, III Bareilly, IV Jalalabad and V Kannauj) were selected on the river banks for fish collection and micro-examination for fish parasites.

Fish parasites are found in classes Trematoda, Acanthocephala, Cestoda and Nematoda. Important parasites of the trematodes are found in the orders Digenea and Monogenea. Some fish parasites are important disease producing agents in man. A total of 30 Pallisentis from 18 hosts of Kalagarh, 26 from 14 hosts of Daswa Ghat, 29 Pallisentis from 23 hosts of Katghar were isolated during the study period from Channa punctatus. C. punctatus collected from Chaubari (Bareilly) showed highest mean intensity where 128 Pallisentis were recovered from 45 hosts.

Out of 49 Channa punctatus from Daswa Ghat one fish was found infected with Clinostomum complanatum while another one was found to be infected with trematode *metacercaria. A single Euclinostomum heterostomum was also collected out of 63 C. punctatus from Chaubari, Bareilly.*

The present research has brought out some interesting findings pertaining to parasitic infection which may adversely affect fish health and fish consumers. Our concern for fish health and its productivity is obvious as it offers an excellent source for meeting out the protein and vitamin deficiency of the state and country at large.

***Key words**: Ramganga, parasites, Acanthocephala, trematodes, cestodes*

Introduction

Rivers are vital components of the biosphere that contain less than one percent of the world's fresh water with their higher ecological and social significance which are being polluted by indiscriminate disposal of sewerage, industrial waste, and by excess of human activities affecting their physicochemical characteristics and leads to various deleterious effects on aquatic organisms (Murhekar, 2011; Annalakshmi and Amsath, 2012).

Ganga and its tributary Ramganga are important river systems of Uttar Pradesh which are rapidly being victimized by increasing pollution. The aquatic fauna is at great risk due to the threat thus imposed and it is high time that attention of scientists be directed in this direction in order to achieve the goals set forth for "Blue Revolution". Our country is marching towards a "Blue Revolution" after the success of the "Green Revolution" and "Operation Flood". Fishery today, is no longer a traditional mode of earning a livelihood for a particular section of our people. With its vast, but partially exploited resources, it represents one of the most important developing sectors contributing towards the growth of our national economy.

It has been estimated that fisheries sector contributes to animal protein supply 63%, GDP 5.24% and foreign exchange earning 4.76% for the nation. For sustainable aquaculture production, it is therefore important to give proper attention to this essential area. Fish not only serve the function of food but also contributes a lot to meet the basic nutritional requirements and also plays a vital role in fulfilling the deficiencies of vitamins, proteins and minerals besides driving away the diet related diseases. It is the cheapest source of animal protein of high biological value (89%) as compared to mutton (80%) and chicken (78%). Besides, fishes also have a rich amount of vitamins, mainly A and D, essential minerals and mineral salts which are essential components of a balanced diet. Since time immemorial, fish has enjoyed a special consideration in human diet. It has become essential to exploit the water resources, which are increasing rapidly due to our water conservation policy in order to meet the demand of protein-rich food for an ever growing population.

Fish not only serve the function of food but also contributes a lot to meet the basic nutritional requirements and also plays a vital role in fulfilling the deficiencies of vitamins, proteins and minerals besides driving away the diet related diseases. Since fishes are utilized by the humans, it is thus important that they should be healthy and free of any kind of infection.

According to Uma *et al*. (2012) fish parasites affect fish production in wild and cultured systems by decreasing their yield, aesthetic value, marketability, palatability, modulate the immune system and reproductive potential and if left unattended, may lead to mass mortality in fish, or in cases, infection in human and other animals that feed on fish. Thus, they are studied with a view to understand their population biology and elucidate their life cycles in order to develop an efficient approach to control them. According to Mas-Coma *et al*. (2008) the climate variables are able to affect the prevalence, intensity and geographical distribution of helminths, directly influencing free-living larval stages and indirectly influencing mainly invertebrate, but also vertebrate hosts. The present venture was therefore undertaken to examine freshwater fishes from river Ramganga from five different experimental stations and to observe their parasitic infestation in order to determine their prevalence, mean intensity, abundance and impact on fish health.

Selection of Experimental Stations (Plate I)

Five experimental stations (Plate II) were selected along the course of river Ramganga as mentioned below:

- **Station I:** **Kalagarh dam** 29°31°10°N 78°45°31°E: The Kalagarh Dam also known as the Ramganga Dam, is situated on the Ramganga river 3 km (2 mi) upstream of Kalagarh in Pauri Garhwal district, Uttarakhand, India.

- **Station II:** **Moradabad** 28.83°N 78.78°E: Moradabad, commonly known as the Brass City is situated at a distance of 167 km (104 mi) from New Delhi, the national capital and 262 miles (421 km) north-west of Kanpur on the banks of the Ramganga river. Two sub-sites were selected:

  A:- Daswa Ghat (Prior to merging of industrial wastes) and
- B:- Katghar (Post merging of industrial wastes), Moradabad

- **Station III:** **Chaubari (Bareilly)** 28.364°N 79.415°E: Bareilly city of Uttar Pradesh is situated on the banks of river Ramganga.
  The annual festival of Ganga Dussehra is organised on the banks of Ramganga annually at Chaubari village near Bareilly.

- **Station IV:** **Jalalabad** 27.12°N 79.78°E: Jalalabad Tehsil has four rivers, Ganga, Ramganga, Bahegul, and Khadri.

- **Station V: Kannauj** 27.07°N 79.92°E: Kannauj is an administrative district of Uttar Pradesh along the river Ganges having an average elevation of 139 metres (456 feet).
- This is the confluence point of river Ramganga with Ganga.

Collection of fish samples

Fishes were collected with the help of local fishermen (Plate III), in live conditions from the above mentioned sites and brought to the laboratory in fish containers. They were kept in aquaria under natural environmental conditions. The fishes were identified according to Srivastava (1980) and Venkateshwarlu *et al*. (1986). The details of fish collection are as follows:

- Kalagarh: *Channa punctatus* and *Glyptothorax cavia*
- Moradabad (Daswa Ghat): *Channa punctatus*
- (Katghar): *Glyptothorax cavia, Wallago attu, Channa punctatus*
- Chaubari (Bareilly): *Labeo rohita, Channa punctatus, Mystus vitatus*
- Jalalabad: *Labeo rohita, Channa punctatus*
- Kannauj: *Labeo bata, Channa punctatus*

Parasitic investigations

The collected fishes were screened for parasites. Prior to sacrificing the fish for endoparasite collection, fish weight, sex, total lengths and site were recorded. Some fishes died in transit, they were also weighed and such fishes were sacrificed on priority. In case the number of dead fish was high, they were frozen at -20°C till investigated.

Live fish were desensitized, the ventral surface of the host was cut open with the help of a sharp scissor. The body cavity from mouth to cloaca was examined visually with the help of a magnifying glass for helminthic infection. Thereafter, the entire gastro-intestinal tract was detached from the body cavity. Different internal organs like esophagous, stomach, small intestine and rectum were placed separately in different petri dishes having normal saline (0.85% NaCl). Different body organs were longitudinally cut open and examined for helminthic parasites.

The recovered parasites collected from the entire gastrointestinal tract were isolated in another petri dish containing normal saline. The lumen of GI tract was washed several times until all the parasites were recovered. Parasites were also washed several times to remove the host's intestinal debris, if any, attached on the surface of parasite.

Prevalence, mean intensity and abundance concepts as suggested by Margolis *et al*. (1982) were followed in the present study.

$$\text{Prevalence \%} = \frac{\text{Total number of host infected X 100}}{\text{Total number of host examined}}$$

$$\text{Mean Intensity} = \frac{\text{Total number of parasite}}{\text{Total number of host infected}}$$

$$\text{Abundance} = \frac{\text{Total number of parasite}}{\text{Total number of host examined}}$$

Helminth Parasites (Plate IV)

(A) *Pallisentis* (Acanthocephala)

Collection and isolation

Pallisentis were collected from the entire intestine and were kept in another petridish containing normal saline. The lumen of GI tract was washed several times by distilled water until all the parasites were recovered. Parasites were also washed separately several times to remove the host's intestinal debris, if any, attached on the surface of parasite. *Pallisentis* could be seen easily through naked eye but sometimes, the smaller worms were viewed under the microscope.

Fixation

Procedure 1: Glycerine Alcohol Preparations

The collected parasites were kept in normal saline at room temperature for one to two hours and relaxed, so that parasites with fully everted proboscis and bursa could be recovered. They were fixed in hot 70% alcohol (70ml. absolute alcohol and 30ml. distilled water). 70% alcohol was boiled in a beaker and these parasites were transferred from the petri dish to beaker for fixation. These parasites were then left in 70% alcohol for at least 24 hours.

Dehydration and mounting of *Pallisentis*

After fixation, these parasites were transferred in cavity blocks containing glycerine-alcohol (5 parts glycerine and 95 parts 70% alcohol). These cavity blocks were placed in desiccators containing anhydrous calcium chloride at room temperature for two to three weeks for dehydration. During this time interval, alcohol of glycerine-alcohol solution evaporated and pure glycerine was left for parasites. After two to three weeks when the dehydration process completed, these worms were mounted in anhydrous glycerine on clean glass slides. Small pieces of cover slips or glass wool were used for mounting so that they were safely mounted without flattening or crushing. The edges of coverslip were sealed with nail paint.

Permanent slides were also made using wax. With the help of a metal rod a wax ring was made and a drop of anhydrous glycerine was placed in this wax ring. Later, the parasite was transferred in the dehydrated glycerine. Coverslip was gently placed over the wax ring and this mounted slide was kept over the heating plate. Wax melted due to the effect of heat and thus, coverslip was permanently fixed.

Procedure 2: Borax Carmine Staining

Parasites with fully everted proboscis were washed several times by distilled water. They were fixed under pressure of a cover glass in AFA (Alcohol Formal Acetic).

Composition of AFA

Formalin 40%	……………………….10ml.
Glacial acetic acid	……………………….5ml.
Ethyl alcohol 70%	……………………….85ml.

After fixation, these worms were washed properly under running tap water. This step was necessary to remove traces of formalin present in the fixative. Parasites were preserved in labeled glass vials containing 70% alcohol.

Staining, Destaining and Differentiation

(A) *Pallisentis*

For staining *Pallisentis,* following stains were used:

Borax Carmine

Borax	……………………….4gm.
Carmine	……………………….2gm.
Distilled water	……………………….100ml.

The stain was made by boiling borax and carmine for about half an hour, until it changed its colour. Equal volume of 70% alcohol was added, allowed to stand and filtered. After 2-3 days it matured enough to be used in the laboratory.

Eosin

1. **Aqueous Eosin**

Eosin powder	………………………. 1.0gm.
Distilled water	………………………. 100ml.

2. **Alcoholic Eosin**

Eosin powder	…………………….. 1.0gm.
Alcohol 70%	……………………….100ml.

For staining specimens with aqueous borax carmine, the specimens were hydrated by processing them through 30% and 50% alcohol and then into distilled water. Trematodes were over stained for 30-40 minutes. For destaining, parasites were placed in a petri dish having acid alcohol to remove excess stain. In between they were observed under the microscope for differentiation of internal organs. Parasites were then washed with distilled water for removing excess acid.

Dehydration

After the specimens took the requisite stain, they were dehydrated. For dehydration, parasites were passed through an ascending graded series of alcohol i.e. 30%, 50%, 70%, 90% and two changes in 100% alcohol for about 15 minutes each. At last, these parasites were transferred to absolute alcohol for proper dehydration.

Clearing and Mounting

After dehydration, specimens were cleared in clearing agent (xylene, cedar wood oil or clove oil) and mounted in a mounting medium (Canada Balsam or DPX).

(B) ***Clinostomum complanatum***

Fishes were examined for the presence of metacercaria, the location of metacercaria and their number was recorded. Collected specimens were washed and preserved in 70% alcohol, after flattening under a moderate pressure using a cover glass slide. The preserved specimens were stained with aceto carmine, dehydrated, cleared and mounted in Canada balsam/ DPX.

(C) Trematode metacercaria

Metacercarial stages of digenetic trematodes usually parasitize major organs of fish like oesophagus, gills, liver, heart and body cavity. Larval trematodes were flattened between two slides or under slight pressure of slide and coverslip, post-fixed in AFA (Alcohol, Formalin and Acetic acid in 85:10:5) and stained with alum carmine. Conventional techniques were employed for permanent whole mount preparations.

(D) *Euclinostomum heterostomum*

The encysted metacercariae of *E. heterostomum* were freed from the host tissue and mechanically excysted in 0.74% NaCl by carefully tearing up the cyst wall using forceps and needle to liberate the worms, which were processed to prepare permanent slides after staining in carmine for microscopic observations.

Light microscopy examination

The above parasites were measured and photographed under Olympus BX 53 microscope with DIC attachment, digital camera and CELLSENS imaging system.

Parasitic observation

Overall infectivity

A total of 38 specimens of *Labeo bata*, 12 specimens of *Glyptothorax cavia* and 64 specimens of *Channa punctatus* from Kalagarh; 49 from Daswa Ghat*;* 8 of *Wallago attu* and 7 of *Glyptothorax cavia* from Katghar (Moradabad) were examined for parasitic infection. Furthermore, 10 specimens of *Mystus vitatus,* 11 of *Labeo rohita* and 63 of *C. punctatus* from Chaubari (Bareilly); 42 of *L. rohita* from Jalalabad and 63 specimens of *L. bata* from Kannauj were examined for parasitic infection. The prevalence, abundance and mean intensity of parasitic infestation were also recorded. A total of 30 *Pallisentis* from 18 hosts of Kalagarh, 26 *Pallisentis* from 14 hosts of Daswa Ghat, 29 *Pallisentis* from 23 hosts of Katghar were isolated during the study period. *C. punctatus* collected from Chaubari showed highest mean intensity where 128 *Pallisentis* were recovered from 45 infected hosts.

Furthermore, out of 49 *C. punctatus* from Daswa Ghat, one fish was found infected with *Clinostomum complanatum* while another one was found to be infected with trematode metacercaria. A single *Euclinostomum heterostomum* and a single adult cestode were also recorded from a fish collected from Chaubari, Bareilly.

A list of all the parasites recovered from the fishes is given in **Table 1.**

River Site	Host species	No. of host examined	No. of host infected	Total no. of parasites recovered					
				Pallisentis	Adult trematode	Trematode metacercaria	*Clinostomum complanatum*	Adult cestode	*Euclinostomum heterostomum*
Kalagarh	*L. bata*	38	12		20				
	Glyptothorax cavia	12							
	C. punctatus	64	18	30					
Daswa Ghat	*C. punctatus*	49	14	26		1	1		
Katghar	*C. punctatus*	63	23	29					
	W. attu	8							
	Glyptothorax cavia	7							
Chaubari	*C. punctatus*	63	45	128				1	1
	M. vitatus	10							
	Labeo rohita	11							
Jalalabad	*Labeo rohita*	42							
Kannauj	*Labeo bata*	63							

Pallisentis

The prevalence of infection of *Pallisentis* parasites in *C. punctatus* from Kalagarh was 28.12%. The mean intensity was 1.17 while abundance was 0.32 whereas, the prevalence, mean intensity and abundance of *Pallisentis* were 28.57%, 1.85 and 0.53 respectively, from Daswa Ghat and 36.50%, 1.26 and 0.46 at Katghar (Moradabad) respectively from *C. punctatus*. Highest prevalence, mean intensity and abundance of *Pallisentis* were recorded in the fishes collected from Chaubari site with the values of 71.43%, 2.84 and 2.03 respectively **(Table 2).**

Table 2: Prevalence, mean intensity and abundance of Pallisentis sp in C. punctatus collected from different sites

Site	Number of host examined	Number of host infected	No. of worms collected	Prevalence %	Mean Intensity	Abundance
Kalagarh	64	18	21	28.12%	1.17	0.32
Daswa Ghat	49	14	26	28.57%	1.85	0.53
Katghar	63	23	29	36.50%	1.26	0.46
Chaubari	63	45	128	71.43%	2.84	2.03

This helminth parasite is included in the Phylum Acanthocephala Rudolphi, 1808. These parasites which were formerly included in Nemathelminths, are recognized as a separate phylum as suggested by Rudolphi, 1808. These worms resemble nematodes in having a round, unsegmented body and separate sexes, at the same time show resemblance to Cestoda in lacking a digestive tract. According to Lee (1966) the body wall of *Pallisentis* has a completely different type of structure from that of other helminths. These worms have a proboscis armed with spines and a body proper, lack a digestive tract and have a body cavity lined with epithelium.

A few young parasites were also observed. Under light microscopy, the parasite body appeared elongated, cylindrical, spinose, vermiform with a knob-like anterior and a tapering posterior end and creamy white in colour when alive. Males generally smaller than females. The body is covered with spines. Maximum diameter is in the region of the anterior rows of hooks. Scanning electron microscopy of the adult parasite was also performed and the structure and arrangement of the hooks could be clearly differentiated (Plate IV).

Clinostomum complanatum

Clinostomum complanatum was recorded from the fish collected from Daswa Ghat with a prevalence of 2.04%, mean intensity 1.00 and abundance 0.02 **(Table 3).** Similarly, the prevalence, mean intensity and abundance of trematode metacercaria from Daswa Ghat were 2.04%, 26.00 and 0.53 respectively **(Table 4).**

Table 3: Prevalence, mean intensity and abundance of Clinostomum complanatum in C. punctatus collected from different sites

Site	Number of host examined	Number of host infected	No. of worms collected	Prevalence %	Mean Intensity	Abundance
Kalagarh	64	0	-	-	-	-
Daswa Ghat	49	1	1	2.04%	1.00	0.02
Katghar	63	0	-	-	-	-
Chaubari	63	0	-	-	-	-

Table 4: Prevalence, mean intensity and abundance of trematode metacercaria in in *C. punctatus* collected from different sites

Site	Number of host examined	Number of host infected	No. of worms collected	Prevalence %	Mean Intensity	Abundance
Kalagarh	64	0	-	-	-	-
Daswa Ghat	49	1	26	2.04%	26.00	0.53
Katghar	63	0	-	-	-	-
Chaubari	63	0	-	-	-	-

Only one host was found infected by metacercariae of *C. complanatum*. The site occupied by the metacercariae was the gill chamber and behind opercula although in heavily infected fish, the parasites are known to occur throughout the body cavity, liver, intestine and ovaries (Plate IV).

C. complanatum is a digenetic trematode which causes yellow grub in the muscle of fish and makes them unsuitable for human consumption. At many occasions human infection has also been recorded (Kifune *et al*., 2000). Many species of fresh water fishes were recorded as the second intermediate host of *C. complanatum* (Aohagi *et al.,* 1993).

Trematode metacercaria

The encysted maturing stage of trematode was observed in *C. punctatus* collected from Daswa Ghat, Moradabad (Plate IV). Although the prevalence was low but the number of worms collected from a single fish were 26 showing a high mean intensity. Several developmental stages were observed and a young parasite with no reproductive organs was also recorded.

Euclinostomum heterostomum

Euclinostomum heterostomum from the fishes collected from Chaubari showed the prevalence, mean intensity and abundance of 1.58%, 1.00 and 0.01 respectively **(Table 5).**

Table 5: Prevalence, mean intensity and abundance of Euclinostomum heterostomum in in C. punctatus collected from different sites

Site	Number of host examined	Number of host infected	No. of worms collected	Prevalence %	Mean Intensity	Abundance
Kalagarh	**64**	**0**	-	-	-	-
DaswaGhat	**49**	**0**	-	-	-	-
Katghar	**63**	**0**	-	-	-	-
Chaubari	**63**	**1**	**1**	**1.58**	**1.00**	**0.01**

The hemophagic clinostomid trematode *Euclinostomum heterostomum* (Rudolphi, 1809) is a common parasite of piscivorous birds in many regions of Asia, Africa, and Europe (Yamaguti, 1971). In the Indian subcontinent, the larval stage of this parasite usually infects the liver and kidney of the second intermediate host fish *C. punctatus* as encysted progenetic metacercariae (Jhansilakshmibai and Madhavi, 1997).

During the present investigation, a meagre prevalence of 1.58% was observed at Chaubari, Bareilly (Plate IV, **Table 5**)

Discussions

Over the years, the river Ganga and its tributaries are getting increasingly polluted. Water pollution has become a matter of global concern (Gupta, 2015). The physico-chemical characteristics of river Ramganga (Gupta *et al*., 2006, 2016) were investigated in order to determine its pollution status and also during the annual fest, Chaubari during Kartik Purnima (Gupta *et al*., 2017). The water quality of river Ganga has also been analysed (Singh and Choudhary, 2013; Matta, 2014). Heavy metals are an important source of pollutants (Kumar *et al*., 2019a) and are known to vary along the course of river Ganga (Kumar *et al*., 2019b).

The characteristic of any water body can influence and determine its parasitic fauna and when environmental conditions, such as water, food and temperature become favourable for mass reproduction of parasites, the disease may spread very quickly. The seasonal variation of water characteristics, predominantly temperature, is considered too strongly to affect fish physiology and immunology and also affects all life-cycle stages of monogeneans, digeneans, cestodes, nematodes, and acanthocephalans in freshwater fishes (Karolina *et al*. 2007; Gonzalez *et al*. 2008).

Among the infectious diseases, parasitic diseases account around 19.40% in aquaculture production system. It is also reported that the parasitic infestations are playing a major role in disease occurrences (78%) in Indian freshwater aquaculture (Lakra *et al*., 2006). Fish not only act as a host for different parasites but also serve as carrier of many larval parasitic forms that cause serious pathological disturbances in many vertebrates including man. Among different parasites, helminthes are the important parasites that cause a great threat for fish health management and aquatic crop production throughout the world (Oniye *et al*., 2004). Helminths of fishes' cause decrease in growth rate, weight loss and emaciation, affect yield of fish products (liver oil etc), spread human and animal diseases, postpone sexual maturity of fish and cause mortalities in fish.

Fish parasites are found in classes Acanthocephala, Trematoda, Cestoda and Nematoda. *Pallisentis* (*Brevitritospinus*) *punctati* (Gupta *et al*., 2015) was reported from *Channa punctatus* from river Ramganga and the seasonal distribution of helminth parasites from *Channa punctatus* (Gupta *et al*., 2017). Important parasites of the trematodes are found in the orders Digenea and Monogenea. Some fish parasites are important disease producing agents in man. Yellow grubs are the larval stages of the flukes *Clinostomum marginatum* or *C. complanatum*, belonging to Digenea. *Clinostomum* need to reach a definitive bird host in order to develop into adults. The adult parasites live in the throat and mouth of different species of birds.

Intestinal infections with helminth parasites are common among vertebrates. The infection alters the intestinal morphology significantly and the quality of mucins secreted by the goblet cells. Changes in morphology or functions of the gut has been related to severe disturbances in the intestinal cell turnover (Sweetman *et al.*, 2010). During the present studies, the distribution of helminth parasites in fishes collected from the course of river Ramganga exhibited infestation with species of helminth parasites which may prove to be deleterious for fish health thereby affecting quantitative and qualitative fish production. It is envisaged that the information made available through the research findings will contribute towards promotion of aquaculture, especially in rural areas where people are ignorant about the ill effects of pollution on fish health which plays a key role in the decline of fish production. The studies will assist in utilization of available water resources for fisheries development, will stimulate optimum production of fish from water bodies, will create employment opportunities and will make protein rich food available to the masses.

Acknowledgements

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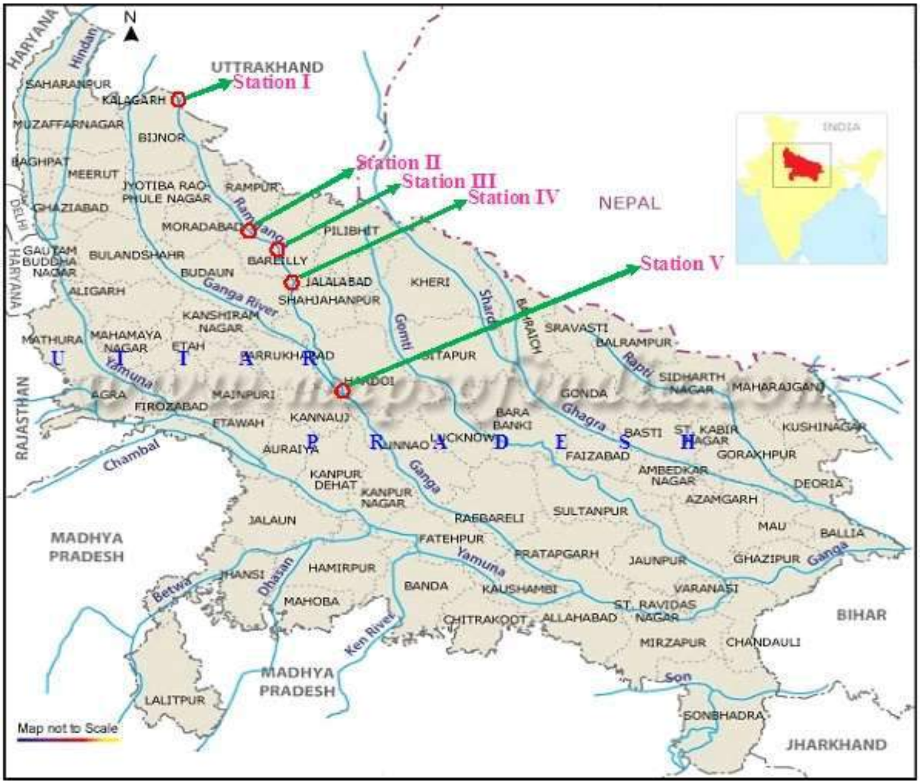

Fig 1: Sampling stations during the course of Ramganga river from Kalagarh to merging point, Kannauj

Site I: Kho Barage, Kalagarh **Site II A Daswa Ghat, Moradaba**


Site II B Katghar, Moradabad **Site III Chaubari, Bareilly**


Site IV: Hullapur, Farrukhabad **Site V: Kannauj (merging point)**

Plate II. Experimental sites on river Ramganga



Plate III. Fishing at experimental site

Anterior end **Posterior end**

Light microscopy of *Pallisentis channai* Gupta *et al*., 2015 from *Channa*

Clinostomum complanatum **Trematode metacercaria**

Plate IV Parasites collected from fishes inhabiting Ramganga river

APPLICATION OF GEOMATICS FOR THE IDENTIFICATION OF LANDSLIDE SUSCEPTIBILITYZONE (LSZ) IN MANDAKINI RIVER BASIN, UTTARAKHAND, INDIA

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Abstract

Power of Geomatics has been used in this paper for integrated watershed management in the Mankini river basin of Uttarakhand district. Mandakini River initiates from Chorabari glacier and joins Alakananda River atRudraprayag area. The river is lying over the highly tectonically active terrain of Uttarakhand. The objective of the current research is to identify the landslide susceptibility zone (LSZ) of the Mandakini basin by using the frequency ratio (FR) model. Slope, plan curvature, aspect, elevation, distance from river, soil, lithology, LULC, distance from fault line, topographic wetness index raster layers are prepared in the GIS science environment to feed the model of landslide susceptibility by using the raster and vector data layers from different sources like-Earth Explorer USGS, Bhukosh GSI. Kedarnath, Rambara, Sonprayag, Gaundhar, Badhani Taal are found under the very high landslide-susceptible zone in the Mandakini basin, where zero tolerance acceptance should be implemented immediately regarding the change in LULC. According to the frequency ratio (FR) model, lithology (FR 10.6) and elevation (FR 5.9) mostly provide a higher impact on theoccurrence of landslides in this Mandakini basin. 45% area under the Mandakini basin falls under a very highly vulnerable area as per an analysis of AUC and needs immediate attention.

***Keywords**: FR model, AUC, watershed management*

1. Introduction

Geomorphology cannot be done without a field survey, but this survey cannot be done in this pandemic situation. Geomatic is a powerful tool to get an idea about geomorphology (Toutin, 2008). The Himalayan area is commonly known as the high transitional area for tectonic upliftments & heavy rainfall. The river Mandakini is derived from the Chorabari Glacier of the Himalayas (Herren, 1987). This river is one of the tributaries of the river

Alakananda. Mandakini River is lying on a crystalline complex Himalayan fold and Main central thrust (Valdiya, 1980). The rate of rainfall annually is above 1000mm. So, the Mandakini River is situated in a highly sensitive area for flooding especially flash flooding, landslide, and other tectonic activities like earthquakes & mass movements (Sundriyal *et al.* 2015). In the year 2013, Kedarnath faced a huge disaster in the Mandakini River due to cloudbursts, which caused tremendous flash floods & landslides. This disaster took a human life and destroyed normal life. Other examples of these disasters occurred in the year 2001, the Budha Kedar landslide; in 1998, the landslide in Okhimath occurred in the Mandakini valley (Chaudhary *et al.* 2010). This disaster occurred not only the physical disturbances but also anthropogenic activities on river banks, river valleys, and river catchment areas. Highly devastating landslides occur in this Mandakini River valley (Chahal *et al.* 2017). In this study, various ways to control landslides to measure the watershed basin have been found with the help of GIS & Remote Sensing tools based on morphological tectonic-hydrological analysis. Rana *et al.* (2016), demonstrated that the Himalayan zone is a disaster-prone area. In the years1984, 1970, and 1978, Garhwal Himalaya had faced landslides and floods. In the recent scenario of 2013, a disaster occurred on a large scale for extreme rainfall. In this paper, they are trying to findout why these huge disasters in Mandakini valley. They used the Weights of Evidence method, LSZ mapping, and pre-post disaster satellite images. They concluded that the landslide happened due to Quaternary sediment cover but no vegetation coverage in Mandakini valley. Chaudhary *et al.* (2010), observed that in 2001, on 16th July, Mandakini, the valley had been triggered by a massive cloud blast. This was an example of a complex landslide. To identify this kind of landslide, they have measured the rainfall characteristics, the geological character of the valley, and the topographical view. The landslide characteristics are observed through surface observation, geotechnical investigations, and subsurface investigations. They concluded that this kind of landslide happened due to high rainfall, thick Quaternary deposits on the steep slope & perennial rivers created the slope instability for that area and the soil also helped in the slope-making process. Taloor *et al.* (2020), illustrated that huge rainfall, landslide, seismic activities damaged the Mandakini River valley. Monsoonal rainfall and tectonic activities gave an impact on this landscape highly. They used geology, geomorphology, morph tectonic and rainfall anomalies. Also, they used Survey of India (SOI) toposheets No. 53 O/13 and 53 C/2; at a 1:50,000 scale as well as the ALOS PALSAR Digital Elevation Model (DEM). They concluded that active folding inside the Mandakini as well as Bhilangana thrust belts would continue to evolve as the topography adjusts to disequilibrium produced

from adjustments in seismic boundary conditions. The gradient is too steep across most studied regions, which accelerates the landslide. Kadavi *et al.* (2018), signifying that landslide is one of the most demolishing disasters in present days. They were examined South Korean landslides in their paper. This paper has included 762 landslide reports on

South Korea and used aerial photographs and data. For this study, they usedsome landslide models like Ada Boost, Logit Boost, Multiclass Classifier, and Bagging. This paper has indicated the high landslide susceptibility zone in South Korea and the mitigation steps. Regmi *et al.* (2012), impacted Lesser and Siwalik Himalayan region, a highly landslide-prone area. In this paper, they studied on Central Nepal Himalayan region. They used DEM, geological maps & field surveys. In this paper, to identify landslide susceptibility zone, they used the Frequency ratio model, and WoE models. This paper indicates that geology & fault lines are given a high impact on landslides and the part of the south of the area in the study is a high zone of landslide susceptibility. Prakash *et al.* (2019), focus on the morphometric investigation of the Mandakini River (Paishwani River) in Madhya Pradesh. They used SRTM DEM & field data. They analyze the morphometry using GIS for identifying as well as understanding parameters of terrain for leading to the development of watershed planning as well as conservation of water management. This paper also gave an impact on resource management by using morphometric analysis. Rai *et al.* (2014), denoted the drainage morphology analysis of the Kanhar River basin. They used ASTER DEM and GIS toolsin this paper. The subwatershed management emphasises this paper to find out the nature of that main watershed and hydraulic characteristics. The prime objective of this paper is to do a watershed behavioural analysis by using morphometry. They also included the element of water resource in this paper and the hydraulic regime which is mentioned there, it applies all over India. Qiu *et al.* (2017), mentioned the comparison between distribution as well as size & relative relief of the landslide at Shaanxi in China. In this paper, they were used GIS tools & DEM. They established a relation between relative relief and landslide. According to them, if relative relief increased then landslides also increased. They used some statistical methods to prove the correlation between these 2 variables and this paper also established it. Charlton (2019),according to his book, said that in the river channel, the channel parameter is very necessary to define. The channel parameters are channel width, depth, slope, wetted perimeters, hydraulic radius, and velocity. This book also helps in channel hydraulic geometry analysis. Maity (2016), according to his book, said that riveris dominant in the geomorphic process. He also said that if discharge increases, width, depth, the city also increased as a power function & downstream hydraulics. Also gave an impact on cross-sectional profiles and long profiles. Geographically, the Mandakini Valley area stretches across at longitude 79 03′27‖ E and latitude 30 33′00‖ N to 30 17`16``N and 79 05`20``E in the Rudraprayag district of Uttarakhand (fig 1). Mandakini River is one of the important and prime tributaries of the Alakananda River. The Mandakini River‘s length is around 81.3-kilometres. The basin catchment area is around 1893.818-kilometre squares. The elevation of this basin area is 1350 meters above mean sea level (Chaudhary *et al.* 2010). Mandakini emerges from the Chorabari Glacier (30 74`52``N, 79 06`73``E) located at Garhwal Himalaya, Kedarnath,Uttarakhand. The Chorabari

Glacier is also known as Chorabari Bamak Glacier (Kumar, Gokhale, Shukla, & Dobhal, 2016). At Sonprayag, Mandakini the River meets with the river Songanga and then this river flows into the river Alakananda, which drains into the river Ganges (Dobhal, Mehta, Kesarwani, & Gupta, 2015).

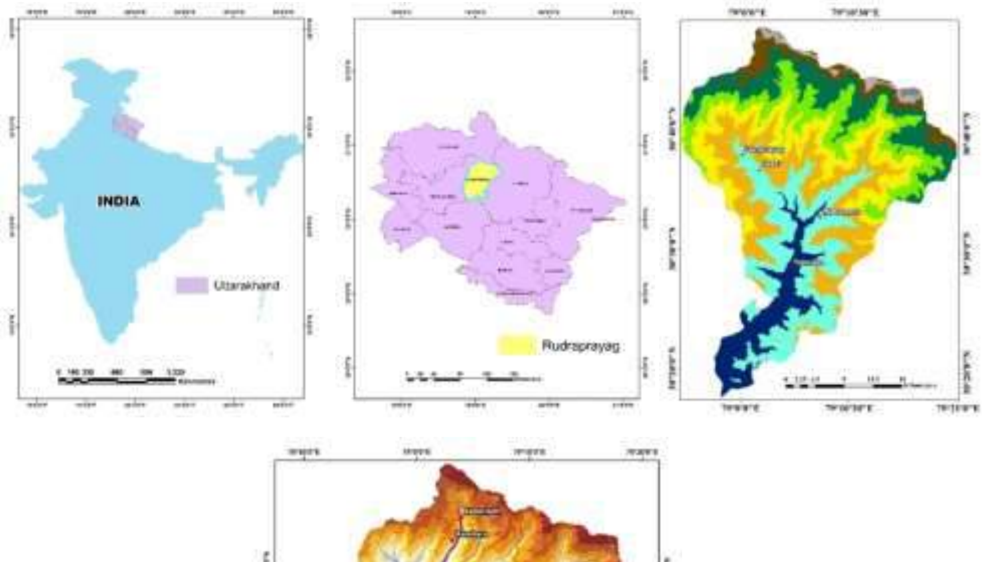


Fig-1: Study Area

2. Objectives

The present research is organized to fulfil the following objectives:

- To study the Geomorphological characteristics of the basin
- To study the Landslide-prone area (LPA) of the Mandakini basin for the sustainability of human livesand properties from landslide hazards

Table 1: Data acquisition in research

Data Type	Source	Year	Purpose
Satellite Image	Landsat 8 OLI	2020	Landslide susceptibility map
	SRTM DEM	2014	Stream order, Relative relief, Drainage density, Landslide susceptibility map
Google Earth	Google Inc.	2020	Mandakini river shapefile, place point data
Geological map	Bhukosh GSI	-	Lithology map
Soil map	Digital Soil Map ofWorld Map	-	Soil map

3. Methodology

The methodology of this paper is based on a literature review. First, to select the study area, need some help with research papers and books. Then selected the study area, the basin of the Mandakini River of Uttarakhand. Then discover the objective which is also based on literature reviews. Then based on the objective, collected data. Extracted drainage ordering system, elevation, aspect, contour, slope, relative relief, drainage density, twi, etc from SRTM DEM. Prepared LULC map from Landsat 8 OLI image. Extracted a long river path from Google Earth. Prepared some profile maps and curve maps on MS Excel. Prepared soil map from Digital Soil Map of

World shapefile data. The projection of all these maps is WGS-1984, UTM zone 43N. These maps are mainly prepared in Q-GIS 3.6 & Arc GIS 10.8.1 software & the profile graphs, curves are in Excel. This paper is fully based on that secondary dataset and remote sensing- GIS tools. These maps give some ideas about the actual place. After preparing all these maps, interpreted them and concluded them. In that way, the whole paper is made up.

4. Results and Discussions

The quantitative measurement & mathematical analysis of any landform‘s slope, shape, geometry, dimension is known as Morphometry. This morphometric analysis is done by liner, relief, channel gradient & basin slope. This quantitative analysis is mainly applied and used to understand the basin of the watershed‘s features and characteristics (Waikar, & Nilawar, 2014). In drainage parameters, the morphometric analysis includes – basin length, area, ordering, perimeter, drainage density, relative relief, bifurcation ratio, as well asthe ratio of stream length, relief ratio, etc. Some of them are discussed below:

Relative Relief: The distinction between the highest altitude, as well as lowest altitude in a particular cell, is known as Relative Relief (Qiu H. *et al.* 2017). Relative Relief (RR) = H_x-H_n (Sarkar. A. 2015) [Where H_x=Maximum altitude, H_n= Minimum altitude]. Relative relief analysis is the most major and significant analysis in morphometry. The highest relative relief indicates the high altitude and steep slope and the low relative relief indicates gentle slope and low altitude (Al-Saady, Al-Suhail, Al-Tawash, & Othman, 2016). In the Basin of Mandakini River, the highest relative relief is 4009.7 meters and the lowest relative relief is calculated as 1247.2 meters (fig 3). To observe the relative relief also understand the agricultural nature & water accessibility (Smith, 1935).

Stream Order and Bi-furcation Ratio: Stream ordering is important to characterize the major parts of the drainage network (Gulge, 2016). Horton 1st derived the stream ordering then Strahler modified it. According to Horton (1945), the 4th order stream and 1st order stream gives rise to the 4th order stream, because it takes up the highest stream order; whereas according to Strahler (1964), two 1st order stream gives rise to the 2nd order stream. In the Mandakini River basin, stream order is built up by Strahler order. In this river basin, the order of stream is classified by 6th order (fig 2). The highest stream order frequency is observed in the 1st stream of order and the lowest stream order frequency has observed in the 6th stream of order. If the stream frequency is low then stream order is high. The river pattern of Mandakini is dendritic because the underlyingrocks are mainly granite, gneiss, volcanic rock, and shale. The Mandakini River is flowing in the southwest direction (fig 2). In the Mandakini River basin, 1st stream of the order is maximum than any other order. In there, approximately 70% 1st stream of order, 20% 2nd stream of order, 5% 3rd stream of order, 3% 4th order stream, 1.5% 5th order stream & 0.5% 6th order stream. According to Schuman in1956, the bifurcation ratio is a dimensional less number to indicate the ratio between one order stream's number & those of the next higherorder in a given drainage basin. The bifurcation ratio is used for measuring flood proneness. If the bifurcation is high then it means the area is well-drained and high chance of flooding. According to Horton, Bifurcation Ratio (Rb) = Ns-1 [Here, Ns-1 indicates the number of tributaries] (Giusti, et.al. 1965). In the basin of the Mandakini River, the bifurcation ratio value differed from 0.93 to 3.48 & the mean bifurcation ratio value is 4.93.

Relief Ratio (Rh) = Highest basin point– The lowest basin point / Total length of the river. The relief ratio is increased by the decrease in drainage area and size. The Low Rh value notify to the slope of the basin is gentle and the basement rock is resistant (Rai *et al.* 2014). In the basin of the Mandakini River, the value of Rh is 0.07, so the slope of this basin is steep and the basement rock is non-resistance.

Stream Length: Stream length is analysed for the extent of the stream and identifies the bedrock. The small number of longer streams only develop when the underlying bedrock is permeable, then the well-drained longer stream develops (Rai et.al. 2014). The 6th order stream length is the longest stream in the Mandakini basin (approx. 46 km). According to Horton (1945), stream length will be increased in a higher order of

stream. This stream length ratio or RL Value shows an increasing trend (Blyth, & Rodda, 1973). In the Basin of Mandakini River, the stream length ratio is changed in each sub-watershed. These changes may have happened for topographical changes, the development of a new stream in the basin for rejuvenation.

Form Factor: According to Horton (1932), the form factor (rf) is a ratio of the square of the basin length andthe basin area (Mir *et al.* 2012). This value of the form factor is always less than 1. This is a dimensionless number, In the Mandakini basin, the value of the form factor is 0.28, which indicates the river basin is elongated. According to Strahler (1964), if the Rb value range between 3.0 to 5.0, that means the drainage pattern do not disturb by the geology (Whitney, 1976). So, the higher value denotes that highly affected by structural disturbance, and high probability to flood in the drainage pattern of the Mandakini River basin.

Drainage Density: Drainage density (Dd) is a measurement of the sum of total channel length per area (Carlston, 1963). This is used to measure run-off potential & dissection of topography (relief, soil, climate, etc.). The density of drainage is affected by the watershed's length. Drainage Density (Dd) =Length of channel/Area.

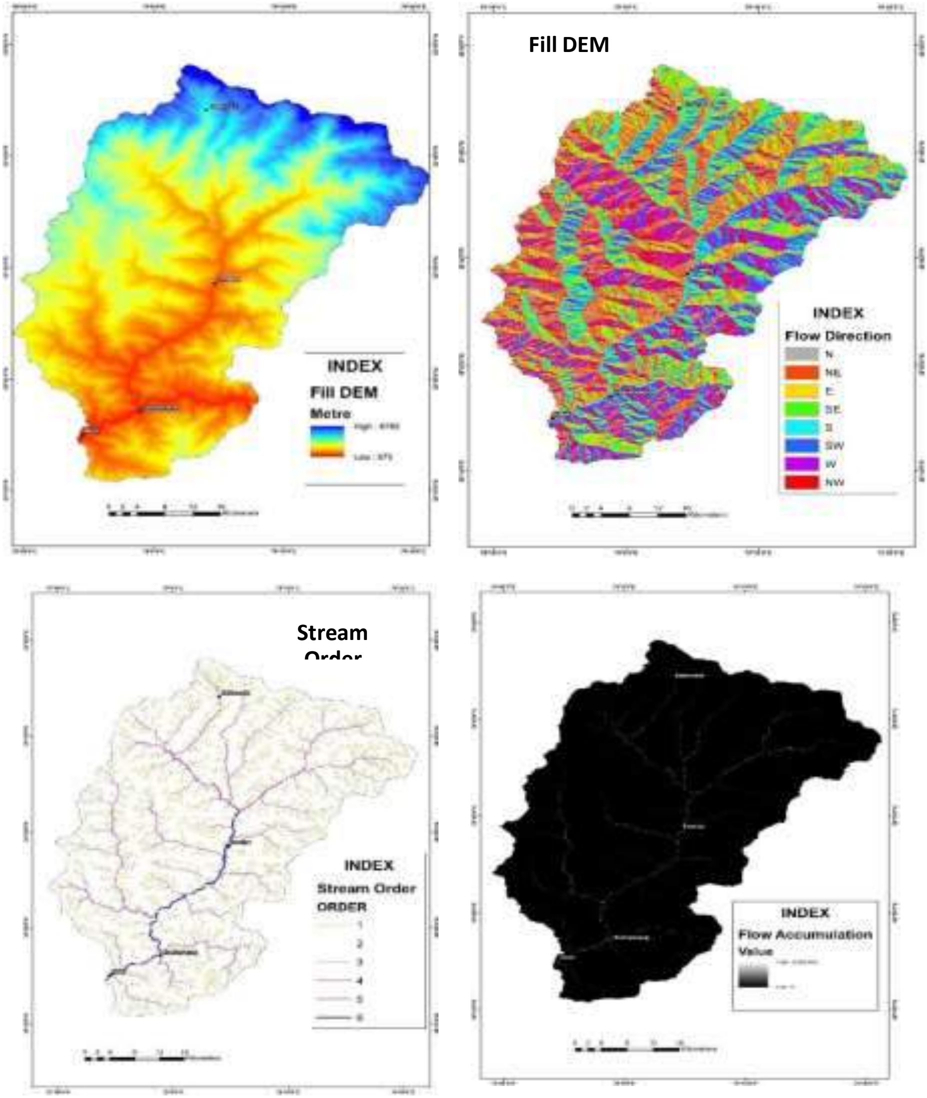


Fig 2: Extraction of Streams from DEM in Mandakini River Basin
Source: USGS Earth Explorer SRTM DEM, Modified by Researcher

(Sarkar, 2015). In the Mandakini basin, the highest value of drainage density is 5.604 km/km sq. & lowest value is 0.068 km/km sq. (fig 4). The higher drainage density specifies the weak basin and has less permeable subsurface features, high relieve low drainage density associated with coarse drainage texture, high erosion as well as high runoff of basin area.

Relief Ratio: The relief ratio, according to Schumm (1954), is basin relief reduced by the maximum lengthof the basin (Pike, & Wilson, 1971). The relief ratio reveals the basin's slope as well as the severity of the extrusion process.

Landslide Susceptibility

Landslides are one of the frightening, devastating natural disasters which take a lot of human lives and their properties (Fang *et al.* 2015). Landslides are mostly occurred in hilly mountainous areas due to the earth‘s downslope, excessive rainfall, and rock mass movement (Kadavi *et al.* 2018). In the Himalayan region, most of the landslides have occurred because this region is one of the active mountain regions which is originated from the Indian & Tibetan Plate‘s collision, 50 million years ago (Khan, Collins, & Qazi, 2011). Landslide susceptibility means the area which tends to generate landslides. Various types of models are used to detect landslide susceptibility. For landslide susceptibility, various statistical approaches were applied. Different types of methods are also used like frequency ratio (FR), as well as weights of evidence (WoE), weighting factors, landslide nominal risk factors, weighted linear combinations of instability factors, etc. (Reichenbach, Rossi, Malamud, Mihir, & Guzzetti, 2018). In this area, the FR model is used. Mandakini River basin area is a landslide-prone zone because this river basin is situated in the region of the Himalayan. Mainly in this region along the river Mandakini, active-rapid landslides occurred (fig 5, A, 5. C). In this area, landslides occurred due to high slope, fault line join, rainfall, bank erosion, gulley erosion & anthropogenic road cutting. Mainly the type of landslide according to hydrologic is wet & flowing (fig 5. B). In this area mainly single landslides occurred (fig 5. D). The elevation is directly proportional to the landslide. If the elevation is high then landslide frequency also increases. The higher elevation in the part of the north of the basin of the Mandakini River than the southern part, as a result, the frequency of landslides increased (fig 7).

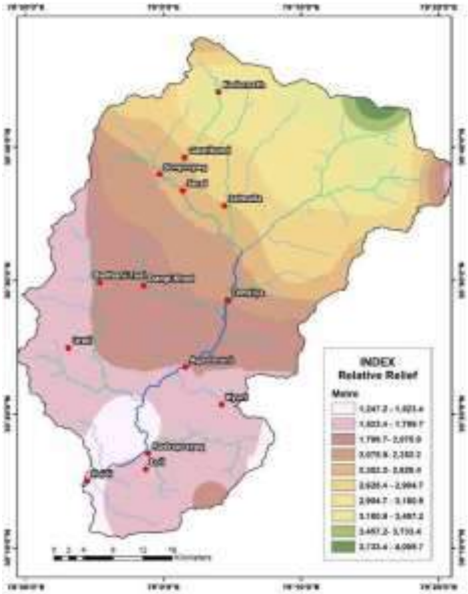


Fig 3: Relative Relief Map of Mandakini River Basin Source: USGS Earth Explorer SRTM DEM, Modified byResearcher

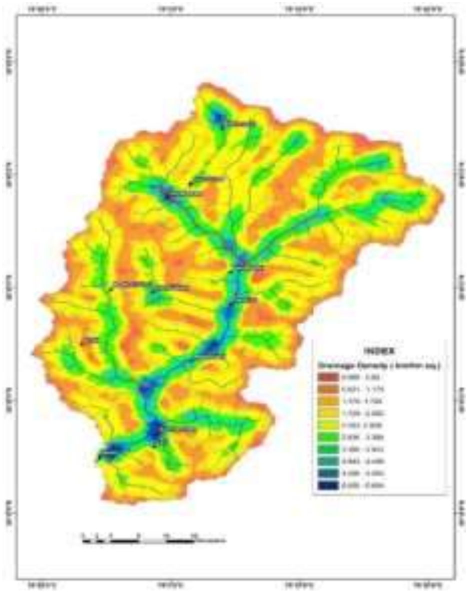
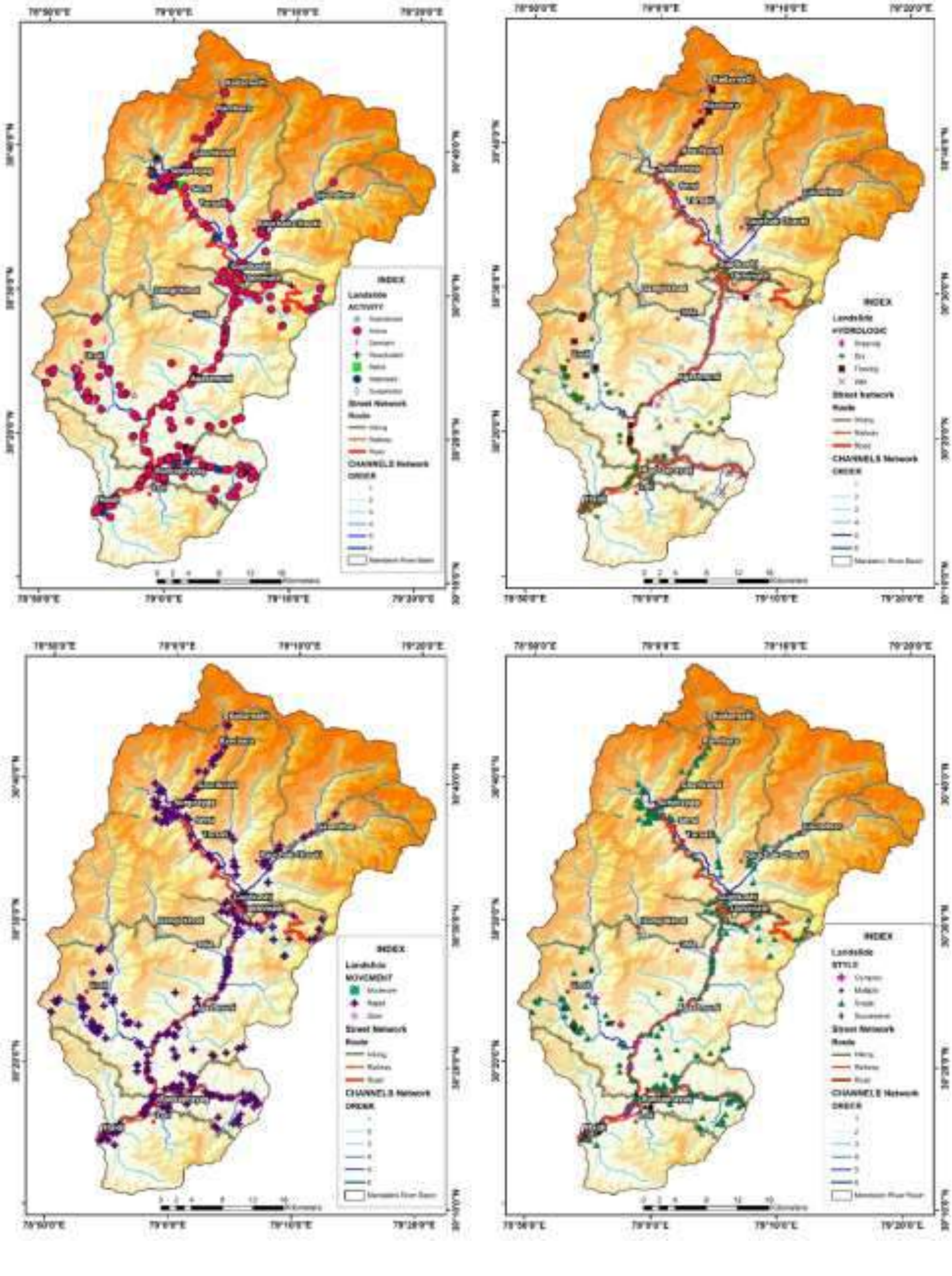


Fig 4: Drainage Density Map of Mandakini River Basin Source: USGS Earth Explorer SRTM DEM, Modified by Researcher

Table 2: List of Landslide Events in Mandakini River basin, Uttarakhand

Place/Name of Landslide	Date of Evident	Loss of People
Ukhimath Landslide	1979	39
Uttarkashi Kedargiri Landslide	1981	-
Tehri Garhwal	1986	32
Ukimath Landslide	1998	109
Malpa Landslide	1998	55
Chamoli	1999	100
Budha Kedar	2001	-
Uttarkashi Landslide	2003	-
Agastyamuni Landslide, Rudraprayag	2005	4
Kedarnath	2013	More than 5700

Source: Rautela, *et al*. 2005



Plan curvature: Plan curvature is indicated the perpendicular direction of the maximum slope. This plan curvature is divided into 3- Concave, Flat & Convex. This curvature is created by SRTM DEM in Arc GIS 10.8.1 version with the cell size of 29*29 (fig 6.2).

Aspect: The aspect map was prepared by SRTM DEM in Arc GIS 10.8.1 with the cell size 29*29 (fig 6.3). An aspect map indicates the direction & steepness of the terrain (Regmi, *et al*. 2012). In this study area, the aspect map was divided into 9 classes.

Elevation: The elevation map was prepared by SRTM DEM in Arc GIS 10.8.1 with the cell size 29*29 (fig 6.4). The elevation map varies from 569m to 6810m.

Distance from river: In landslide susceptibility mapping, runoff plays an important role. It indicates the nearest river in the area (Paudel, Oguchi, & Hayakawa, 2016). This buffer map was prepared by SRTM DEM in Arc GIS 10.8.1 with the cell size 29*29 (fig 6.5).

Soil: The soil map was prepared by World Soil Map data in Arc GIS 10.8.1 with the cell size 29*29 (fig 6.6). This map is also important to identify landslide susceptibility.

Lithology: The lithology map was prepared by Bhukosh GSI data in Arc GIS 10.8.1 with the cell size 29*29 (fig 6.7). This map is very important to detect landslide susceptibility because identifying the characters gives knowledge of the active geomorphological processes of Himalaya (Gorum *et al.*, 2008).

Land-use Landcover (LULC): Landuse & landcover map was prepared by Landsat OLI data in Arc GIS 10.8.1 with the cell size 29*29 (fig 6.8). This map also gives an impact on landslide susceptibility zoning (Tsangaratos and Benardos, 2014). This map is divided into 6 classes: agricultural land, shrubs, dense vegetation, settlement, waterbody, and forest cover.

Normalized Difference Vegetation Index (NDVI): NDVI map was prepared by Landsat OLI data in Arc GIS 10.8.1 with the cell size 29*29 (fig 6.9). This map also gives some idea about landslide susceptibility zonation.

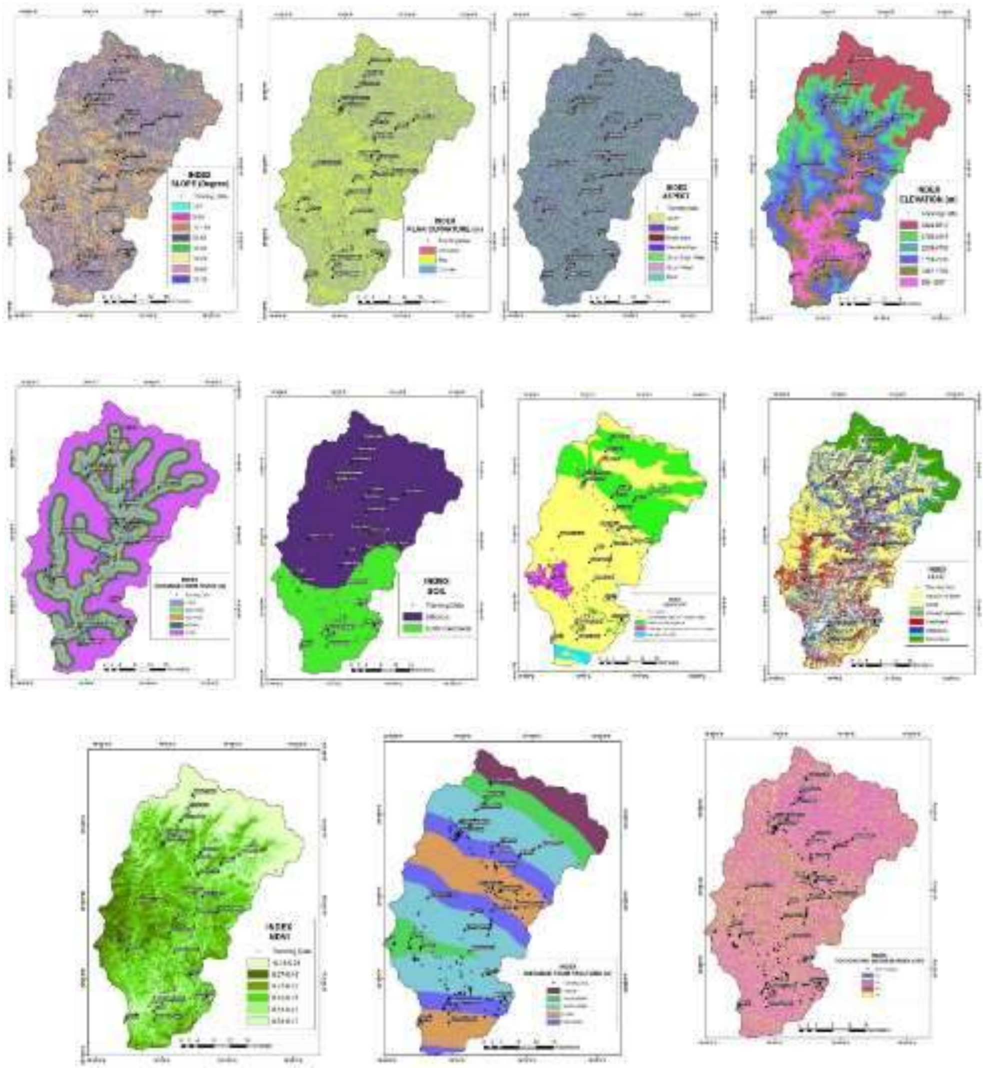


Fig 6: Various Geomorphic Parameters using to identify Landslide Susceptibility Mapping 1. Slope (degree) 2.Plan Curvature (m) 3.Aspect 4.Elevation (m) 5.Distanve from River (m) 6.Soil 7.Lithology 8.LULC 9.NDVI 10.Distance from Fault line (m) 11.TWI. Source: USGS Earth Explorer SRTM DEM & Landsat OLI Images, Bhukosh GSI Landslide Point Data, Modified by Researcher

Distance from Fault Line: Distance from fault line buffer map was prepared by Bhukosh GSI data in Arc GIS 10.8.1 with the cell size 29*29 (fig 6.10). This map shows the strong relationship between landslides.

Topographic Wetness Index (TWI): Topographic wetness index is mainly demeanour by hydrological processes to quantify the control of topography. TWI is the combination of local upslope topographic area & slope (Sorensen *et al*. 2006). The map of TWI was made with the help of SRTM DEM data in Arc GIS 10.8.1with the cell size 29*29 (fig 6.11). This mapping also helps to identify landslide susceptibility mapping. The below process calculates TWI: TWI = In (a /tan β)

where a is indicates cumulative upslope area draining through a point tan β is indicated the slope angle at the point.

Frequency Ratio (FR) Model

The frequency ratio model was used in this study area because this model is simple & easily understandable. The frequency ratio (FR) model is one of the bivariate statistical methods (Guru, Seshan, & Bera, 2017). Thisfrequency ratio indicates the landslide zone area of the total area. It may be explained that- LSI= ΣFR(Regmi *et al.* 2012).

FR is calculated as: FR= $\{N_{pix}(S_{Xi})/\Sigma_{i=1}^{m} S_{Xi}\}/\{N_{pix}(X_j)/_{j=1}^{n} N_{pix}(X_j)$

Where $N_{pix}(S_{Xi})$ is the number of pixels with landslides within the class in of parameter variable $XN_{pix}(X_j)$ is the number of pixels within the parameter variable X_j

m is the number of classes in the parameter variable X_i

n is the number of parameters in the study area (Tehrany, Pradhan, & Jebur, 2015).The frequency ratio provides the Prediction Rate (PR) value.

Table 3: Table for prediction rate through FR model

Data Layer	Class	Class Pixels	Landslide Pixels	FR	PR
Slope (degree)	0-10	3.93	2.13	0.54	2.5094
	10-19	15.64	9.96	0.63	
	19-29	27.88	24.19	0.86	
	29-38	28.88	38.79	1.34	
	38-48	17.22	20.28	1.17	
	48-57	5.35	3.91	0.73	

	57-67	0.98	0.71	0.71	
	>67	0.08	0	0	
Plan Curvature	Concave	10.86	7.82	0.72	1.6598
	Flat	54.72	53.02	0.98	
	Convex	34.40	39.14	1.13	
Aspect	Flat	10.76	10.21	0.94	1
	North	9.66	7.39	0.76	
	North East	11.49	11.26	0.97	
	East	11.05	15.49	1.40	
	South East	12.75	13.73	1.07	
	South	9.85	5.98	0.60	
	South West	11.16	13.38	1.19	

	West	11.00	12.67	1.15	
	North West	12.23	9.85	0.80	
Elevation (m)	569-1267	13.43	45.90	3.41	5.96419
	1267-1753	17.95	26.69	1.48	
	1753-2236	18.54	21.70	1.17	
	2236-2756	16.42	4.62	0.28	
	2756-3344	12.11	1.06	0.08	
	>3344	8.79	0	0	
Distance from River (m)	0-400	4.03	44.44	11.01	5.62081
	400-800	3.66	20.51	5.59	
	800-1200	3.66	12.39	3.38	
	1200-200	6.39	10.25	1.60	
	>2000	82.23	12.39	0.15	
Soil	Eutric Cambisol s	30.69	53.75	1.75	5.04111
	Lithosols	69.30	46.24	0.66	
Lithology	Gravel, Pebble, Sand, Silt, Limestone, Shale	0.96	2.42	2.50	10.6390
	Gneiss, Schist & Amphibolite	0.20	834.09	4160.38	
	Marble Band & Porphyroblastic Nonfoliated Granite	0.31	1789.41	5701.06	
	Grey Sand, Silt & Clay	**0.01**	**1429.54**	**76971.27**	
Land use Landcover	**Agricultural Land**	**37.45**	**14.42**	**0.38**	**3.13631**
	Shrub	**1.96**	**1.96**	**1.00**	
	Dense Vegetation	**20.07**	**27.86**	**1.38**	
	Settlement	**12.73**	**18.36**	**1.44**	
	Waterbody	**5.04**	**13.44**	**2.66**	
	Forest Area	**8.37**	**23.24**	**2.77**	
NDVI	**-0.18-0.04**	**14.47**	**2.31**	**0.15**	**3.42705**

	0.04-0.11	10.70	20.13	1.88	
	0.11-0.16	21.39	37.95	1.77	
	0.16-0.21	25.07	26.07	1.03	
	0.21-0.27	19.76	11.88	0.60	
	0.27-0.45	8.63	1.65	0.19	
Distance from Fault line (m)	0-500	19.51	21.12	1.08	3.18128
	500-10000	19.64	29.57	1.50	
	10000-15000	20.55	21.83	1.06	
	15000-20000	18.69	19.71	1.05	
	>20000	12.51	7.74	0.61	
TWI	<2	13.09	9.02	0.68	4.39142
	2-4	31.97	36.41	1.13	
	4-6	50.09	54.55	1.08	
	>6	4.86	0	0	

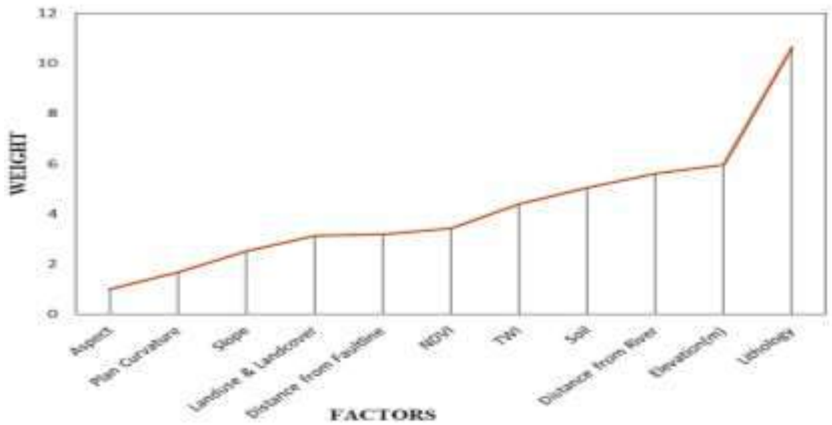
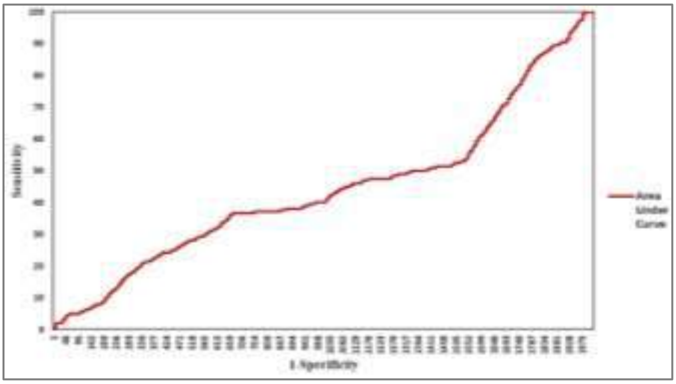


Fig 7: Weight used for individual factors for the landslide of Mandakini basin, Source: Source: USGSEarth Explorer SRTM DEM & Landsat OLI Images, Bhukosh GSI Landslide Point Data, Modified by Researcher



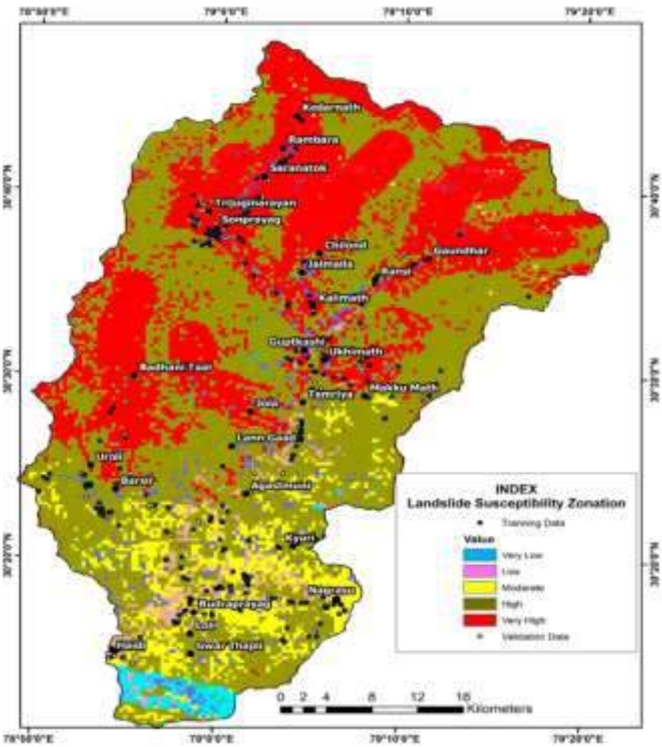


Fig 9: Landslide Susceptibility Map based on the Frequency Ratio Model Source: USGS Earth Explorer SRTM DEM & Landsat OLI Images, Bhukosh GSI Landslide Point Data

After adding this data, using a raster calculator in Arc GIS, a landslide susceptibility map was prepared. These PR values indicate the landslide of this region is highly affected by lithology (10.6390) & less affected by aspect (1) (fig 7). To identify the correlation between the location of the landslide and factors of controlling factors: soil, aspect, curvature, distance from river & fault line, NDVI, LULC, lithology, TWI, FR methods are used (Sahin, 2020). The final map of landslide susceptibility is dependent on the FR model (fig 9). The very high zone is found in the higher area of altitudinal with the higher slope region. The value of FR is high on the slope between 29 -38 (1.34) and in elevation, the high value of FR (5.96419) is located in 1753-2236m. A high FR value indicates a high landslide susceptibility zone. Similarly in distance to the river and fault line FR value is high near the river and lineament. In Marble Band & Porphyroblastic, the Nonfoliated Granite area landslide occurrence is high because of the high FR value (10.6390). Throughout the Mandakini River basin research, the landslide mainly occurred by lithological variation and the elevational location. The landslide is mainly affected in Kedarnath, Ukhimath, Sonprayag, Gaundhar, and Bandhani Taal areas. AUC (Area under curve) is essential to identify the highly vulnerable area. AUC curve predicts the landslide-prone zone. After landslide susceptibility zonation mapping, AUC is calculated in Arc GIS (Rahmati, & Pourghasemi, 2017). The AUC is shown as a line graph. According to the AUC curve, 45% area is a very high vulnerability area for landslides (fig 7).

By the morphometry analysis, the number of stream orders is 6 and the river pattern is dendritic. The highest relative relief in this area is located in the north-eastern part of the basin which is 4009.7 meters and the lowest is located in the southwestern part (Haidi) of the basin which is 1247.2 meters & the highest drainage density is located in the near of Kedarnath, Sonprayag, Temriya, Rudraprayag, Loli, Uroli (5.604 km/km sq.).The basin is elongated (0.28) the basin slope is steep and basement rocks are non-resistance (Rh value 0.07).

The bifurcation ratio of this basin is 4.93, indicating the high tendency to flood, which influences the landslide. In this basin area, lithology & elevation mainly played an important role in the landslides. The PR value of Lithology is 10.6390 and the PR value of Elevation is 5.96419. The high landslide susceptibility area is located in Kedarnath, Rambara, Saranatok, Trijuiginarayan, Sonprayag, Gourikund, Gaundhar, Chilond, Kalimat, Guptakashi, Ukhimath, Badhani Taal, Jola of Mandakini River basin area. More than 45% area is highly prone to landslides in the Mandakini basin.

5. Conclusion

Mandakini River basin is high land with a low latitudinal area. The whole work is done by geomatics tools (Satellite data, RS GIS) without any kind of field survey for this Covid-1 pandemic situation. So, some limitations occur. Through geomatics, geomorphological analysis has been analysed in the basin of the Mandakini River. Landslide is one of the most dangerous disasters that take many lives & properties. Mandakini River basin area is a landslide-prone zone. This paper does landslide susceptibility mapping by the Frequency Ratio model (FR Model). With the help of ARC GIS and excel, the landslide classes are divided into 5 i.e., Very High, High, as well as Moderate, Low & Very low (fig 9). The Very high zone is in the Kedarnath, Rambara, Saranatok, Trijuiginarayan, Sonprayag, Gourikund, Gaundhar, Chilond, Kalimat, Guptakashi, Ukimath, Badhani Taal, Jola of Mandakini River basin area. The landslide occurs here due to thehigh elevation and the lithological characteristics of the basin's basement. The lithology is mostly Quartzite, schist, marble rock, Paragneiss, etc. and the elevation is 5000 meters approx. This area is near to Himalayan region. So, due to tectonic upliftment and movement landslides also occur. In this study area, 2 parameters - lithology [PR value 10.6390] & elevation [PR value 5.96419] are mainly control the landslide (fig 7). They play an important role. According to the AUC curve, 45% area is a very high vulnerability area for landslides (fig 7). According to the FR model, the very high zone is situated in this 45% of AUC. The statistical approaches estimate that percentage.

Mandakini River basin is rapidly developing into an urban region. This region is spotted as a tourist sport. So, to increase economic conditions, so many hotels, roads, and railways build-up near the river. These hotels, buildings, and transpositional networks are built by cutting the hills and riverbank. So, the equilibrium of the mass has become imbalanced, and as a result landslides, landfall, floods occur. This paper is fully prepared by Satellite images, GSI, I-diva, Digital soil map of the world shapefiles, and Landsat data. Some journal papers inspire some mappings ideas. Missing the instrumental analysis works, filed photographs, and ground- level data for this situation. Due to this global pandemic, all work is done from home. So probably this is the major drawback of this study. Using of SRTM DEM is also another limitation in this paper. ASTER DEM & Carto-sat DEM‘s resolution is high than SRTM DEM‘s.

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AN APPRAISAL OF LAND AND WATER CONDITION IN THE DOWNSTREAM AREA OF THE RESERVOIR:A CASE STUDY

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Abstract:

A change in land use and land cover has got tremendous impact on environment. Some anthropogenic activities have altered the land use land cover. Some man made engineering construction like reservoir ,irrigation canal, dam considerable for changing of a land use land cover of an area. In case of agricultural land use change, the reservoir and irrigation canals are playing an crucial role in the study area. In this back drop, the present investigation has been carried out in the upper catchment area of Kumar river basin Purulia West Bengal eastern India. The main purpose of the reservoir and irrigation canals is to provide the sufficient water to the agricultural fields. These are made for multi cropping purpose. At the same times, these are responsible for displacement of settlement and inundation of agricultural land .Ground water condition of the upper and lower catchment area also have been changed. After construction of the reservoir and irrigation canals, the soil moisture condition is also being changed as a result the natural vegetation which has become more lively and the agricultural production has been increased in the study area. The present investigation has got some specific objectives like i) to detect the land use land cover changes after construction of the reservoir and irrigation canal especially in the case of agricultural practice and ii) to detect and delineate pasture land for livelihood interpretation ground water condition by well inventory technique, interpretation of satellite imageries were used for the presentation investigation. It has been observed that the major changes occurred in case of agricultural land use, settlement pattern, social forestry and natural vegetation.

***Keywords**: Ground water, Change in land use, Land Cover*

1. Introduction:

Land is the integral component of environment. In modern times the concept of land resource is gaining much importance. It involves various locations of settlement and other many geographical features and resources as well. According to FAO(1997a) and

UNEP(1999) ‗Land use is characterized by arrangements, activities and inputs people under take in a certain land cover type to produce, change or maintain it' (Brar,2013).Land use is produced by the interaction between cultural practices, state and physical needs of the society with the natural potential of the land(Chawla,2012).Land is very unique by its use. One can use land in different purpose like agricultural purpose, settlement purpose, agroforestry, social forestry, industrial purpose. Early humans used land with simple little modification for their food, storing, shelter, keeping their arms warm. But to fulfil the increasing population demand. The land is using multi purposely (The Environment Literacy Council, 2015). Land is a process that convert the natural environment in to built environment such as settlement, road network, industrial zone etc. Land use data are needed to be analysed to understand the environmental process because it is use to formulate the solution of various land management issues like salinity and water quality which is related to land degradation. To ensure the optimal use of land the within the social, cultural, political environmental and economic context, the land playing a very vital role. Land use land cover changes are very important for biochemical cycles, climate change and food production from regional to global scale.

The land use land cover changes alone has contributed to approximately 35 percent anthropogenic carbon-di-oxide(CO_2) emission across the globe (Hongton et.al, 2012). Often improper land use is responsible various types of environmental degradation. In fact some anthropogenic have altered the earth environment by changing the land use land cover (LULC) in past several centuries (Tian et.al, 2014). Some engineering like dam, reservoir are considered as the sources of natural security, economic stability, agricultural survival. Due to construction of the dam the evaporation rate in the agricultural area is increased and the flow of water in downstream is reduced. Increased evaporation in irrigated areas can cause stability in the atmosphere as well as increase of rainfall downwind of the irrigated land. As a result total moisture level is increased in the surrounding atmosphere. It denotes that the proper irrigation system is the key factor to bring the long time sustainability in agriculture. Engineering construction like dam are related to the ecological degradation of the downstream section.

In the above context, the upper catchment area of Kumari River Basin (Figure no.1) has been chosen for the present investigation. The area is the south eastern extension of Chhotonagpur Plateau, Purulia, West Bengal. The area under study is bounded by the latitude $22^0$55´-$23^0$15´N and longitude $86^0$08´-86 ^{0}38´E.The Kumari dam (Figure no.2) was constructed for irrigation purpose in the year 1984. Similar types of investigation has been carried out different parts of world due to varied agroecological condition. There is intensive cultivation in humid and sub humid region. Another important investigation was carried out by Sayema Jamal et. Al (2016) on Mithiri Water Shed of semiarid areas of western Rajasthan, India pertaining to climate change, agriculture, water resources and social status using remote sensing data and GIS technique (Burrough1990, Burrough and MC Donnel,1998).

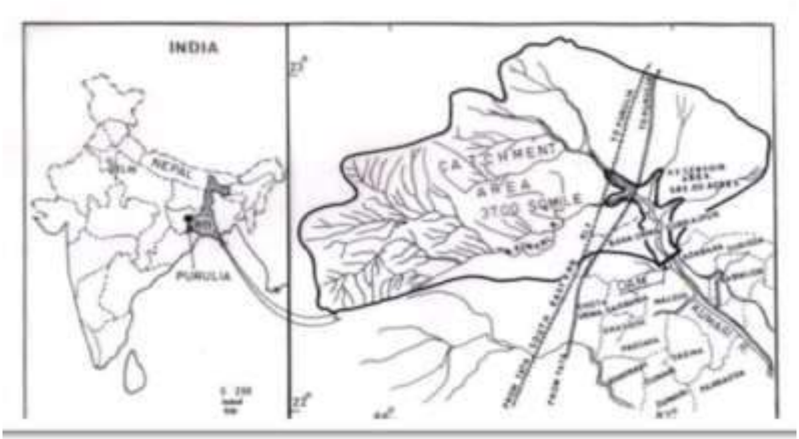

Fig-1: Upper catchment area of the Kumari River

Fig-2: Kumari dam

2. Study Area

The district of Purulia (Figure no.3) is located in the border of Jharkhand and West Bengal. It was curved out former district of Manbhum of Bihar in 1956 and added to West Bengal. Geographically it is the part of Chhotonagpur plateau of eastern India consisting of ―succession of rolling uplands with intervening hollows‖ and infertile lateritic soil. The study area is bounded by latitude $86^{0}08'$-$86^{0}38'$E and longitude $86^{0}08'$-

$86^0 38'$. The district has an area of 6,259.0 sq.km. As per 2011 census, the total population is about 29.30 lakhs (Census Handbook, 2011) Like the topography of the district. Its population structure has several points of dissimilarity with the topography of the district. The maximum number of the people of the district are schedule tribes (19.58 percent). The bulk of population consists of Hinduized and Semi Hinduized communities who still preserve some of the tribal life style. Economically the district is the poorest district among the sixteen district of West Bengal (Bagli, 2019). Only 45.01 percent people are land oner and 33.37 percent people are land less. Once Sal forest dominated the district as flora now it is almost lost. Only occasional trees and shrubs attest to the past environment. The natural vegetation of the district is consists of trees, shrubs and grasses. The major tree including Sal (Soria robasta), Palash (Butea fondosa), Arjun (Terminalis arjuna), Shimul (Bombax malabaricum) etc. The most important shrubs and herbs are Boinchi (Flacontia n emontchi), Bharenda (Jatropa gossypifolia) etc. Some few grasses found in the field are Sar (Saccharum munja), Kakmachi (Solanum nigram) The upper catchment area of Kumari River Basin is situated in the western part of the Purulia district, West Bengal of eastern India bounded by latitude $22^0 55'$to $23^0 5'$N and longitude $86^0 8'$ to $86^0 38'$E. It is actually a regenerated land mass which include variety of landscape units (Sing,1969). Tributaries of Kangsabati River. are the main drainage of the area.

The district has a moderate annual rain fall i.e 1400mm (Mishra,2012). Ground water recharge is inadequate due to crystalline nature of the country rock and uneven relief of the terrain (Mukherjee and Das,1989). The climate of the district is characterized by hot summer and cold winter. May is the generally hottest month with a mean daily minimum at 12.8^0C. Purulia district belongs to agro-eco sub region of Chhotonagpur plateau. The ecological condition is not so good due to improper greeneries. The laterite and infertile soil has the tendency to degrade the ecological condition. Immense care are needed for profitable cultivation. Due to continuous exploitation the soil lost its ability to absorb moisture from rainfall (Mahato, 2010).Very low agricultural productivity and deforestation are the reason of nutritional crisis. This influence the migration tendency. Migration process continued even in postcolonial period from Purulia to Assam tea garden, Bradhaman and the other places for their livelihood. Ecological crisis is the most common reason of tribal migration.

It can be said that undulated topography, high relief, slope, laterite soil, Precambrian granite gneiss country rock decline ground water, high drainage density, increasing aridity are the physical factor that are playing an important role to maintain the land degradation process in the study area (Mahala, 2018).

Physiography and Land Form of the Study Area

The study area is an erosional landscaped developed on the Precambrian basement rock. Granite and metasedimentary are the main lithologies. Among the two physiographic divisions, high land is composed of denudational and structural hills. The rocks of the area is traversed by several sets of joints among which NNE-SSW master joints are prominent which show (dip>50^0). Low lying undulatory and forms the peneplane region. The thickness of the soil cover varies from 3m - 6m.

The soil of the study area are broadly categorized in to residual type which has been derived from weathering of pre-cambrian granite, gneiss and/or composite gneiss. Residual soil has got an extensive areal extent. Alluvial soil are present in the valleys of major stream/rivers. Reddish clay loam or simply reddish clay are very common in the study area .The ground water condition is mainly controlled by secondary porosity which is interconnected fractures, joints within the country rock. The narrow alluvial tract of main drainage have moderate to good ground water potential. The main upland of the district is Ajodhya Hill.

Geological setting

As the study area is an erosional landscape many erosional land form like inselberg undulated valleys are the main evidence of erosional process. Peneplain pre-cambium is the most conspicuous feature of the area. Lithologically the area was composed of meta sedimentary and granite rock. It is actually the a regenerated land mass (Singh,1969) which include a variety of landscape unit. The area must have been suffered by several cycle of erosion aided by geotectonic upliftment (Mukherjee and Das,1986).The study area has some specific physical characteristics like undulated plateau, granite gneiss geology with some little soil depth, aridity etc (Mahala,2018). This study area has got various types of mineral resources which are basically non-metallic types. According tothe geological survey of India there are 10 types of mineral deposition in the area such as coal, rock phosphate, quartz (Sensus,2011).

Drainage and groundwater condition of the study area

The drainage pattern of the study area is rectangular to angulate pattern as per the Survey of India (SOI) toposheet. The higher order stream like Kumari river adjoining rivers show the evidence of structural control. Joint pattern has influenced the main stream course development. The main stream shows a base flow during dry month whare as river bank full stage during monsoon time. As the rocks are generally impervious, groundwater accumulation take place within the weathered residuum. Many water wells have been developed in the upper and lower catchment area. Wells in upper catchment area shows almost near surface water body condition and wells in the downstream shows high depth. The water table rises up to 1.00 m in the rainy season till the end of October. This is a ‗White Zone' as per ground water status.

Reservoir and irrigation canal

Kumari river is the main drainage system of the study area. The tributaries are the main source of water in the study area. A reservoir has been constructed in the upper catchment area of Kumari river with a catchment area of 94.72 sq.km. The reservoir has two canals. The main canal length is 37 km. and the subsidiary canal length is 24 km. The main purpose of the canal is to supply irrigation water to the adjacent agricultural plots. Many cultivated areas are seen in the both sides of the canals. Canals are constructed towards E-W alignment. And in some places the canals are branching out from the main canal. In this area targeted area under Kumari Irrigation Scheme is 3642 hector (Kharif) and 432 hector (Ravi crop). However, 3255 hector (Kharif) has been achieved and 320 hector (Ravi crop)has been achieved.

3. Objectives

- To identify the changes in land use and land cover after the construction of the reservoir and irrigation canals.
- To delineate a new potential area for rehabilitation of the evacuees from the reservoir inundated area.

4. Material and methods

- Water shed of Chhotonagpur area i.e Kumari Reservoir Basin.
- Reconnoitory visit to the field.
- Collection of primary and secondary data.
- Groundwater level data collection through well inventory technique.
- Survey of India (SOI) topographical sheet (scale 1:50,000), IRS data (Geo Coded FCC)Construction aided by field verification.
- Thematic map generation of various land use land cover type .
- Delineation of changes in LULC during pre and post construction of the reservoir
- Identification of the site for rehabilitation of evacuated people and pasture land byusing GIS technique.

- Google Earth Image of the year 1992,2008 and 2018 (pre and post monsoon data).

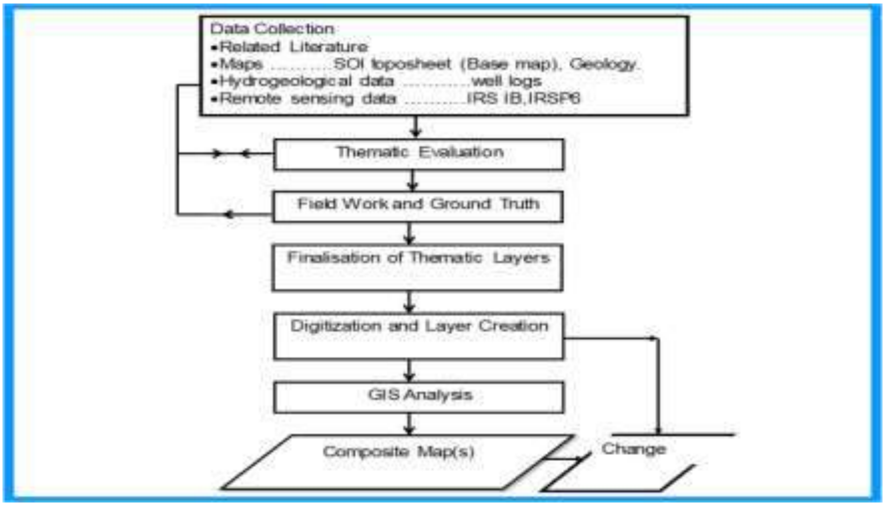

Fig-3: Flowchart of methodology

5. Results and discussion:

Kumari river is the main tributary of Kangsabati river. Tributaries of the Kumari river is the main drainage of the study area. It shows a rectangular drainage pattern as revealed through satellite image interpretation. Kumari river is a 5^{th} order drainage. Reservoir was constructed named Kumari reservoir under Kumari Irrigation Scheme in the year of 1984. The catchment area is 94.72 sq.km. However, the construction was started about 10 years before. Kumari reservoir has got two main irrigation canals. Adjoining agricultural plots are being fed by two main irrigation canals and their branches. The canals have of E-W directional trend. The Kumari reservoir surface area is of 1.39 sq.km and the main canal length is 37.00 km (Sench Patra,2005) and the total canal length under study area is 27.57km.(Google earth image,2018) and the branch canal length is 24.00km (Sench Patra op.cit).

Hanumata reservoir is another important reservoir in the study area which is situated in the NW part of the study area. The reservoir was constructed on 2017. The reservoir catchment area is 55.55sq.km (Sench Patra op.cit) and the surfacearea is about 0.97 sq.km (Google Earth Imagery,2018) and the total canal length is approximately 31.62km (Google earth image,1992). Hanumata reservoir has got two major irrigation canals i.e LBMC(Left Bank Main Canal) and RBMC(Right Bank Main Canal). No changes was found when it is compared in between 2008 and 1992 imagery as par as the reservoir area is concerned. However, the total canal length has found to be decreased. In recent year during 2018 the Kumari and Hanumata canal length have been found to be of same as that of 2008. Siltation was observed in the Hanumata canal and due to the effective canal length was found to be decreased.

In the study area canals are playing a vital role as far as the agriculture practice is concerned. The area is semiarid to sub humid in nature. Water scarcity is a common phenomena. Multiple cropping for agricultural field is now possible after the construction of the irrigation canals. After interpreting the satellite image and by field verifications it has been observed that the area of different types of land use are as follows: Ground water level in the reservoir area shows higher level than that of the lower catchment area. Water level in the well in the reservoir area is of 7ft as detected by well inventory technique. Surface drainage, water level in confined status and natural precipitation (rain fall) are the main sources of reservoir water. Average Annual Rainfall (A.A.R) of the region is 1440 mm (Mishra,1984). High evaporation in the reservoir area also changes the microclimate condition of the area.

6. Significant irrigation facility of the study area:

In the study area ,the targeted area of irrigation project under Kumari river irrigation is 3642 hectare for kharif and 432 hectare for Ravi crops (Sench Patra op.cit). The moisture content of the agricultural plots is 2.3 percent to 2.5 percent and Ph is 7.2-8.0.

From the imagery, SOI toposheet and Google earth data of the year 1973, 1992, 2008, and 2018.(Figure No.5a,5b,5c,5d) it has been found that settlement pattern is scattered type. In fact under the geographical history of an area, settlement also is an expression of human occupation of the earth surface (Sodhganga.inflibnet.ac.in/bitstream/10603/107930/11/11-chapter%21.pdf).

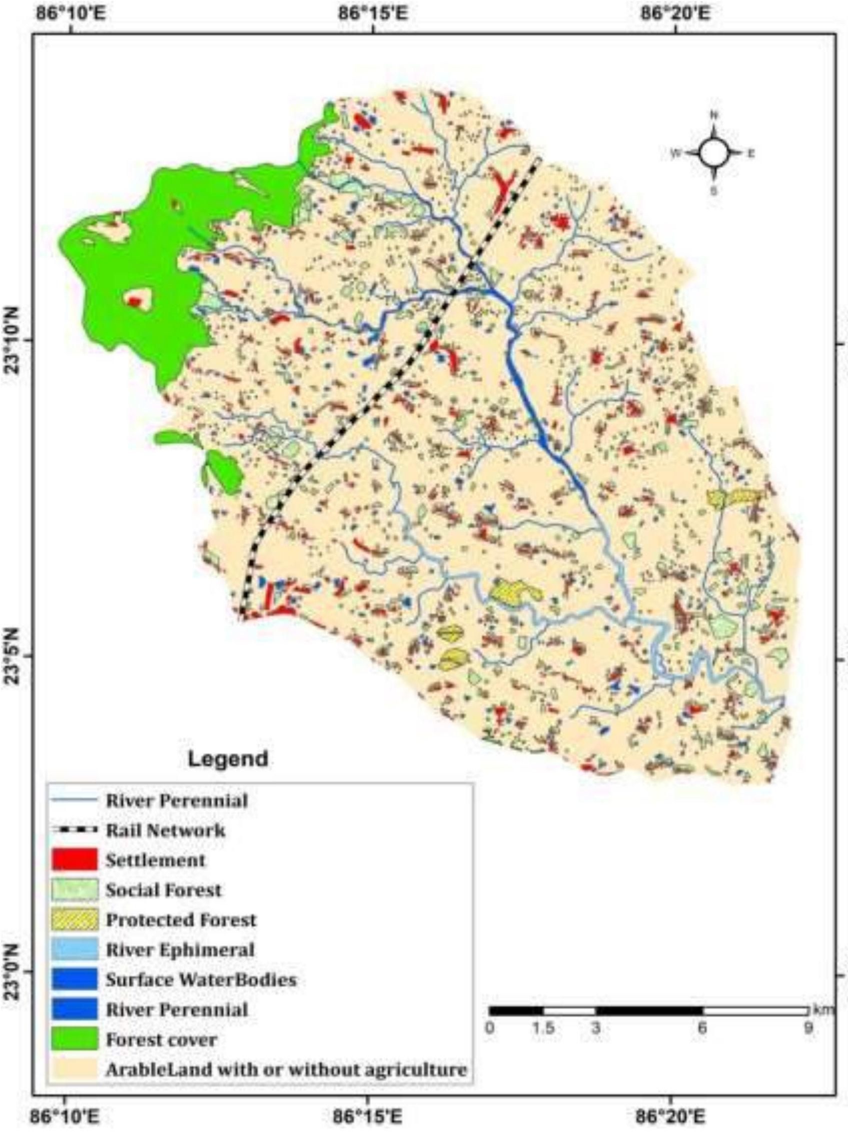

Fig-.5a: Land use map of 1973

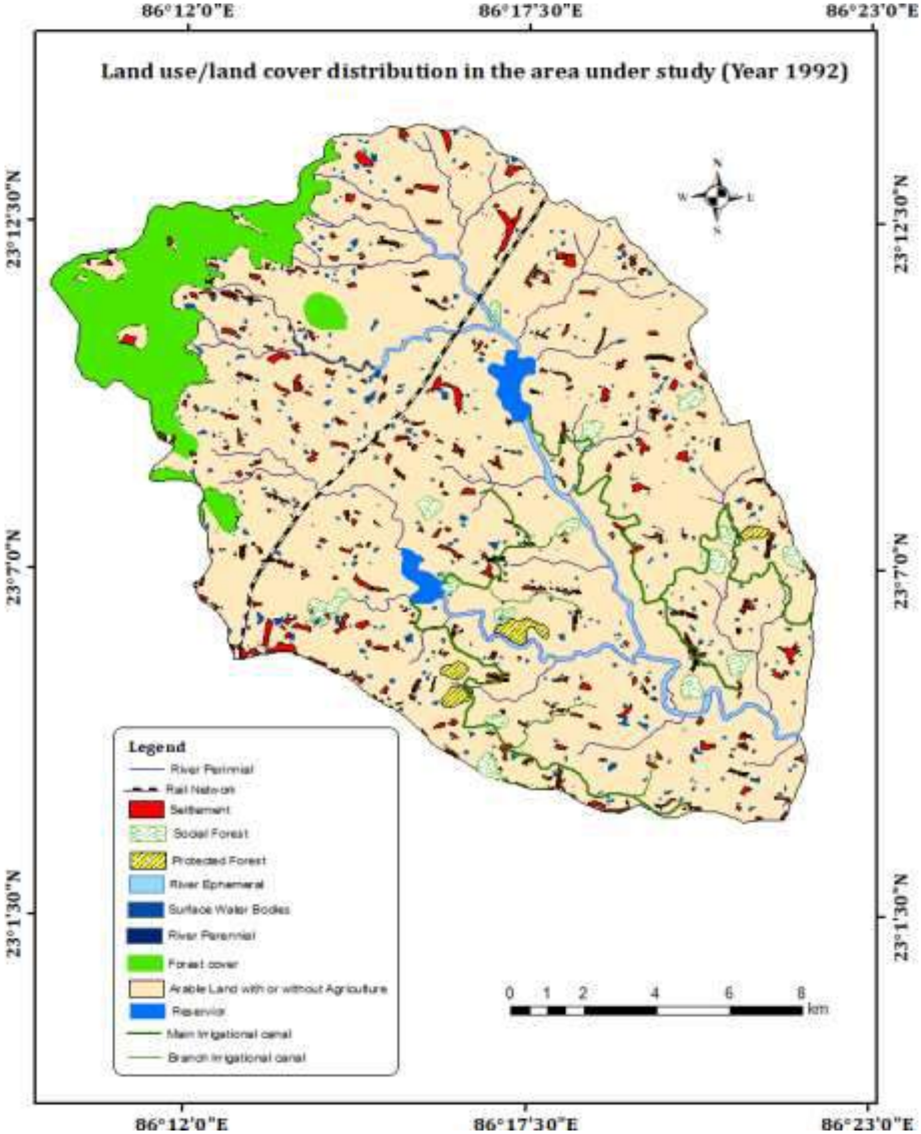

Fig-5b:- Land use map of 1992

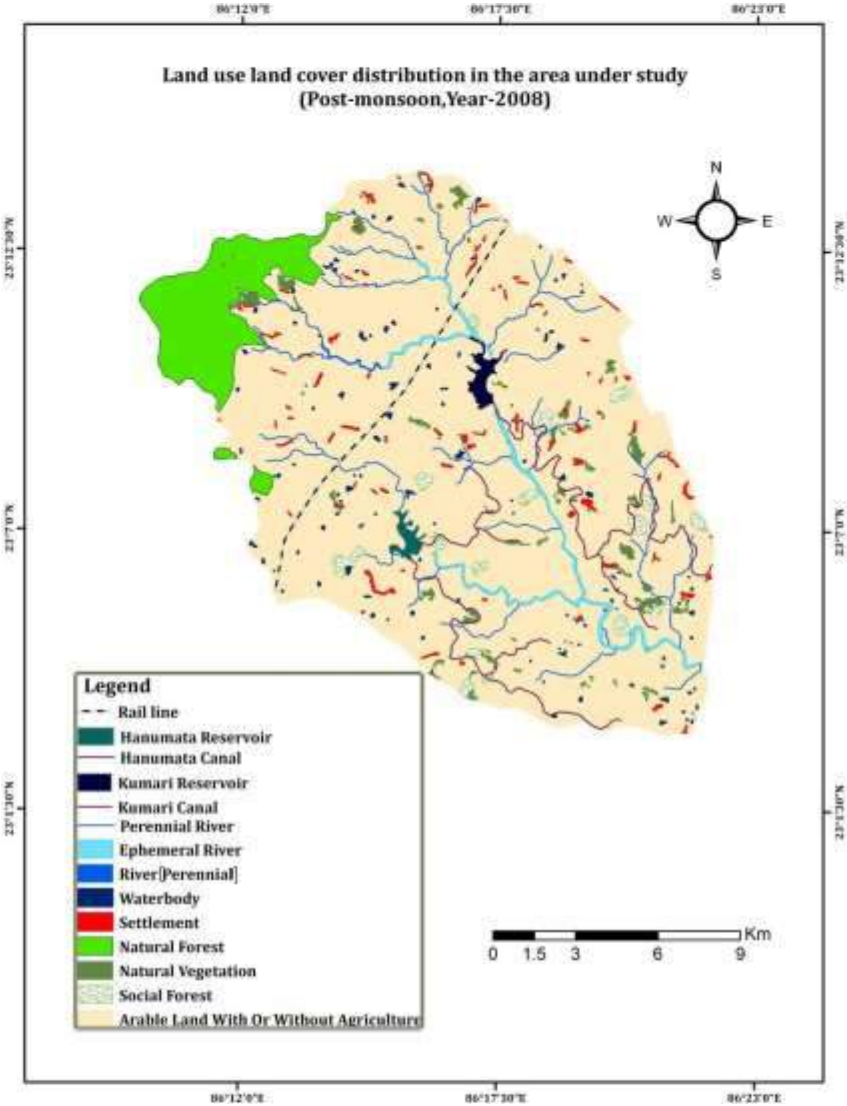

Fig-5c:- Land use map of 2008

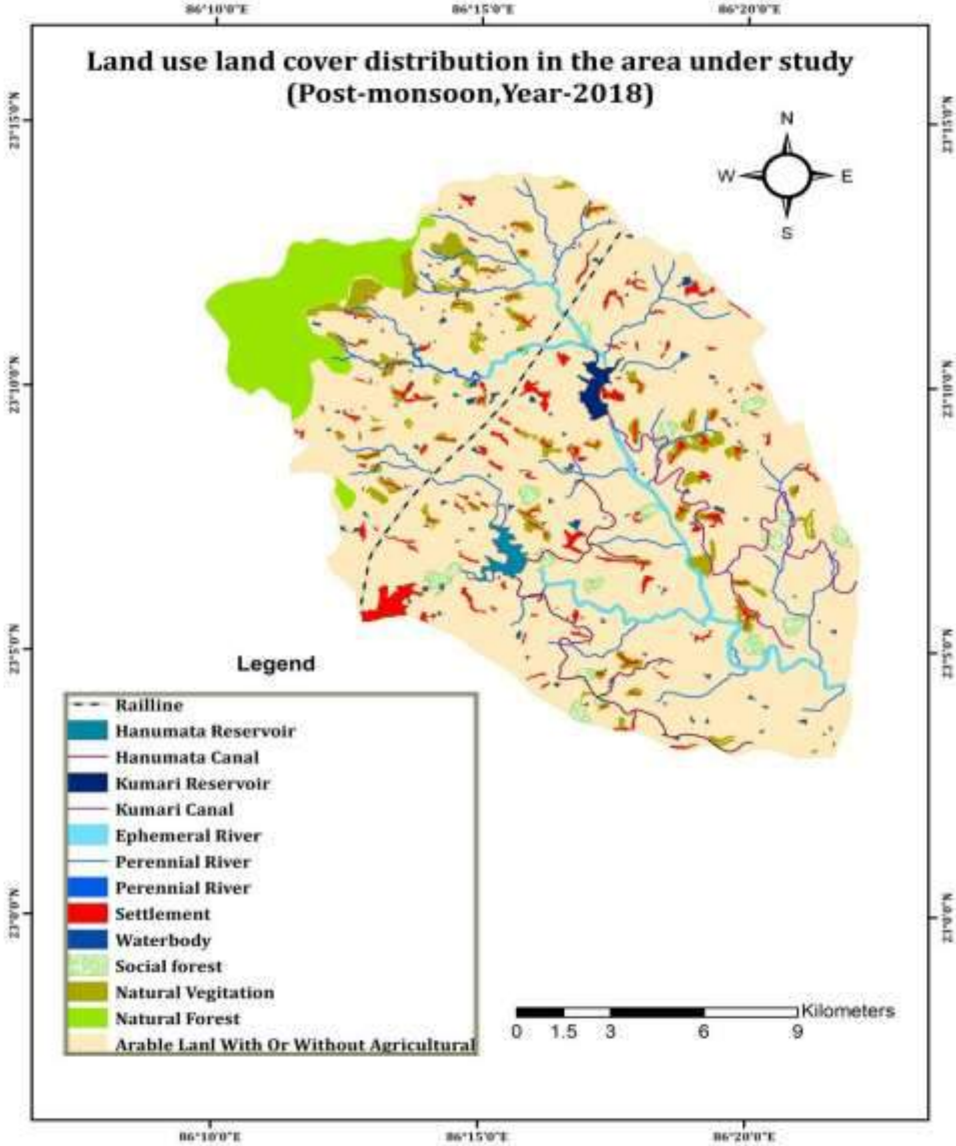

Fig-5d:- Land use map of 2018

In the study area, before construction of the reservoir, the upper catchment area of the watershed had maximum no of settlement. Due to construction of the reservoir human settlements and agricultural fields were submerged with reservoir water. The settlement area was 3,78 sq.km. during 2008. According to SOI toposheet of 1973 area was

8.22sq.km. and the nature of the settlement was scattered type. It was also observed that immediate after constructionof the reservoir in the year of 1984, the settlement area was 8.22 sq.km. and which again remain same as per SOI toposheet of the year 1992. However, the settlement area started to decreased for the year 1992. Settlement area reduced to 378 sq.km. in the year 2008(as per google earth imagery 2008).But in the year of 2018,the scenario startedto change. The settlement area becomes 9 sq.km. in the year of 2018.With the development of irrigation system,agricultural production increased and that is what affect the rural people to settle and concentrate on small village of thestudy area. And, this is the way how village are expanding in the study area.

7. Conclusion

In fact during the second five year plan (1956-57 to 1960-61) irrigation project got the actual boost up in India. In fact in the study area two main irrigation schemes are in action. 1) Kumari Irrigation Scheme, 2) Hanumata Irrigation Scheme.1)Kumari Irrigation Scheme: Under Kumari Scheme main canal has been constructed in Balarampur block from 35 km. and about 15000 people are taking facility of irrigation water. In fact due to construction of reservoir and dam, mainly …land and ..land were submerged. Ground water level in the upper catchment area shows higher level where (BGL) as in the downstream the level is low (BGL). Water logging caused by excessive irrigation water may cause soil salinity. Reservoir water may be a potential area for utilizing as irrigation purpose and it has been found veryfruit full towards multiple cropping and GIS can play a havoc towards the mapping of land use and land cover (LULC) and their changes through time. Minor changes in land use and land cover and thematic information pertaining to land use land cover change using google earth technique has been found suitable and effective.

Hanumata irrigation scheme: Hanumata irrigation scheme was started during 1974-1975. Gross storing capacity of the reservoir is 5700 cm. The targatted area under Hanumata scheme is 2024 hectare for Kharif and 743.02 hectare for Ravi.

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REVIEW OF MINIMAL FLOW REGULATION NORMS AND ITS SUITABILITY FOR BEAS RIVER BASIN

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Introduction

Concerning about the impacts of most dams and the degradation of rivers turned into a noteworthy public issue involving numerous researchers, activist groups and concerned individuals. Minimal flow is theflow necessary to preservethe river ecosystem and its dependents and inability to maintain the minimal flow will affect the health of the ecosystem.Hydropower is standout amongst the most economical and nonpolluting wellsprings of energy. India ranks eighth in total energy creation of hydroelectric power. The environmental flow goes about as a principal factor to anchor river ecological framework. Scarcely any nations have come to understand their regard as it helps in understanding and maintaining the health of the water subordinate ecosystem. There isn't aremarkable definition of environmental flows yet.

Environmental flows at times called as ecological flow both having comparable meaning based on their utilization. The rich water resources of the state include five noteworthy river basins namelythe Yamuna, Satluj, Beas, Chenab,and Ravi, which have various streams and rivers. The state is accounted for to have the generating capacity of in excess of 20,463 MW of hydroelectric energy. The Beas River has a distinguished hydropower capability of just 6000MW (State of India's Rivers for India Rivers Week, 2016). To tap this potential, the Himachal Government has just built a few errands and huge undertakings amounting to a limitof 3263 MW are under development in the Beas river basin. During the summer period river bedcould be dry leading towater shortage period.

Therefore, there is a greater need to evaluate hence15% of the minimum watched the flow of the stream must be discharged, to the downstream of preoccupation structure for the assurance of greenery, fauna and aquatic life among intake and conversion point of tailrace and the stream.

According to [1]–an e-flow is the water managementstrategy provided for water resources structures to sustainenvironments and their dependent points wherethe flow of water is controlled.‖. [2]stated that –e-flow is the ratio of water that is left in the river to the water necessary for the water ecosystem to save the unwavering quality of the river‖.

Environmental flows in like manner have another name or different definitions in different nations, for instance, instream flow, minimal flow and so on. At the law of national level,prevailing national regulationis, however, to provide a sensible, practical & legitimate course of action of water for ecological flows in several nations. At present, there is no international understanding especially stressed over environmental flows. Only a few nations have understood the criticality of non-inefficient vocations of water and have created specific regulation to accommodate it. Regulation of environmental flows in a couple of nations have influenced achievements or ventured to up.

Present research reviews the various minimal flow norms and regulation followed by various countries and various minimal flow values evaluated for projects in India and straight down to a suitable minimal flow value pertaining to the environmental conditions and other factors for the Beas River basin.

Study Area

The Study area (Beas river basin)is one of the huge river's tributaries to the Indus basin. Itinductees in the upper Himalayas beginning Beas Kundnearby Rohtang Pass in Himachal Pradesh and streams in the east-west course in Himachal Pradesh till it generates in the plains adjacent town Talwara in Hoshiarpur District of the Punjab State.

Whatever remains of the catchment area contributes water in light of rainfall especially from the high rainfall zones of Kangra, Palampur, and Dharamsala, the greater piece of the discharge of this river is found between the extended lengths of June and October in view of the concentration of rainfall in these months. The typical yearly inflow of Beas River is around 14,800 MCM. The river is a tributary of Ravi. Beas River is a in view of the concentration of rainfall in these months. The typical yearly inflow of Beas River is around 14,800 MCM. The river is a tributary of Ravi. Beas River is a lifeline of the overall public of Himachal Pradesh in the way that it is the basic wellspring of new water supply and the agriculture.

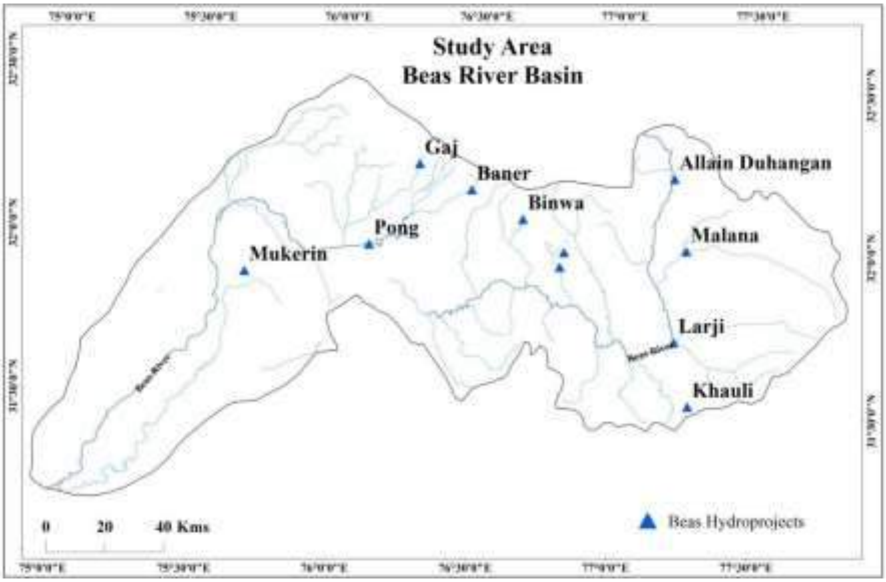

Fig. 1 Study area map

- **Tributaries**

The Beas River has different tributaries that define its nature. Upstream, its indispensable tributaries include Parbati, Sainj,andTirthan. Downstream, the Uhl, Neugal, Juni, Gaj,andChakkiare the essential tributaries. From the point of the viewpoint of aquatic life and fish fauna, particularly it's the streams which are imperative since they fill in as spawning grounds. Indeed, the Department of Fisheries has drawn up a negative once-over of streams in the Beas for hydropower advancement from the point of the viewpoint of the presumable impact that these undertakings would have on Beas' fish population and migration.

Environmental Flows Law and Guidelines in foreign countries

- **European Union (EU)**

[3]states that –although the WFD (Water Framework Directive) does not unequivocally indicate environmental flows, reasonable withdrawal percentage varies from 7.5% to 35 % of a total natural flow for the natural flow regimes" [16].

- **France**

France is one of the first nations which give the quantifiable scope of qualities for Ecological flows in regulation. [4]cited that under the law legal/allowable ecological flow should be –One- fortieth of the ADF (Average Daily Flow) underneathwater structures such as dams worked under the watchful eye of the law, One-Tenth of ADF fora new building or for relicensing) [17].

- **The United Kingdom**

According to [4], e-flow are termed as "minutest satisfactory flows. After that, the rule is being followedsuccessfully. It is as such that the agency/ authority that can determine/ decided the minimal flow based upon the commendable flow and constraints in relation to that individual. The methodology for determining the flow also varies accordingly with the measuring point at which the flow is determined [19].

- **Germany**

According to the Water (Federal Water Act-WHG), March 2010, rewrote Germany's water regulation based upon stretched out legislative forces conceded to Federalism Reform of Federal Government. WHG essences the ecological flow for ecological consideration. Like the United Kingdom, the minimal flow depends upon various factors which area matter of debate inlegalizing a definite minimal flow.

- **Switzerland**

Switzerland which is a part of the European Union has separate norms as Swiss Water Protection Act circles up precise ecological flow regards for diverse ordinary flow rates, that has to be preserved or increase in some cases, based upon ecological and geographic factors. It focuses on maintaining the health of the water-dependent ecosystem and provides sufficient water for livelihood [20].

- **The United States**

In the US E-flow are named as In-stream flows. The administration of dam, lake or any such water resources in each locality can determine and maintain their own instream flow norms with respect to their environmental characteristics. [5]estimated e flows for six different states and river basin in the state for their adequacy of ecological flow. Florida Law thatnecessitates the environment department or state water administrationof the district to set up Minimum flows based on their requirements.[23]

- **Australia**

The act of water 2007 in Australia does not give an unequivocal need to ecologicalwatercourses of action; anyway, it necessitates that ecological water is given indistinguishable constitutional affirmation from inefficient water benefits. To cite from [6]the agreement confines exchange rights related with water distributionsbesides the usage of water for the river ecosystem‘s health Australian Capital Territory government issued E-Flow Guidelines (2006) in Australia, according to which extreme flow events can occur at times of rare cases to maintain the ecosystem from extinction.

- **South Africa**

E-Flows are termed as "ecological save" in South Africa, which are regulated as law by The South African National Water Act (NWA).1998, South Africamade the NWA effective considering the water needed tomaintaining ecosystem (ecologicalhold) and human needs (ecological spare) [15].The law acknowledged that the ecological hold is the water essential to guarantee the river ecosystems the spare implies both the sum and nature of the water termed as an ecological spare.

Minimal flow norms in India

Setting up a standard environmental flow involves many procedures and consideration such as ecosystem, water needs, future, etc., having investigated administration and methods of main rivers in the nation. Initially, the definition of a river is provided followed by a delineation of the prevailing legitimate & institutional estimates that influence river‘s condition in India. There are different laws and related institutions that have continuedto be unproductive. Recently National Green Tribunal passed an act upon the minimal flow.

In India, E Flow assessment showed up in the late 1980s and first coined in 1992 as "minimum flow" by Center Water Commission. There was no essentialness given for the E flow assessmentas there were no management methodologies encompassed as an issue of goliath certainty. In 1999, Supreme Court guided the legislature to sustain the required e-flow for the Yamuna (10 m^3/s) for the river flowing New Delhi. In 2001, the administration amended the law regardingthe economical flow as a demonstration, paving course for the researches to manage this topic in a broader start. From 2005, many types of research in view of the distinctive E flow methodologies were outlines with reference to the methodologies followed in other nations. Each one of these investigations oversees river flow alone and considers diverse methodologies to restore the riverine ecosystem. India has a couple of imperative estuarine areas including the Ganges– Brahmaputra delta, Mahanadi, Krishna, Godavari, Cauvery, Zuari. Notwithstanding this various EIA of Hydropower dams were examined in understanding with the economic flow in the Indus Riverequestrian. Most of these rivers are dammed and the freshwater inflow into theestuary is truly constrained.

In India, the importance of environmental flow was realized in the late 1980s and first coined in 1992 as "minimum flow" by Center Water Commission. In the year 1999, 10m^3/s was designated as the minimal flow in the Yamuna river. After the pollution of the rivers in India,the environmental flow has been designated as 10% for the water resources structures in the year 2007-2008. In the year 2010, the percentage of environmental flow was increased to 20%. The authority for the maintenance of the environmental flow was given to the river administers and they decided the percentage of the environmental flow. In the year 2017, National Green Tribunal (NGT order) passed a law that 15% of the e-flow needs to sustained in the stream/dam/ water resources during the lean period for preserving the health of the ecology after the "Ministry of Environment, Forest and Climate Change" with the reference ongoing Judgment articulated on river Ganga had guided 20% minimum condition flow to be maintained from Haridwar onwards in perspective of the ordinary lean season flow adjacent to the nation will maintain minimum 15 % to 20% of the ordinary lean season flow of that river.

- **National Green Tribunal**

The MoEFCC (Ministry of Environment, Forest and Climate Change) done river basin investigation of 6 river basins i.e. Siang, Twang, Bichom, Subansiri, Dibang and Lohit River Basin and upon think about the Ministry has recommended the minimum flow of the river to be 18% of the ordinary of lean season flow of the river. In some situations, it wasstated to be even 20%. The Tribunal on the ongoing Judgment articulated on river Ganga had guided 20%environmental flowflow to be maintained from Haridwar onwards in view of the ordinary lean season flow also the country will maintain a minimumof 15 % to 20% ordinary lean season flowof that river.

Environmental Flow recommendations in India

There are a few constraints and factors in which India varies from other nations,

- ✓ Religious significance
- ✓ Agrarian economy
- ✓ Tropical storm hydrology
- ✓ Exploitation of groundwater
- ✓ Wastewater transfer in rivers

According to the Notification from — Department of Pollution Control Government of Himachal Pradesh (no. PCF (2) - 1/2005 dated 09/09/2005), –the minimum amount of flow to be discharged and maintained immediately downstream of the redirection structures of existing and upcoming hydro-electric activities, consistently, ought to be a "limit estimation of at least 15% of the minimum inflow seen in the slender season to the main river water body whose water is being bridled by these ventures".

Table 2: E-flow Recommendations for various projects

Projects	Recommendation
NathpaJhakri Hydropower Project (1500 MW) [7]	7 m^3s^{-1}
Rampur Hydro-electric Project (RHEP) (412 MW)[8]	4 to 10 m^3s^{-1}
The Upper Ganges basin (2007) [9]	Water has to maintained at a level of 70% all the time and during drought period atleast 30% should be maintained
Yamuna River through Delhi [11]	50–60% of the total flow.
Mahanadi River (2009)[12]	The environmental flow at Andhiyakore 0.388 m^3/s, Bamnidhi 23.19 m^3/s, Baronda 0.213 m^3/s, Basantpur 36.28 m^3/s, Ghatora 0.04 m^3/s, Kantamal 14.72 m^3/s, Kesinga 5.12 m^3/s, Kurubhata 0.9 m^3/s, Tikerpara 298 m^3/s, Manendragarh 0.43 m^3/s, Rajim 0.99 m^3/s, Salebhata 0.7 m^3/s, Simga 1.5, Sundergarh 0.96 m^3/s.
Kumbh Mela 2013 at Triveni Sangam, Allahabad [10]	225m^3/s.
Ram Ganga venture on Ram Ganga River at Kalagarh	4.70 cumecs

Cauvery River (2014) [13]	The resultant minimal flow at these location ranges from Belur (0.07- 9.05) m^3/s Hadige (1.67-33.40) m^3/s Akkihebal (1.18 - 19.59) m^3/s Kollegal (18.24-364.88) m^3/s .
The Ganges River (2010) [14]	a minimum of 542 m^3/s flows is required during April and an extent 22715 m^3/s is required during August and September

Role of Various Agencies

- **Government Sector**

The minimal flow isn't maintained in the river of the hydropower extends in Himachal Pradesh, latest news on the Hydropower ventures. Currently, the government is aiming to increase the production of the hydropower potential overviewing the environmental effects upon the ecosystem and also the mountain communities depending upon it. Hence as a role of government, it should keep an eagle‘s eye in maintaining the e-flow in the dam while planning, executing the hydropower projects.

- **Non-Government sector**

Our study area Beas river basin in Himachal Pradesh comprises of hydropower ventures possessed by both the public and private corporations understood that owing to inadequacy in maintaining the minimal flow. These organizations subsequently met up intentionally and tried to shape a water basin level association. Regardless of power production, the private sector must run hand in hand with the administration sector in preserving the ecosystem of the mountain networks.

- **Individuals**

With the reference of many contextual analyses of healthy environmental communities‘ close hydropower projects, the key is that the approach of the project is bottom-up, starting at the network level. The people group can't simply depend upon the legislature and private institutions at all conditions subsequently the network individuals must assume up the liability in preserving the ecosystem.

Conclusion

Hydropower is stood out amongst the most economical and non-polluting sources of energy. India ranks eighth amongst all in terms of energy production of hydroelectric power. The concentration was more on that a wide number of projects are completed; anyway what influences neighborhood living of remotely located individuals and effect upon ecosystems in different means are overlooked by government. Most of the Hydropower projects are built upon the mountain region; Mountain communities depend upon the honey cultivation, tree bark trade, and other herbal shrubs cultivation and trading, the construction phase affects the environmentby deforestation, exploitation of land and other resources upon which the mountain community regions rely upon. Likewise, the operation affects the mountain communities who primarily depend upon the fish, agribusiness, and cattle by overexploiting the water for the production of hydropower.

Irrespective of the minimal flow law passed, government, private and individual people must go hand in hand to preserve the environment. Failure in maintaining the 15% minimal flow norms for the hydropower by the government and private institutions, individuals must help from their side in order to maintain the ecosystem in prosperous. Role of local institutions, government schemes, mountain policies, and governance have their respective goals and they are being focused, followed for the betterment of the mountain communities.

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MANAGEMENT OF RIVERS AND STREAMS AS SOURCE OF WATERAND INFRASTRUCTURAL DEVELOPMENT

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Abstract

A river is a very important source of fresh water and a river basin system is a very important natural water system for use in agricultural, urban, and industrial sectors. With the fast pace of development followed by India, the requirement for water is increasing rapidly. Utilization of the river system in a monsoon-fed country like India needs various infrastructural modifications of the river basin and river channel. The present paper discusses such case histories related to nala diversion in township development in Durgapur and in coalmining sites. Additionally, introductory remarks have been presented on dams and barrages.

Keywords: *Hydro geomorphology, Dam, Barrage, Nala Diversion, Channel Design*

1. Introduction

Rivers and streams are the lifeline of a nation or country. Urban civilization in India has grown by the side of major rivers. Perennial rivers of India mostly get water supply from the melting of snow in high mountains. These rivers or streams then get significant water supply from rainfall during monsoon through a hydrological process of Rainfall – Runoff. Rivers and streams form a geomorphological component and control the overall drainage system of the country. Here we must also consider the importance of very important hydrogeomorphologic units like basins, catchments, or watersheds. From this very important subject of hydrology and geomorphology, we now traverse to the impact of developmental processes and utilization aspects of rivers and streams and also rivers and streams as an important component of the overall environment of a nation. Rivers and streams form a very important storehouse of a critical essential resource water without which life cannot exist on this planet. Rivers and streams allow area drainage and free the locality out of excess water during excessive rain. The present paper deals with the utilization of river water resources for urban and industrial development keeping in view the present-day fast development and also the impact of these developmental processes on the health of rivers and streams and remedial measures.

Site Selection For Urban And Industrial Centres:

The first step in the development of an urban or industrial establishment is the selection of a suitable site. While socioeconomic and marketing factors play an important role implementation of the project starts from an integrated study of the geomorphologic, hydrologic, and climatologic study and assessing the impact of modifications of topographic and geomorphologic factors and associated drainage problems to be created by these modifications. The topographic modifications have a major impact on the overall regional drainage and this requires the study of stream and nala diversions in the whole site keeping in view the basin morphology and basin characteristics. Here we take up two examples one is a development of a township namedAerotropolis near Andal Airport near Durgapur .and the other is an opencast mine Tubed Mine in Latehar Jharkhand.

Sujalam Skycity (Andal Aerotropolis) is India‘s first aerotropolis located in the Andal block of Paschim Bardhaman district in West Bengal, India. The city is supposed to cater to the large industrial and mining area covered by Andal, Durgapur, Ranigunj, and Asansol. The city is located adjacent to Kazi Nazrul Islam International Airport which was developed in association with Singapore-based Changi Airport International.The project is developed over an area of 8.83 Square Km.

Chatterjee (2015) made a study of the Aerotropolis near the Andal Airport from an environmental point of view. Chatterjee (2015) observed that the area around the airport selected for the township is sensitive to the environment and needs to follow detailed guidelines for environmental management. The tool used is a sensitivity analysis of the surrounding area considering land use, surface water, groundwater, and vegetation characteristics. Kundu & Datta (2021) have studied the land use and land cover details of the Andal Aerotropolis area through the preparation of LULC Maps for the years 2015 and 2019 to study the change of land use and land cover during the developmental process from 2015 to 2019. The maps have been prepared for four classes namely vegetation, water bodies, settlement, and fallow land. Kundu & Datta (2021) have noticed a massive change in the map from 2015 to 2019 and have noticed a gradual increase in urban areas and a reduction of fallow land, water bodies, and vegetated land. The development of land for the Sujalam Skycity necessitated the diversion of existing nalas in the proposed township area. Figure 1 presents the location of Tamla Nala on Satellite Image. The figure also shows the Damodar River and Ajoy River.

Fig-1: The location of diversion of Diversion of Tamla Nala

Fig-2: Location of Diversion near Airport Site

In opencast mine, Nala diversion is an essential aspect of mine site development. Naveed Ali, Vijayagopal, and Garg (2015) presented a case history of designing a mathematical model of diversion channel of Kewari Nala flowing through the Jitpore block in Godda District of Jharkhand. Kewari nala flows through the mine area and needs diversion. Mala diversion was proposed along the western boundary of the coal block. The first step was rainfall analysis and estimation of daily extreme rainfall with a return period of 25 years, 50 years, and 100 years. Through rainfall runoff analysis peak floods for return periods 25 years, 50 years, and 100 years were estimated. Then a flood routing model was used to design the diversion channel.

Tubed Coal Mining Project is a 6 MTY mine that covers an area of 460 Ha in the Auranga Coal Field. The Auranga coal field is the easternmost part of the North Koel Valley of the Gondwana Basin. It is about 8 Km west of North Karanpura Coalfield which is the western part of Damodar Valley of Gondwana Basin. Auranga coal field covers an area of 250 sq. km and is located in the Latehar District of Jharkhand State. The tubed block is one of the identified NonCIL blocks and lies in the northern part of Auranga Coal Field. The Tubed block exhibits undulating topography. The general slope of the block area is towards the west. Sukri River flows in the southwestern part of the block. The ground elevation of the block varies from 386m in the North West Valley area to 412m in the North East High Land area. The drainage of the block is mainly controlled by the Sukri River and associated Nalas. Sukri River flows in the southwestern part of the block. Three east-west flowing nalas drain to the Sukri River. In addition, there is a nala located in the northern part of the block which also joins the Sukri River. Thus the block needs diversion of the Sukri River and part of associated nalas to prepare the block for mining activities. Figure 3 presents the Sukri River and associated nalas.

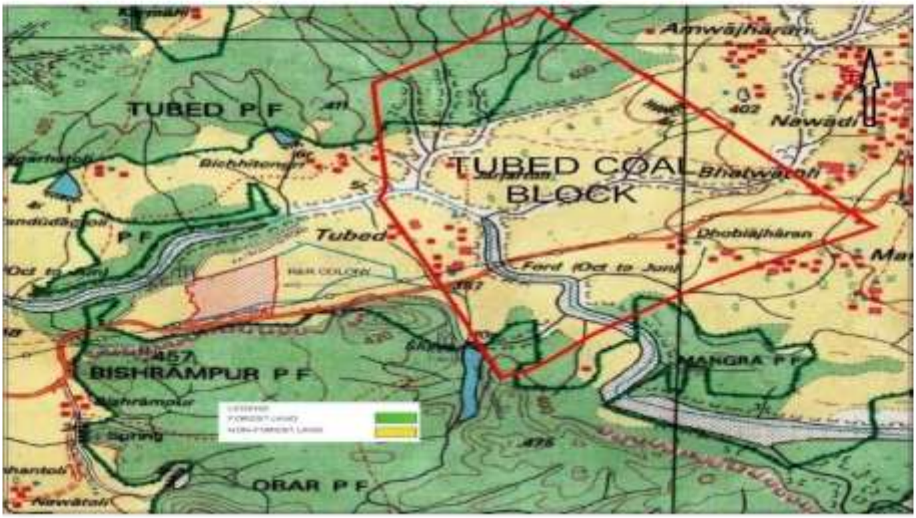

Fig-3 : Sukri River in the Tubed Block

The objective of the diversion of the Sukri River and associated streams to the periphery of the coal block hasto be planned through the design of an artificial channel to carry the peak flow of the watershed concerned and finally merge with the Sukri River flowing out of the block. It should be kept in mind that the Sukri River is a part of the regional drainage system and thus the whole diversion system should be designed so that it does not in any way affect the regional drainage system. It should also be considered that rivers and streams can be properly utilized to act as a source of water for the project during the construction phase and operating phase. The engineering of Nala diversion needs a comprehensive observation of the morphology and topography of the surface area of the block and the collection of long-term hydrological data, particularly rainfall, evapotranspiration, and infiltration. In addition, a brief note on hydrogeological features and shallow-depth aquifer conditions have to be studied. Based on the collected data rainfall–runoff analysis has to be carried out with an aim to the estimation of peak flood flow. The ideal diverted channel cross section should be developed keeping in view the ground slope of the area and the estimated ground slope of the channel. Preferably channel section should be trapezoidal. Manning's equation should be used to arrive at the channel section.

2. Barriers Across Rivers And Streams

Rivers and streams are important sources of fresh water. Thus, most of the cities, towns, and water- consuming industries are developed by the side of rivers. The source of water in a river mainly originates from rainfall. However, perennial rivers get water from snow melt in high mountains in addition to rainwater. India gets maximum rainfall during monsoon months (June, July, August, September, and October). Thus, in order to get a steady supply of water for consumers we need adequate storage of water. Here it must be remembered that the requirement of water is maximum during summer months when rainfall is minimal. Storage of water is achieved by the construction of an obstruction structure on the river channel and inundation of the adjacent area of the river bank. This obstruction structure is called a Dam. A dam is a barrier that stops the flow of water in a river and results in the creation of a reservoir. Reservoirs created by dams suppress floods caused by major rainfall and also provide water for irrigation drawn from reservoirs through canals. In addition, the reservoir supplies water for human consumption, industrial use, and, aquaculture. Dams also facilitate in production of hydroelectricity through the utilization of the potential energy of the head of water.

Although a dam allows storage of substantial water upstream of the dam it has a massive impact on the surrounding physical and socioeconomic environment. The people living on the upstream side of the dam suffer during the construction of the dam lose their dwellings and face rehabilitation. However, the major benefit is transferred to the people living in the downstream side. A list of major dams in India is presented inTable: 1.

3. Major Dams in India

Table-1: **Major Dams in India**

NAME OF DAM	STATE	RIVER
Bhavanisagar Dam	Tamilnadu	Bhavani
Tungabhadra Dam	Karnataka	Tungabhadra
Rihand Dam	Uttar Pradesh	Rihand
Maithon Dam	Jharkhand	Barakar
Koyna Dam	Maharashtra	Koyna
Bisalpur Dam	Rajasthan	Banas
Mettur Dam	Tamilnadu	Kaveri
Krisnarajsagar Dam	Karnataka	Kaveri
Indirasagar Dam	Madhya Pradesh	Narmada
Cherutheni Dam	Kerala	Cherutheni
Sardar Sarovar Dam	Gujrat	Narmada
Nagarjuna Sagar Dam	Telangana	Krishna
Hirakud Dam	Odisha	Mahanadi
Bhakranangal Dam	Punjab HP border	Sutlej
Tehri Dam	Uttarakhand	Bhagirathi

Another barrier structure on the river is a barrage. While a dam is constructed primarily for the storage of large quantities of water a barrage is built primarily for diverting water and raises the water level by only oneor two meters. A barrage is a type of low-head diversion dam that is equipped with a number of gates to control the supply of water to an adjacent canal. This allows the structure to regulate and stabilize river waterelevation upstream for use in irrigation and other systems. Table 2 presents a list of major barrages in India.

TABLE 2: Major Barrages in India

NAME OF BARRAGE	STATE	RIVERS
Asan	Uttarakhand	Confluence of Asan River with Yamuna Canal
Dakpathar	Uttarakhand	Yamuna River
Farakka	West Bengal	Ganga
Talwara	Punjab	Beas River
Hathnikund	Haryana	Yamuna River
Bhimgoda	Uttarakhand	Ganga
Jobra	Mahanadi	Orissa
Dowleswaram	Andhra Pradesh	Godavari
Kota	Rajasthan	Chambal
Prakasham	Andhra Pradesh	Krishna
Durgapur	West Bengal	Damodar
Okhla	Delhi	Yamuna
Harike	Punjab	Confluence of Beas & Sutlej

Ghosh (2023) has described how a captive dam Mandira Dam on the Sankh River has been utilized for the supply of water to the Rourkela Steel Plant. A dam Mandira Dam was constructed on the River Sankh to ensure an adequate supply of water to the Rourkela Steel Plant during the dry season. Mandira Dam is located near Kansbahal in Sundargarh District, Odisha. The Mandira Dam is constructed across the Sankh River about 16 Km upstream from Mandira. The distance from Mandira Dam to Rourkela City is 32 Km. Mandira Dam is captive to the Rourkela Steel Plant to ensure adequate water supply during the dry season. An intake water structure is constructed on the river Brahmani at Tarkera along with a raw water treatment plant for pumping of raw water, treatment, and pumping of treated water as make-up water to the Steel Plant.

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Fig-4: Tarkera Intake Water Structure On The River Brahmani

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GROUNDWATER POTENTIAL ZONE OF AJAY RIVER BASIN USING RS-GIS TECHNIQUES

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Abstract

Water is an indispensable natural resource for survival of any species in the globe. For centuries, civilization has flourished on the bank of river based on the easy availability of water. Groundwater is one of the prime sources of freshwater supply, but, its occurrence and spatial distribution are highly uneven and affected by several surface and subsurface features. The Ajay is an ephemeral, monsoon influenced river, originated from the Chhotanagpur plateau at Batpar of Jamui, Bihar, flowing through heterogeneous lithology and merge with the river Bhagirathi in West Bengal. Here, an attempt has been made to discover the Groundwater Potential zone of the Ajay river in West Bengal. Remote sensing and Geographic information system (GIS) has emerged as a powerful tool for storing, analyzing, and displayingspatial data and using these data for decision making in several areas including engineering and environmental fields i.e. - groundwater exploration, conservation, evaluation. The present study has been incorporated the applied remote sensing techniques, such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and to obtain rational, quantitative and significant results through paleochannel investigations. Nine thematic layers concerning with geology, geomorphology, hydrology, land use land cover , soil, TWI, Drainage density, Lineament density have been employed in this study with properweightage depending on their role in groundwater formation to identify the groundwater potential zone. By using analytical hierarchy process (AHP) , whole study area has been classified into four zones ranging from excellent to poor. The result shows that the southern part composed of alluvial plain has the excellent potential compared to the northern lateritic and pediment part where groundwater potential is moderate. Eventually, few recommendation and suggestion have been framed for sustainable water resource management that will help the researchers, planners and other decision-makers for judicious exploration and management of the groundwater resource in the study area.

Keywords *- Groundwater potential zone, Water resource management, Hydro-geomorphology , RS GIS & AHP , NDVI .*

1. Introduction

Water is one of the main Natural resources that essential for human‘s daily life, domestic, industrial and other various multipurpose socio-economic developmental fields. Groundwater is one of the most Vital Natural Resources and the largest available sources of fresh water which is stored in the subsurface geological formations in the critical zone of the earth‘s crust. (Fitts, C. R. , 2002). This needs periodic assessing and monitoring for its sustainability. Over exploitation and large withdrawal of groundwater resources imposes stress on groundwater distorting the aquifer recharge equilibrium and majorly affectingthe ecological imbalances (Garg,1976).

Contamination of groundwater can result in poor drinking water quality, loss of water supply, high clean- up costs, high costs for alternative water supplies, and/or potential health problems. A wide variety of materials e.g. synthetic organic chemicals, hydrocarbons, inorganic cations, inorganic anions, pathogens, and radio nuclides have been identified as contaminants found in groundwater (Fetter, 1999). Surficial water shortages increased reliance on groundwater as an alternative water source. Improving access to safe drinking water can result in tangible benefits to health (Jhariya et al. 2016).).

In developing countries like India around 80% of all diseases are directly related to poor drinking water quality and unhygienic conditions. In India, most of the population is dependent on groundwater as the only source of drinking water supply (Phansalkar et. al., 2005). In India severe water scarcity is becoming common in several parts of the country, especially in arid and semi-arid regions. The Ajay is a monsoon influenced river,originated from the Chotanagpur plateau at Batpar of Jamui , Bihar, flowing through heterogeneous lithologyfrom Jharkhand and merge with the river Bhagirathi in West Bengal. Ajay river is also facing a gap in Improperplan for suitable groundwater exploration, distribution and a lowering of the groundwater level. Therefore, the decline of groundwater resources is the most important for the groundwater management and sustainabilityof groundwater utilization with special reference to Ajay river. The term groundwater potential indicated theavailability of groundwater in a particular area. The groundwater potential of a region depends up on differentfacts and it varies from place to place according to its properties variation . Variation of the groundwater potential within a short distance and the same geological formation has also been observed in that study area(Dar et al. 2010; Nasir et al. 2018; Choudhariet al. 2018; Pradhan et al. 2018).

In such a situation, the proper identification of the Groundwater potential zones is necessary to prevent financial loss, drought, overflooding and effort through effective planning and management, in terms of its occurrences and accumulation (Yadav et al. 2014, 2016; Pradhan et al. 2018).There are different methods andtools available for the discovery of groundwater probable zones in a particular area (Sadeghfam et al. 2016; Mogaji & Lim 2018;), among which, tools like integrated remote sensing (RS) and geographic information system (GIS) are categorized as the most useful and inexpensive tools in groundwater mapping which requirevery little mechanical and physical work. The Remote Sensing and GIS tools have opened new paths in waterresources studies , water resources management, groundwater assessment and modeling.

Locating potential groundwater centers is becoming more easy and cost-effective. In groundwater studies, GIS is commonly usedfor site suitability analyses, managing site inventory data, estimation of ground water vulnerability to contamination, groundwater flow modeling, transport modeling and leaching, and integrating groundwater assessment models with spatial data to prepare spatial decision support systems . Mapping and integration ofgeology, geomorphology, drainage, soil, slope , LuLc ,lineament density , drainage density ,Twi has been carried out in Ajay River basin by using GIS and Multi-criteria decision making (MCDM) techniques for assessing Groundwater Prospect Zones through AHP method . So in this study Creating connection between multiple parameters obtained from satellite imagery and secondary data is an important process in groundwater exploration. Groundwater is the major source of water for drinking and agriculture purposes when compared to surface water in this region. Agriculture is the first occupation for livelihood in this area. Major Shifting of Landcover to Landuse has been noticed from Decadal change detection studies. Agricultural, industry and domestic water users in the study area is mainly depend upon the pumping of groundwater from the Ajay river basin. In spite of the largescale pumping of groundwater from this area, no attempt has been made to make use of remote sensing and GIS techniques to identify groundwater potential zones. Hence, the present study was carried out with the objective of mapping the spatial distribution of groundwater potential zones in the Ajay river basin , which will assist in proper management of groundwaterresources in this area.

Finally The ground water potential zones have been divided into suitable categories namely Verylow, Fair, high & excellent recharge potential zone. The output of this study will provide valuable information to develop sustainable groundwater management and suitable location for wells pumping that can be used by decision-makers, government agencies, and private sectors. Furthermore, the results of this study important to have proper administration, management, and sustainable use of groundwater resources in Ajay river & associated watershed.

2. Literature Review

The recent techniques such as the RS and GIS have been used for identification of groundwater potential zones by several researchers (Krishnamurthy et al. 1996; Chowdhury et al. 2009; Rashid etal. 2012; Magesh et al. 2012; Adiat et al. 2012; Satapathy and Syed 2015; Agarwal and Garg 2016; Ahmed and Mansor 2018).

Deepesh Machiwal et al., (2010) proposed a standard methodology to delineate groundwater potential zones using integrated RS, GIS and multi-criteria decision making (MCDM) techniques. The methodology is demonstrated by a case study in Udaipur district of Rajasthan, western India.

Jobin Thomas et al., (2011) The information on geology, geomorphology, lineaments, slope and land use/land cover was gathered from Landsat ETM + data and Survey of India (SOI) toposheets of scale 1:50,000 in addition, GIS platform was used for the integration of various themes. The composite map generated was further classified according to the spatial variation of the groundwater potential in tropical river basin (Kerala, India) using remote sensing and GIS techniques.

Murugesan Bagyaraj et al., (2012) have carried out groundwater study in the Dindigul district of kodaikanal hill, a mountainous terrain in the Western Ghats of Tamilnadu. All thematic maps are generated using the resource sat (IRS P6 LISS IV MX) data and Inverse distance weight (IDW) model is used in GIS data to identify the groundwater potential of the study area. For the various geomorphic units, weight factors were assigned based on their capability to store groundwater.

As per Satiprasad Sahoo et.al (2016) on Delineation of groundwater potential zones (GWPZ) has been performed for a coastal groundwater basin of eastern India by using Analytic Hierarchy Process(AHP) from different influencing features. Through Sensitivity analysis it reveals that absence of rainfall and lineament density increases the poor groundwater potential zones and Omission of hydrogeology, surface geology, soils, and NDVI show maximum increment in good GWPZ.

According to Chakrabarti (2001), during the early Chalcolithic period (~2000 BC), most of the lower Ajay River Basin was covered by dense Sal forest and the rivers on the west bank of the Bhagirathi River do not have vast floodplain. As a result, villages were developed in the available areas along the river bank, on the river bed and parafluvial zones. The study attracted the attention due to some archaeological fact, related to the existence of palaeochannel in the past, which is located 20 km away from the present channel of Ajay River.

3. Objective

The primary objectives of this study are

- To delineate the groundwater potential zones of this area using Remote Sensing (RS) and Geographic Information System (GIS) techniquesthrough AHP method.
- To understanding associated factors affecting Ground Water prospective zonation mapping instudy area and find out the areas which have good ground water potential in the hard rock terrain of the present study.
- To suggest proper sustainable development of groundwater resources in this area.

Further the focus of the study is to explore the hydrological evolution of the Ajay River, especially to determine geomorphology, hydrology, land use land cover , soil, drainage density, Lineaments how they are distributed in present Ajay Rivers.

4. Study Area

Ajay is a Sanskrit word that means ‗unconquerable'. The Ajay river basin is situated between the coordinates 23° 12'– 24° 18' N and 86° 9' – 88° 6'E. The river originates from Batpar village, Jamui,Bihar and it enters in the Bhagirathi river at Katwa, West Bengal. From Originating in the Jamui district in Bihar, the Ajay river flows through three neighbouring states - Bihar, Jharkhand, and WestBengal. It is one of the major rivers of West Bengal. It's catchment area is 2500 square miles or 6800square kilo meters. The study area lies in the north-eastern part of the ‗Rarh Bengal' (Bagchi and Mukherjee, 1979). The Ajay is one of the most significant river in Bengal basin and the western tributary of Bhagirathi-Hooghly followed by its principal river system Ganga .This basin is boundedby Chotanagpur plateau in west, Ganga–Brahmaputra Delta in east, and in between Mayurakshi and Damodar basin in north and south direction respectively (Roy&Sahu, 2015).

After entering West Bengal, first it flows between West Bardhhaman district and and then Birbhum district. Finally, the Ajay River enters Purba Bardhhaman district's Katwa subdivision and joins Bhagirathi river in Katwa town. Upper part of the river course flows through unclassified gneissic complex. In middle reach, it runs through Gondwana formation and recent alluvium. The lower part of the river is underlined by sequences of quaternary sediments (Bhattacharya 1972). The entire Ajay, is meandering in nature with varying degree of sinuosity. The Ajay basin area within West Bengal has been classified into six major geomorphic units by the Geological Survey of India,1985

Major geomorphic units are: (1) Residual Hills, (2) Pediplain, (3) Illambazar Surface, (4) Nutanhut Surface, (5) Ajay Plain, and (6) Diara Plain

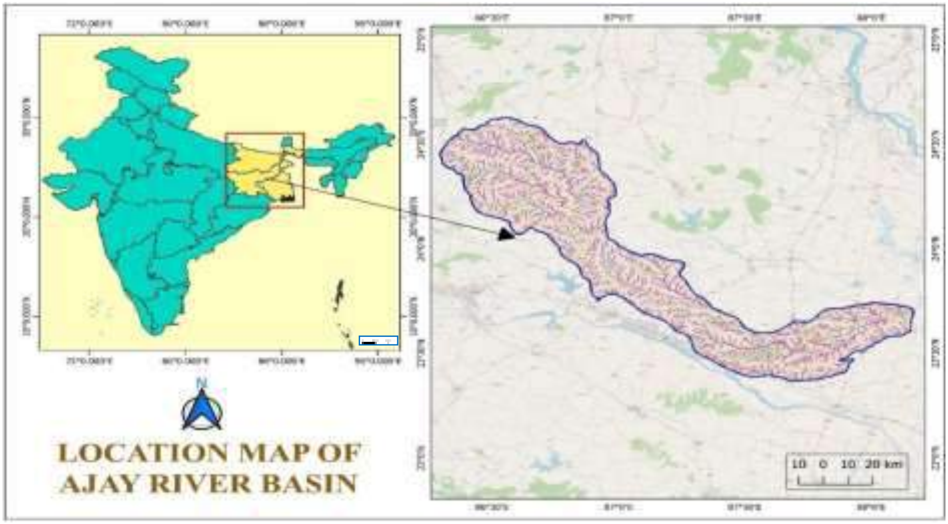

Fig 1: Location of the Study Area

The river starts to follow through alluvium tract in Bengal basin after Pandaveswar where the width of the river is maximum (Jhaetal.,2011), and then it is joined with the Hinglo River and flows through Rarh region in Birbhum district in south-east direction. It then joins with the Kunur River and changes its movement towards north-east direction near Mangal kote Purba Bardhhaman district. The Ajay River changes its coursenear Kowarpur village towards east and meets with Bhagirathi River near Katwa town (Bandyopadhyay,2018)as represented by (Fig.1). The studied area is characterized by undulating topography and gentle slope towardseast-southeast with varying elevations. Illambazar Surface, Nutanhut Surface and Ajay Plain are very clear within studied segment. Lateritic terrains are prominent beside the bank of the Ajay river around Bolpur and Orgram forest area . These lateritic terrains are known as Nilgarh Surface or Illambazar Surface. Pedocal soilalso stretches over a large region of the Ajay river basin within West Bengal,which is known as Nutanhut Surface.

The hydrological regime of the Ajay is influenced by the extreme fluctuations of the monsoonal rainfall (Niyogi 1988; Bandyopadhyay et al. 2016). The study area experiences an average of 1298 to 1508 mm annual rainfall . The Ajay river is also known for being a river originating floods. There hasbeen a record of 14 floods from the Ajay river in the 20th Century. This is why the embankments havebeen done on the lower reaches of the Ajay to prevent floods.

Table:1 – Ajay River Location Layout

Country	India
State	Bihar Jharkhand West Bengal
Districts	Jamui,Deoghar.Giridih,Jamtara Katwa
Tributaries (Right Bank)	Pathro (Jharkhand) Jayanti (Jharkhand) Tumuni (West Bengal), Kunur (West Bengal)

5.. Data Acquisition

The study has been done by considering 9 different influential data layers, viz., geology, lineament density, geomorphology, landuse and land cover, drainage density, rainfall, slope, TWI and soils were derived from ample of geospatial data sets, e.g, SOI toposheets, IRS R2 LISS IV,LANDSAT 8 ,SRTM satellite images, mineral and soil resource maps from datahub i.e. National remote sensing center (NRSC), and USGS etc. The required data were collected from various sources and processed in ARC GIS 10.7.1 to prepare the final database. The thematic maps of slope, drainage, drainage density, lineament density were extracted from the SRTM (shuttle radar topography mission)-DEM Data with a resolution of 30m. Geology and geomorphology maps were obtained from the Geological Survey of India (GSI)- BHUKOSH, SOI Toposheet 1: 50,000 scale. The soil map was obtained from the FAO Soil Portal. The thematic map of landuse and land cover was generated from Landsat 8 data.

The geomorphology and LU&LC maps were digitized satellite image by using visual interpretation techniques. To understand the surface features slope, LULC, geomorphic units and lineament density have been considered. Groundwater recharge and formation were found to be affected by the nature of slope.30- meter SRTM digital elevation data have been used to generate slope map of the study area.

Table 2 :- Data Acquisition with Sources

Data	Sources
Digital elevation model (DEM)	(USGS 1 arc second), UTM-45, WGS 1984.

Land use land cover map (LULC)	Landsat 8 OLI, United States Geological Survey Earth Explorer.
Geology	Geological survey of India , BHUKOSH .
Geomorphology	Geological survey of India , BHUKOSH.
Slope	Dem (USGS 1 arc second), UTM-45, WGS 1984.
Drainage density	Dem (USGS 1 arc second), UTM-45, WGS 1984.
TWI	Dem (USGS 1 arc second), UTM-45, WGS 1984.
Soil	Food and Agricultural Organization (FAO)
Rainfall	High-resolution gridded datasets Crudatasets.

Various lithological units of the study area have been extracted from the quadrangle map no 73M prepared by Geological Survey of India (GSI). USGS SRTM image & SOI Topographical map (73M/4 and 73M/5) have been used to classify the land use land cover information. Supervised image classification using maximum likelihood algorithm has been applied to generate the LULC of the study area. Lineaments are the linear to curvilinear features generated by the crustal movement. It influences the infiltration rate thereby groundwater recharge has been influenced by the presence of lineaments (Haridas et al. 1998; Magesh et al. 2012). SRTM satellite data along with the geological map have been employed to extract the lineament of the study area. Hence, according to potential capabilities weightage were assigned. So, area with higher lineament density has been given greater weight compared with the area with lesser density.

6. Methodology

After Data procurement for different parameters individually , all the thematic layers are converted into rasterand weights were assigned using AHP technique. Where minor effect was given 0.5 weight and the major effect was given a weight of 1.0. The major and minor effect and their cumulative sum of each influential factor were calculated. Finally, the groundwater potential zone map was generated from the integration of allthe raster layers using weighted overlay analysis technique using following formula (Jha et al. 2010; Agarwalet al. 2013; Shekhar and Pandey 2014).

GWP = HGwHGwi + SlwSlwi + GwGwi + LuwLuwi + DWwDWwi + LwLwi + SwSwi …. (1)

where W represents normalized weight of each thematic layer and Wi stands for normalized weight of the features. HG = hydrogeomorphology; Sl = slope; Lu= land use/land cover; L = lineament density; S = soil texture and DW represents fluctuation.

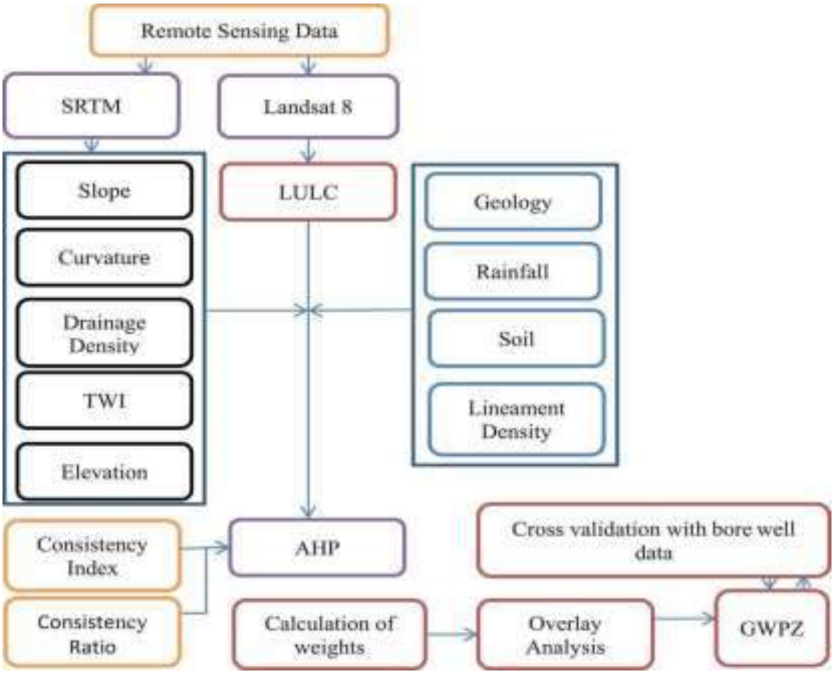

Fig 2: Workflow & Research Methodology For preparing GWP Zones

Before AHP modelling , to build the study strong various mathematical preliminaries were used to checktheparameters like Ndvi, Ndwi, Otci etc.

6.1. Normalized Difference Vegetation Index (NDVI)

In the case of NDVI, Tucker (1979) has used the following equation to visualize the vegetation cover. It detects and quantifies the presence of live green vegetation using this reflected light in the visible and near- infrared bands. High NDVI values (approximately 0.6 to 0.9) correspond to dense vegetation such as that found in temperate and tropical forests, Moderate values represent shrub and grassland (0.2 to 0.3) , Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow.

$NDVI = (\rho NIR - \rho R)/(\rho NIR + \rho R)$ …. (2)

where ρ is reflectance to its respective spectral bands. NIR is near infrared band of TM data (Band 4) and Ris red band of TM data (Band 3).

6.2. Normalized Difference Water Index (NDWI)

To minimize the errors of usual NDWI on soil water monitoring, a modified NDWI using Near infrared band (NIR, Landsat 8) has been followed which is based on McFeeters(1996).

$NDWI = (Green - NIR)/(Green + NIR)$ …. (3)

Where NIR is near infrared band of Landsat 8 OLI data (Band 8) and Visible green band is (Band 3). The positive value of NDWI (0 to 1) indicates the presence of water or moist soil layer and the negative value (−1 to 0) shows the existence of bare soil or other objects excluding water bodies.

6.3. Terrestrial Chlorophyll Index (OTCI)

Here Sentinel -3 OLCI Terrestrial Chlorophyll Index, Based on combination of bands.

$OTCI = (B12 - B11)/(B11 - B10)$ …. (4)

The Terrestrial Chlorophyll Index (OTCI) is estimated based on the chlorophyll content in terrestrial vegetation and can be used to monitor vegetation condition and health. Low OTCI values usually signify water, sand or snow. Extremely high values, displayed with white, usually suggest the absence of chlorophyllas well. They generally represent either bare ground, rock or clouds. The chlorophyll values in between rangefrom red (low chlorophyll values) to dark green (high chlorophyll values) can be used to determine vegetationhealth.Here we used more parameters for making the result strong & justify.

Hillshade, is a technique where a lighting effect is added to a map based on elevation variations within thelandscape. It provides a clearer picture of the topography based on the sun's effects on terrain. With this tool, the visualization of the surface analysis has been greatly possible here. On other hand Digital Elevation Model (DEM) is a representation ofthe bare topographic surface of the Earth excluding trees, buildings, any other surface objects. Here USGS SRTM DEMs used to be derived from topographic maps.This tool is use for accurate modelling ofhydrodynamics as well as allows the generation of contour linesand terrain models.

6.4. Formulation of AHP model

AHP is a simple and famous multi-criteria decision-making process which is used to weight criteria. In this study, Nine criteria have been selected to calculate the potential ground water zone. Each criterion has segmented into parts where the lowest value indicates poor status and the highest value indicates the good oneand sometime inverse relations are there.

6.4.1. Formation of pairwise comparison matrix:

It represents the relative importance of various attributes with respect to the fulfllment of goal. The matrix has been created using scale of relative importance on the basis of Saaty‘s 1–9 scale (Saaty 1980). Here, 1 represents equally important,whereas 9 represents extremely important. Considering the groundwater prospect, poor to very good linear ranking has been assigned where 1 represents poor status, while 5 represents very good potential.

6.4.2. Normalized pairwise matrix:

It has been used to calculate the criteria weight. All the elementsof the column are divided by the sum of the column to create the normalized pairwise matrix.Thereafter by averaging all the elements of the row and dividing it with the number of criteria, weight has been obtained.

Table 3 :- Delineation of Ground water Potential Zone By Weightage AHP Method

Factors	Asssigned Weight	Geomorphology	LULC	Rainfall	Geology	Drainage Density	Slope	Soil	Lineament Density	TWI	Normalized Weight	Percentage Weight
Geomorphology	9	9	8	7	6	5	4	3	2	1	0.3534	35.34
LULC	8	9/2	8/2	7/2	6/2	5/2	4/2	3/2	2/2	1/2	0.1767	17.67
Rainfall	7	9/3	8/3	7/3	6/3	5/3	4/3	3/3	2/3	1/3	0.1178	11.78
Geology	6	9/4	8/4	7/4	6/4	5/4	4/4	3/4	2/4	1/4	0.0883	8.83

Drainage Density	5	9/5	8/5	7/5	6/5	5/5	4/5	3/5	2/5	1/5	0.0706	7.06
Slope	4	9/6	8/6	7/6	6/6	5/6	4/6	3/6	2/6	1/6	0.0589	5.89
Soil	3	9/7	8/7	7/7	6/7	5/7	4/7	3/7	2/7	1/7	0.0504	5.04
Lineament Density	2	9/8	8/8	7/8	6/8	5/8	4/8	3/8	2/8	1/8	0.0441	4.47
TWI	1	9/9	8/9	7/9	6/9	5/9	4/9	3/9	2/9	1/9	0.0392	3.92

6.4.3 Consistency index:

To check how far the calculated value represents the reality, consistency ratio has been calculated. Pairwise comparison matrix has been multiplied by the criteria value. Thereafter, sum of the row represents weighted sum value. Eigen value or the priority vector (λ.max) has been calculated by makingthe ratio between these two and averaging it with the number of criteria (Jha et al. 2010; Adiat et al. 2012).

$$CI = \frac{\lambda \max - n}{n-1} \quad \ldots.(5)$$

where C1 to Cn represent weighted sum value and n is the number of criteria. Thereafter, consistency index (CI) has been computed by the following formula: Finally, we calculate consistency ratio (CR) by the following formula:

$$CR = \text{CI} \quad \ldots.(6)$$

RCI is the consistency index of randomly generated pairwise matrix.

Rating assignment for classes in a thematic layer was based on their relative importance for groundwater potentiality. The Ratings of 1–5 were adopted where the rates of 1, 2, 3, 4 and 5 represent very poor, poor, moderate, good and very good, respectively, in-term of groundwater storage potential

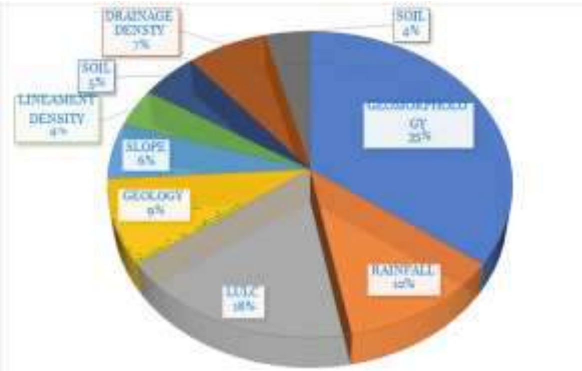

Fig 3: Normalized Weightage Percentage of Thematic layers for Groundwater potential map

7. Results

The geomorphology, lineaments, LULC, slope, drainage density, soil and geology maps were converted into the raster format. Analytic hierarchy process (AHP) was applied to weight, ranking, and finally reclassify these maps in the ArcGIS version 10.7 . The resultant products of each criteria are discussed below.

7.1 Geological framework

Geology plays a vital role in the groundwater occurrence and flow as it is influenced by the porous and permeable hydrogeological zones (Arya 2019). Geologically, the basement complex of the basin is composed by crystalline rocks of the Chotonagpur gneissic complex (CGC), comprising the granitic-gneisses, found predominantly in the northern part of the basin. Upper part of the river course flows through unclassy Bed gneissic complex. In middle reach & lower part, it runs through Gondwana formation and recent alluvium. Formations of granites and granitic gneiss occupy almost 55% of the basin area. Groundwater in these formations mainly occurs in weathered, fractured and jointed layers and in semi-confined conditions. These crystalline rocks are hard and compact with little porosity and permeability. They have water bearing and water yielding properties with the development of secondary porosity and permeability by weathering and fracturing. Although Lower Gondwana , Rajmahal Trap, Bihar Mica Plateau kinds of geological features are distributed through entire southern watersheds. The area is chiefly composed of Chhotanagpur granitic gneissic complex which have the least groundwater potential, and the southern Fluvial alluvial plain has the maximum groundwater potentials.

Fig 4: Geology Map of Ajay River Basin

7.2 Geomorphology

Geomorphology represents the landforms and topography of an area, and is the main factors used widely for the delineation of groundwater potential zones (Arulbaji, 2018). Geomorphological features provide significant indications of groundwater resources and also it gives indirect information about groundwater occurrence. The geomorphology of the study area has been classified into active flood plain, dam and reservoir ,low dissected denudation hills and valleys, low dissected structural hills and valleys, moderately dissected denudation hills and valleys, moderately dissected structural hills and valleys, quarry mine group, pediment - pediplain complexes and water bodies. Alluvial Tract and associated waterbodies has widely distributed throughout the entire ajay river basin. Flood plainsgenerally show good groundwater potentials because of the high infiltration rate of the weathered deposits. Thus, it possesses high groundwater potential; pediment-pediplain complex has moderate groundwater potential. Majority of The area in this watershed forms the moderately dissected plateau (MDP), flat-topped residual mountains seen in plains in form of dissected hills and valleys(Fig-5). This geomorphic units have moderate porosity and low to moderate groundwater potential. As Geomorphological units are the important aspects of the physical feature of the earth's surface, evaluation of the topography, hydrogeological investigations and identification of groundwater resources (Krishnamurthy and Srinivas,1995).

Fig 5: Geomorphology map of Ajay River Basin

7.3 Lineament Density

A lineament is a linear feature in a landscape which is an expression of underlying geological structures such as faults, fractures and joints. They provide the pathways for ground water movement and circulation, and have capacity to hold and store water. Lineaments are structurally controlled linear or curvilinear features, which are identified from the satellite imagery by their relatively linear alignments. These features express the surface topography of the underlying structural features. The lineaments shown in the map are natural, linear or curvilinear features. In the study area, four sets of lineaments were interpreted which trend in the NE–SW, NW–SE, N–S, and E–W directions upon five consecutive classes. Generally, the presence of lineaments affects the drainage pattern; hence, drainage line has been examined thoroughly to extract lineaments. Lineament density increases the hydraulic conductivity. The lineament map was generated from SRTM DEM data with 30m spatial resolution. Its density was processed in ArcGIS 10.7using grid cells method based on Eq.

$$LD = \sigma^{i=n} \, (\,) \, (KM^{-1})$$

where LD is the lineament density, Li is the sum of the length of all the lineaments (km), *i* represent each linear feature in the study area, and *A* is the effective area of lineament cell grids (km^2). Most of the lineaments area mainly concentrated in the northern part of the study area which predominated by hard rock terrain formed with granite, gneiss and amphibolite rock of Proterozoic periods. Southern part of study area is also known for many major intersection of lineaments (Fig. 6). Lineaments intersection can also take part in important role in groundwater accumulation, whereas areas with minimum occurrence of lineaments which have poor groundwater potential are specified with lowerweightage and a high lineament density area has good groundwater prospects.

7.4. Drainage Density

Drainage density is defined as the total length of all the streams in a drainage basin divided bythe total area ofthe drainage basin (Horton 1932; Harini et al. 2018). A high drainage densityrepresents less infiltration and hence, do not favour much the groundwater potential of the area. Low drainage density represents high infiltration and hence, contributes more to the groundwater potential. Drainage density is an inverse functionof permeability and therefore an essential parameter in assessing the groundwater potential zone. High drainage density values are favourable for runoff and hence indicate a low groundwater potential zone . The drainage density index of the watershed was calculated using Eq.

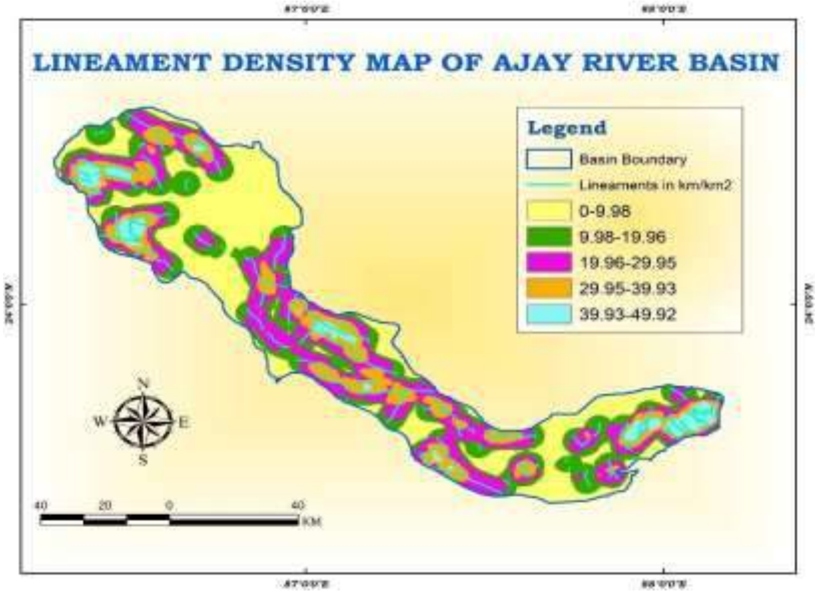

Fig 6: Lineament Density Map of Ajay River Basin

where DD means drainage density and A is the area. Numerous palaeochannels, oxbow lakes and elongated sediment fills has found in Eastern India, particularly along the lower Ajay River. In the study area, it varies from 0.018 to 19.50 km/km2 as shown in Fig.6 and classified into five classes such as 0.0189– 0.2313, 0.2313 – 0.9553,0.9553-2.5024,2.5024-8.1587,8.1587-19.5050 km/km2represent as very low, low, moderate, high, and very high. Drainage density is a best indicator to predict the infiltration rates and the relation between surface run off and permeability in any terrain. (Allafta,2020).. For final groundwater potential zonation, higher ranks were allocated to low drainage density zones, and lower ranks were assignedto high higher drainage density zones.

5. Rainfall

Rainfall is the only source for recharge of surface water into the subsurface through weatheredand fractured zones. Rainfall is an important parameter to delineate groundwater potential andmajor hydrological sources ofgroundwater storage. Rainfall data for 10 years (2011-2021) was collected from High-resolution gridded datasets Crudatasets then based on this data spatialdistribution map has been prepared using Inverse distance weighted

(IDW) tool in the Arc GIS (Fig. 8). The basin annual average rainfall, is divided into very high (1463-1508 mm), high (1428-1463 mm), moderate (1387-1428 mm) and low (1342-1387 mm) very low (below 1342mm). The weight, rankings of each factor and its sub-classes were assigned as per rainfallintensity and its recharge of groundwater. Rainfall occurrence is very high among southernpart of the basin , as rainfall high runoff rate is also high but due to low amount of slope ,capable to store more water which means there is Good groundwater storage. On the other hand Northern Chapter of the Ajay Interfluves is majorly scattered Rainfed areas knowing as lowest groundwater potentiality level.

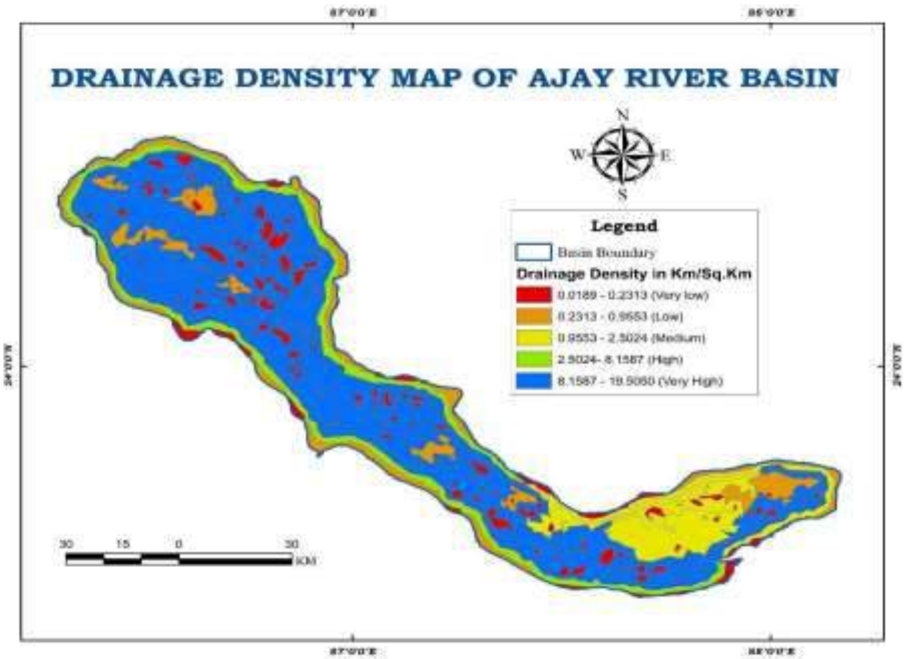

Fig 7: Drainage Density River Basin Map of Ajay

7.6. Landuse and Land Cover

Landuse and Land cover play a significant role in the development of groundwater resources.Different types of land use-land cover are a significant sign of the level of groundwater prerequisite and consumption. In thestudy area, various LULC features were identified from Landsat 8 data. The LULC classes are assessed by supervised method in

GIS platform by incorporating satellite images of Landsat 8 data.

Fig 8: Rainfall map of Ajay River basin

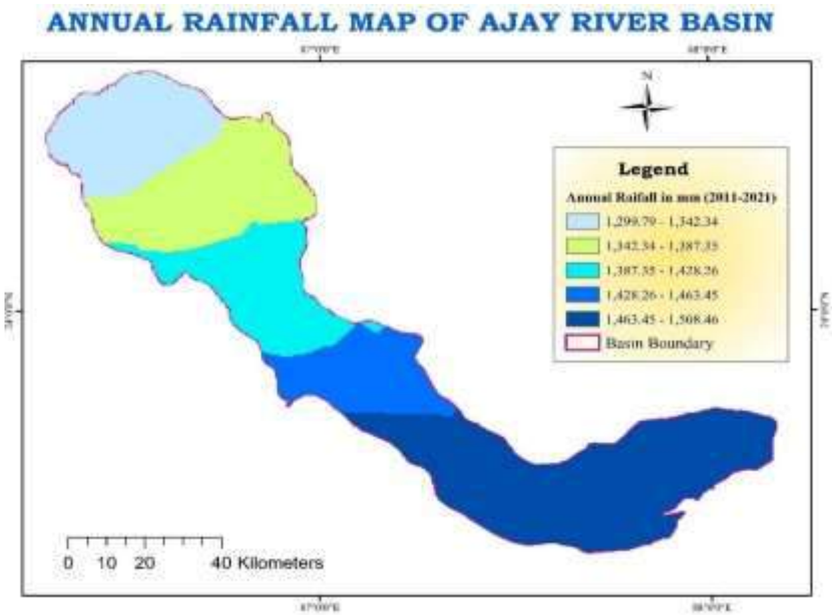

Table 5 :-landuse & landcover coverage of Ajay river basin

LULC	Class	Pixel_Sum	Percentage %	Area sq km
River	1	152103	2.012022157	136.8927
Waterbody	2	131304	1.736892483	118.1736
Ridge with Vegetation	3	1387429	18.35294432	1248.686
Vegetation	4	505140	6.68200412	454.626
Waste/ BareLand	5	1120699	14.82463344	1008.629
Settlement	6	1156430	15.29728397	1040.787
Agriculture	7	3106603	41.09421951	2795.943

The LULC map include agricultural land, ridge vegetation , water bodies, barren land, and built-up area. Primarily this undulating terrain has been covered with High dense ridge vegetation & some bare surfaces. A high weight was given to water bodies followed by forests, cultivated area, barren lands and settlements based on there water holding capacity.

Fig 10: Landuse and Landcover Map of Ajay River Basin

7.6.1. NDVI

Vegetation has a key role to play in the subsurface water recharge practice becauseit augmented the infiltration rate by clutching the precipitated water. Water bodies along with fallow lands and vegetative covers are more constructive than agricultural lands and built-up area forgroundwater recharge. Weightage has been assigned in order to water

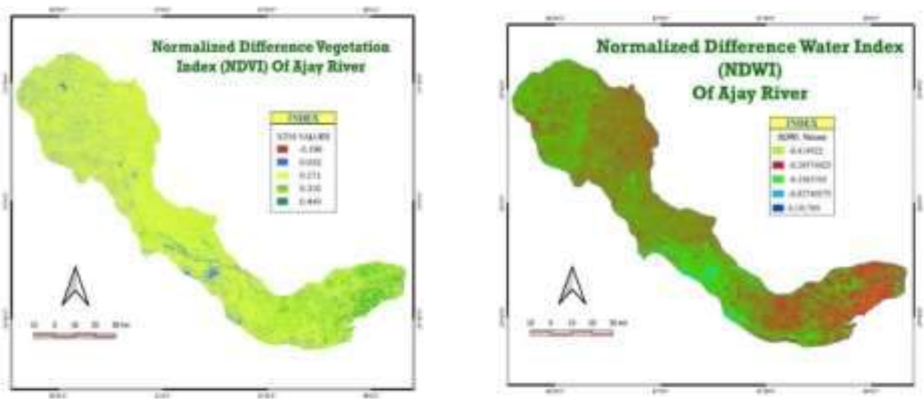

Fig 11: NDVI & NDWI Map of Ajay River Basin

bodies, agricultural land, vegetation and built-up area as per their ability to enhance the recharge procedure.

7.6.2. NDWI - To identify overall surface water bodies, normalized difference water index (NDWI) has been prepared (Fig. 11) which explains the facts that major share of water bodies are covered mainly by Bakreshwar Panchet Dam and numerous streams and sub tributaries of river Ajay, whereasvegetation patches are ample around the dam region.

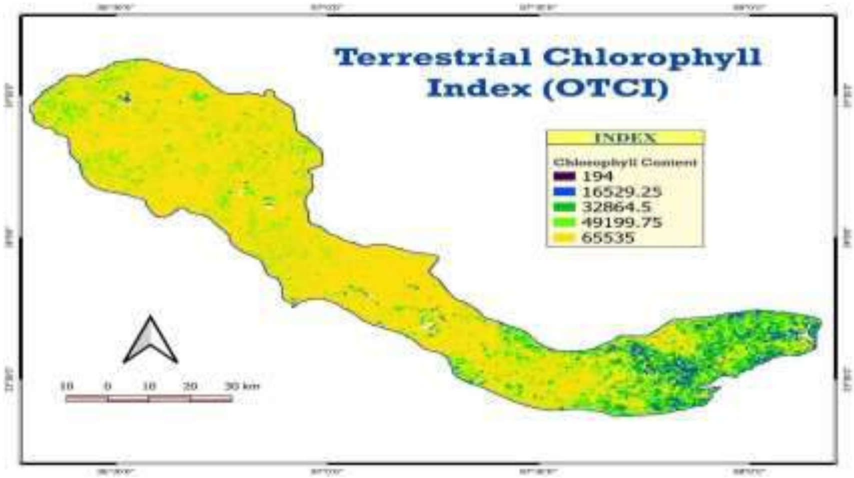

Fig 12: OTCI based on Chlorophyl Content of Ajay River Basin

7.7. Slope

The slope is the adjustment in elevation of topography and is expressed as a percentage or in degrees. The slope of an area plays a significant role in the isolating of precipitation and runoff. Whereas the slope is directly proportional to the amount of runoff, it is inversely proportional to the infiltration ofsurface water to groundwater storage (Satapathy and Syed 2015).So slope of higher percentage value has been given low priority and vice versa. Slope is defined as the angle, inclination, steepness, or gradient of a straight line on surface. The slope map of the basin was prepared from the SRTM DEM30 m data.

The slope of the study area varies from 0 to 62 degrees and its map is categorized into five classes asshownin Fig. 12. The low values i.e., 0 to 1.64 were assigned higher rank, whereas the class of highervalues is 20.24to 62.20 in terms of degrees which had been given lower rank because the runoff is high. Along the north and north western part of the study area shows the steep slope and a remainingmajor portion of the study area fallen under the nearly surface level.

Fig 13: Slope Map of Ajay River Basin

7.8. Soil Characteristics

Soils play an important role in the groundwater movement in the unsaturated zone. It depends on moisture content in the soils, infiltration rate, the grain size of the soils and specific composition of the soils (Cosby et al. 1984; Harini et al. 2018).The soil map has obtained from Food andAgriculture

Organization (FAO). Entire region is basically fascinated with diversified soil group characteristics .Five major soil types were identified in the study area, viz,- Chromic Cambisols (Bc) , Eutric Cambisols (Be) , Ferric Luvisols (Lf) ,Orthic Luvisols (Lo) , Eutric Nitrosols (Ne). Generally Luvisolic soils are forest soils that derived from sedimentary rocks having high rainfall. This soil texture‘s are high infiltration rate and favour for good groundwater potential zones, whereasCambisols, Nitrosols soils are low infiltration rate and less availability of the groundwater potentiality. Soft, friable, non plastic, crumb and platy, well-drained, yellow dirty brown-gray soil are available inupstream of Mangalkote and soil with good moisture content fertile soil are noticeable towards downstream of Mangalkote. A calcium-rich soil has developed within the layers of both alluvium deposits and laterite formation indicates the development of pedocal soil in the distant pastidentifiedin Nutanhut Surface.

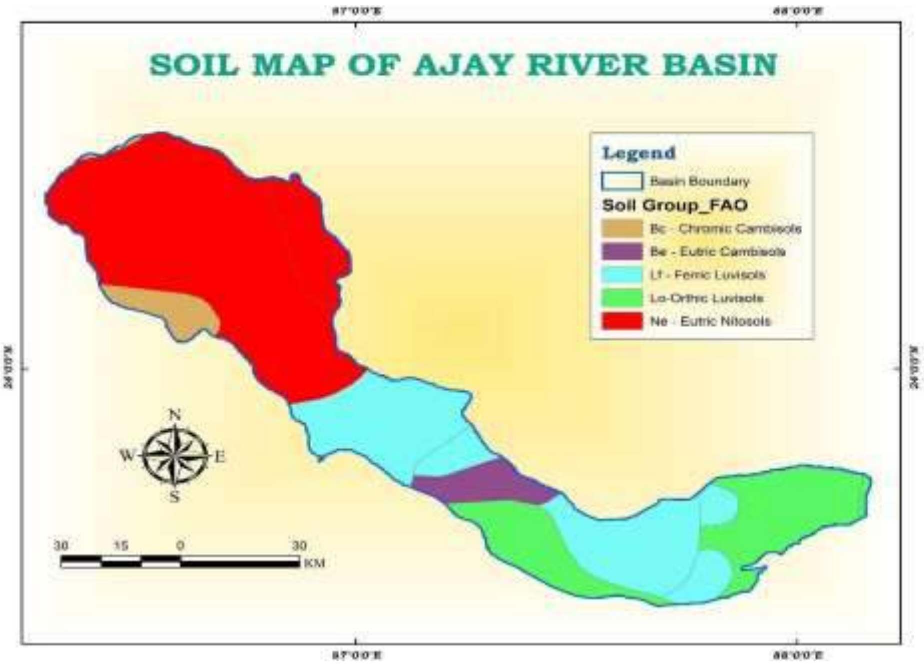

Fig 14: Soil map of Ajay River Basin

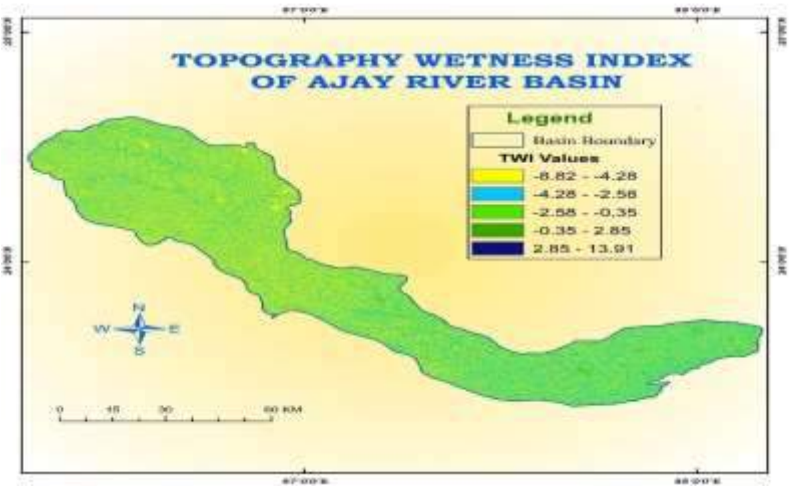

Fig 15: TWI MAP of Ajay River Basin

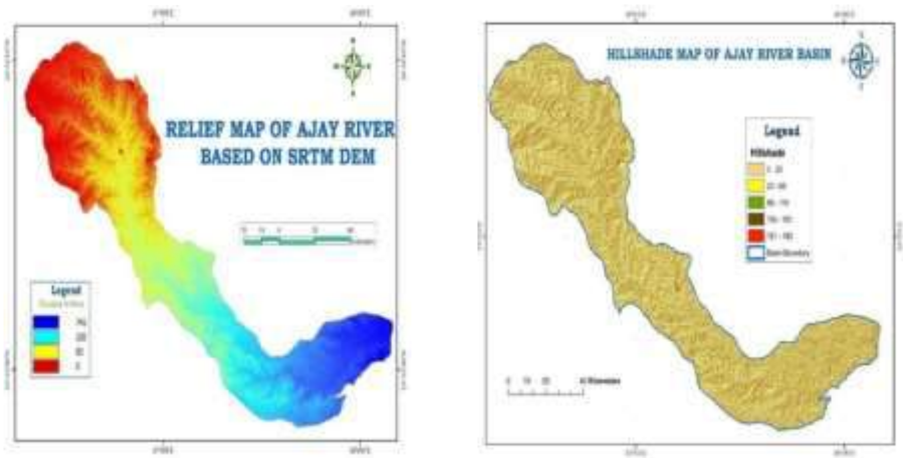

Fig 16: 3D Relief & Hillshade Visualization of Ajay River Basin

8. Depth to Groundwater Level Study

Two season-based (pre-monsoon and post-monsoon) groundwater level reflects the actual groundwater condition of the area, Results have been prepared from the volume of water table differences between the pre-monsoon and post-monsoon and in observable wells which have been collected from the database provided by the Central Ground Water Board (2015-16). The hydrological regime of the Ajay is influenced by the extreme fluctuations of the monsoonal rainfall (Niyogi 1988; Bandyopadhyay et al. 2016). Here a Case study of Bardhamman district has selected in which majorportions of Ajay river flows. In pre-monsoon season, eastern most part of the study area has more accessible water level, whereas southern alluvial plain has high level of water level. In post-monsoon season, the northern part composed with hard rock has more accessible water level than the southern alluvial plain (Fig. 17). High level of fluctuation has been assigned low potential weight and vice versa. Groundwater fluctuation is maximum in both the eastern and western corner of the study areawhich put more hindrance against good groundwater potentiality (Fig.18). Maximum fluctuations is seen at Orgram, Barakar block in 2015&2016 .Whereas minimum level of ground water fluctuations has been found in Andal,Kalla1,Ausgram 2,Barakar,Salapur blocks.

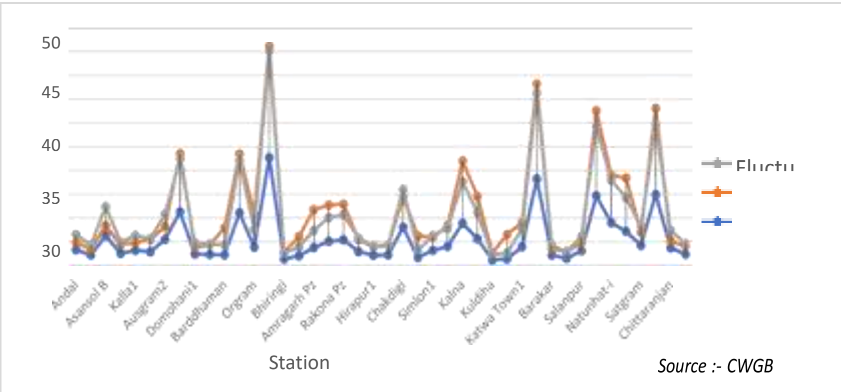

Fig 17: Station wise Depth to water Level for the Period of Post monsoon, 2015 and Post monnsoon, 2016 of Bardhhaman District

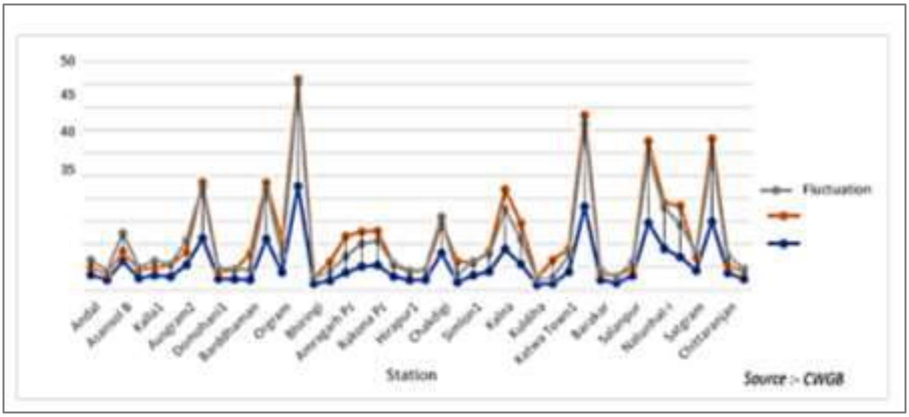

Fig 18 Station wise Depth to water Level for the Period of Pre monsoon, 2016, of Bardhhaman Distirct

9. Identification of Groundwater Potential Zone

Groundwater potential zones are essential to where the people suffered from water scarcity inthe regions of arid and semi-arid. The Ground water potential zonation map was generated by integrated all the 9 thematic layers through the weighted overlay analysis in the GIS Environment. The weights and ranking assigned for each theme is based on its influence on ground water occurrence. In the present study, nine themes were used for demarcation of ground water potential zones in Ajay River basin. The groundwater potential map (Fig. 19) demonstrates that the excellent groundwater potential zone is concentrated in the south- western region of the study areadue to the distribution of alluvial tract and flat land with highinfiltration ability. This indicates that, soil type and slope etc plays a vital role in groundwater augmentation. The ground water potential map of the study area finally generated using Arc GIS 10.7 was categorized into four zones such as very poor 2520 km (36 %), fair 2004 km (30%) , good 1564 km (23%), very excellent 802 km (11%).

10. Recommendation for Sustainable Groundwater Management

To manage the subsurface water resources primarily, we should reduce the dependency on these particular resources for our daily need. Augmentation of groundwater recharge is also very much pertinent way to enhance these resources. Recharge well is more or less uniformly distributed overthe region. More attention should be paid for the northern part of the study area as this region is mainly composed of hard rock of granite and gneiss with amphibolites, as well as endowed with laterite upland. There is also need the reuse and recycling of water. Besides the use of artificial recharge, there is also need to converge other efforts such as Rainwater Harvesting, Wastewater Treatment that indirectly benefit recharge of ground water . There might be a need for the administration to strengthen and reorient its role in aquifer management. More numbers of ponds, wells have been excavated nowadays to store the rainwater for different uses which can also haveatendency to percolate as well as recharge the groundwater store. Here groundwater can be artificially recharged by redirecting water across the land surface through canals, local infiltration basins and ponds; adding irrigation furrows or simply injecting water directly into the subsurface through injection wells will better replenish the entire Groundwater level of Ajay River basin. To achieve sustainable water resource management public concern (properly dispose of all waste, minimize the use of chemicals, protecting greens and avoiding felling trees) and land use plans and regulations may also protect important water supply aquifers and well fields

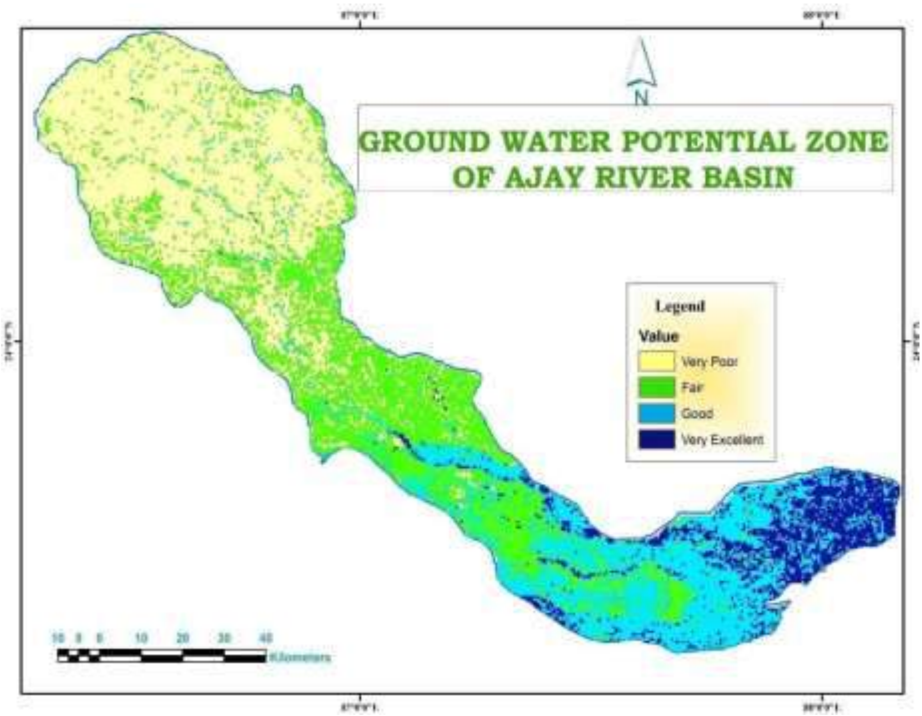

Fig 19 Groundwater Potential Zone Map of Ajay River Basin

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LAND USE AND LAND COVER CHANGES IN THE LOWER KANKAI RIVER BASIN: A GEOSPATIAL APPROACH

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Introduction

Bank erosion and lateral migration is a common geomorphic characteristic of an alluvial river. Rivers originating from Eastern Himalayas are characterized by huge sediment load due to intensive rainfall and weathering activities. Each year during monsoon season huge amount of sediment is carried by the rivers downstream which causes rise in river bed and prone to flash floods. Due to deposition of sediments, rivers avoid their existing path and shift accordingly by lateral erosion and grasp the surrounding settlements and agricultural land. The quantification of land loss due to erosional process of the river is important mostly from the perspective of the people living in the flood plain (Guite & Bora, 2016).

The lower course of Kankai Mai River flowing through the South-eastern portion of Kishanganj district and NE part of Purnea district of Bihar is very prone to flood and massive bank erosion. The river follows a meandering pattern in its lower course before joining Mahananda and deposits excessive amount of sand and eroded materials in the channel bed. This deposition has led to spill the channel and as a result after every monsoon season the main flow of the river changes its position very frequently by repositioning the bank lines. Due to the river bank erosion, land use pattern changes monotonously (Arefin, Meshram and Seker, 2020) and sand deposition degrades the fertility of existing agricultural lands. In this paper an attempt has been made to study the continuous shifting of the perennial flow of the river and resultant agricultural land loss leading to LULC change along the river banks. Multi-spectral satellite images were used to assess the pattern of channel shifting and severity of agricultural land loss for 231 villages along the banks of Kankai river in the time period of 19 years. Remote Sensing and GIS technology have been used to identify and measure the temporal and spatial pattern of agricultural land loss along with land use land cover change detection. The satellite images of Landsat 7 ETM+ and Landsat 8 OLI for the year of 2001, 2013 and 2020 were collected during the winter season (November and December) when stream line recedes and maximum extend of bank erosion is clearly visible.

Objectives

- To assess the dynamic nature of river Kankai Mai in Bihar.
- To identify the areas where agricultural land degradation is severe.

Study Area

The Kankai-Mai River is one of the important rivers flowing through Nepal and Indian state of Bihar which joins Mahananda near Dalkhola. For the current study the lower course of Kankai-Mai River has been selected which is flowing through the Kishanganj and Purnea district of Bihar. Total Length of the river lyingin the study area is about 60.29 km from Dharhar village in the North to Bhasia village in the south where Kankai meets Mahananda River. Total 231 villages along the banks of Kankai River were selected in the study area as these are more prone to bank erosion and occurrence of channel shifting

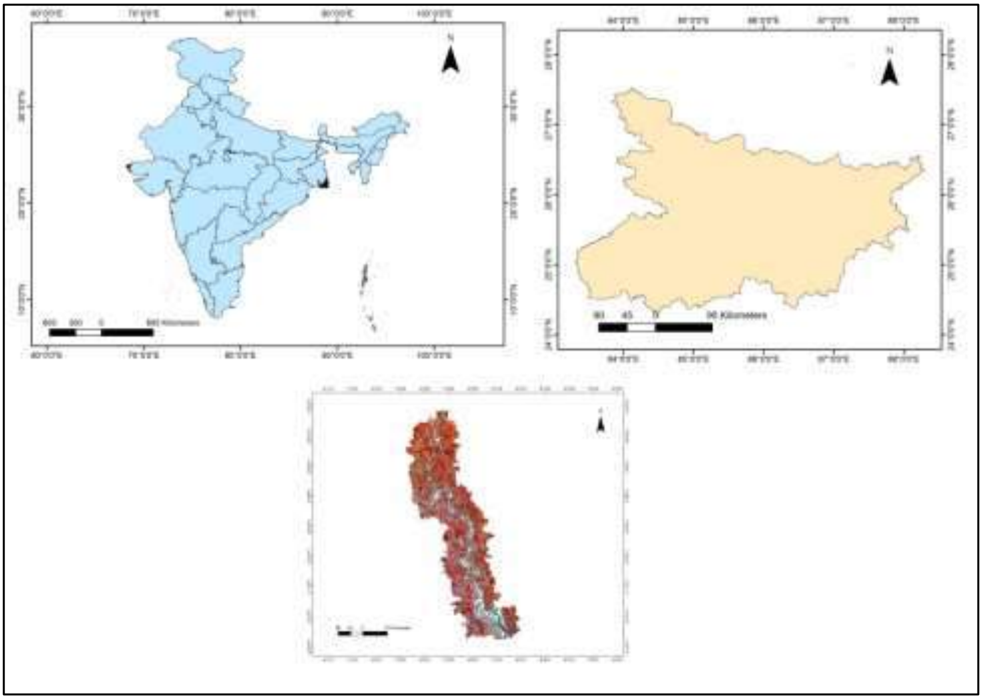


Fig 1: Study Area

Major Findings

Land use Land Cover change

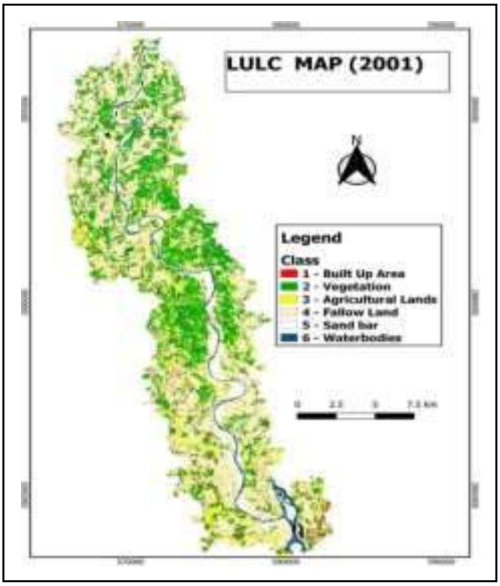
Land use Land cover change detection of the study area has been done for the year 2001, 2013 and 2020. Results show that Agricultural land has decreased from 32 sq. km in 2001 to 23.51 sq. km in 2013 and 17.48 sq. km in 2020. Fallow Land has increased from 141.80 sq. km in 2001 to 151.68 sq. km in 2020 but slightly decreased in 2013. Sand bar occupied 12.17 and 13.97 sq. km area in 2001and 2020 respectively but covered only 4.01 sq. km area in 2013. Water bodies showing the almost same pattern covered 10.85 and 13.65 sq. km area in 2001 and 2020 whereas covered 9.92 sq. km area in 2013. These patterns indicate that in 2001 and 2020 Kankai River was more volatile compared to 2001. As a result sand deposition in a wide area took place, vegetation washed away and fallow land covered most of the flood plain. On the other hand in 2013 vegetation and agricultural areas can be seen clearly in November asinfluence of river water was less. LULC classification map of the corresponding years are shown below.

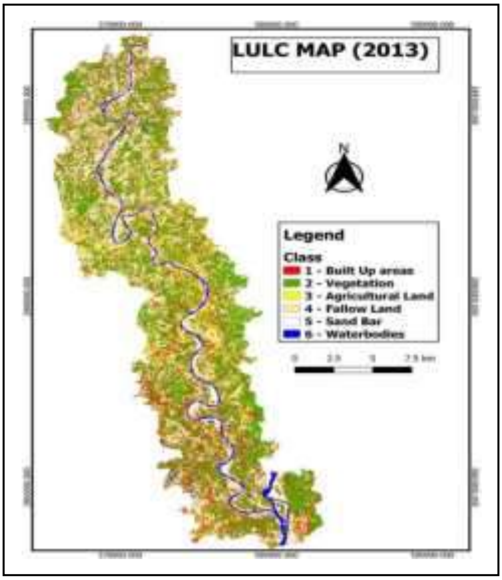
Table 6: Classification table of the LULC maps

	2001		2013		2020	
Elements	**Area(sq.km)**	**%**	**Area(sq. km)**	**%**	**Area(sq. km)**	**%**
Built-up Area	10.33	3.65	43.11	15.23	26.38	9.32
Vegetation	75.89	26.81	103.66	36.63	59.86	21.15
Agricultural land	32	11.35	23.51	8.30	17.48	6.17
Fallow Land	141.80	50.09	98.82	34.92	151.68	53.58
Sand Bar	12.17	4.29	4.01	1.41	13.97	4.94
Water bodies	10.85	3.83	9.92	3.50	13.65	4.28

Accuracy Assessment:

Table shows accuracy assessment of the classified maps. Error Matrix method has been applied to assess the accuracy of the classified maps. Standard Error, Producer Accuracy, Users Accuracy, Kappa Hat Classification and Overall accuracy have been mentioned. Overall accuracy is 92.8077 for 2001 classified map, 86.76 for the 2013 Map and 100 for the 2020 LULC Map. On the other hand, Kappa hat values are 0.87, 0.81 and 1 for the respective areas thus we can say this is a good image classification


LULC MAP (2001)
N
Legend
Class
1 - Built Up Area
2 - Vegetation
3 - Agricultural Lands
4 - Fallow Land
5 - Sand bar
6 - Waterbodies


LULC MAP (2013)
N
Legend
Class
1 - Built Up areas
2 - Vegetation
3 - Agricultural Land
4 - Fallow Land
5 - Sand Bar
6 - Waterbodies

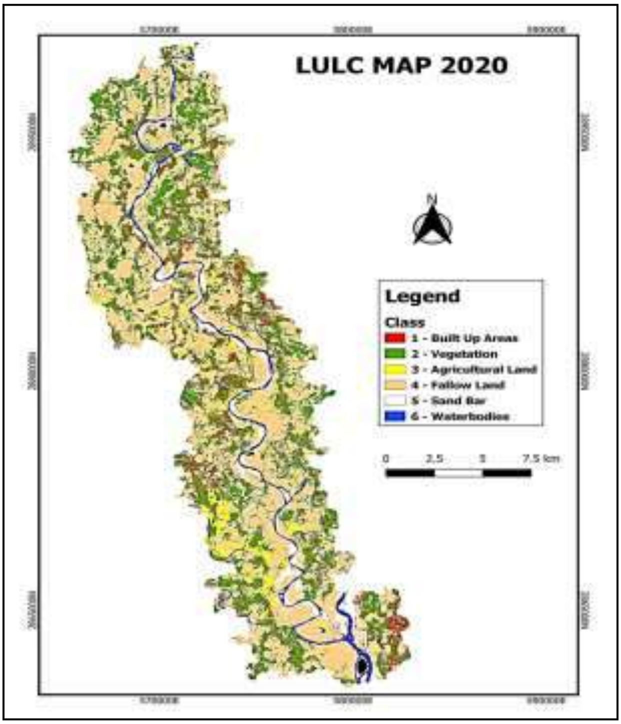


Fig 2 : LULC Map of 2001, 2013 and 2020

Table 7: Accuracy assessment table of 2001, 2013 and 2020

Elements (2001)	**SE**	**PA**	**UA**	**KAPPA HAT**
Built-up Area	0.0036	81.69	62.85	0.61
Vegetation	0.0076	89.23	92.78	0.90
Agricultural land	0.0065	100	70.31	0.67
Fallow Land	0.0051	96.59	96.92	0.93
Sand Bar	0	100	100	1
Water bodies	0.0051	56.37	100	1

Overall accuracy: 91.8077

Kappa hat Classification: 0.87

Elements (2013)	**SE**	**PA**	**UA**	**KAPPA HAT**
Built-up Area	0.010	77.64	58.49	0.53
Vegetation	0.010	100	89.19	0.83
Agricultural land	0.11	60	100	1
Fallow Land	0.009	94.88	91.52	0.87
Sand Bar	0.002	78.23	100	1
Water bodies	0.009	57.30	100	1

Overall accuracy: 86.76

Kappa Hat Classification: 0.81

Elements (2020)	**SE**	**PA**	**UA**	**KAPPA HAT**
Built-up Area	0.001	100	100	1
Vegetation	0	100	100	1
Agricultural land	0	100	100	1
Fallow Land	0	100	100	1
Sand Bar	0	100	98.00	1
Water bodies	0	100	100	1

Overall accuracy: 100

Kappa Hat Classification: 1

Conclusion

River Bank erosion and its impact on agricultural land loss along the banks of Kankai River showed the dynamic nature of river Kankai in spatial and temporal extent. Multi-spectral satellite images provide a vivid overview of the changes which occurred in the floodplain over 19 years. Remote Sensing and GIS technology has been very helpful to analyze the temporal pattern of channel shifting and associated LULUC changes in the Kankai river flood plain. The past and present condition of the lower course of Kankai River shows that, the channel has migrated from its former path in meandering position leaving behind serpentine lakes and old riverbeds. The frequent changes in river channel leads to severe bank erosion and degraded agricultural and fallow lands.

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SOIL LOSS ESTIMATION OF BHAGIRATHI HOOGHLYRIVER USING RUSLE MODEL

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Abstract

Globally, soil loss is a significant problem contributing to nutrient loss, water quality degradation, and sand accumulation in water bodies. Agricultural intensification, soil degradation, and some other human impacts all contribute to soil erosion, which is a significant issue. Management and conservation efforts in a river system can benefit from asoil loss estimation study. Modelling can establish a scientific and accurate method to reduce soil loss. In this study, GIS and remote sensing techniques have been integrated with the Revised Universal Soil Loss Equation (RUSLE) model to estimate soil loss in the entire stretch of Bhagirathi Hooghly river, West Bengal, India. To determine soil erosion-prone areas, rainfall, soil texture, land use and land cover maps, as well as a digital elevation model (DEM) were used as input. The five factors are being considered as input parameters of RUSLE model such as Rainfall erosivity (R), Soil erodibility (K), Slope length and slope steepness (LS), Cover management (C) and Support practices (P). Accordingly, the study area was categorized into five soil loss severity classes: very low (<10%), low (10-20%), moderate (20-30%), high (30-40%) and severe (>40%) risk classes. After analysing all the factors, it has been discovered that the lower part of Bhagirathi Hooghly river happens to be mostly affected by soil loss. The results of study area can be helpful to conservation of soil management practices and watershed development program in the basin area.

Keywords: *GIS; remote sensing; RUSLE; soil loss; Bhagirathi Hooghly.*

Introduction

Soil erosion is one of the most severe problem in the country, with changing economic implications and food security. The bio-physical environment, including climatic conditions, soil particles, ground cover, and their interaction, is affected by soil erosion. The slope length and the shape of the terrain significantly impact the runoff process. The areas with heavyrainfall and high elevation are susceptible to soil erosion.

Estimating soil loss and implementing optimal management practices is essential to the effectiveness of soil conservation planning. Assessing soil erosion risk using traditional approaches is costly and time-consuming. Soil erosion is an obstacle in the path of sustainable development and needs attention for better management through proper planning. Agriculture output is impacted bythe world-wide issue of soil deterioration brought about by erosion. Erosion has a detrimental impact on the ecosystem by reducing plant water availability, generating nutrient losses, and increasing runoff. As a result, interest in preserving and restoring soil resources has grown globally.

Remote sensing and GIS technology associated with the soil erosion model can guide decisions for preventing and controlling soil erosion in the region.There are several models applied for spatiotemporal predictions of soil loss severity mapping.Revised Universal Soil Loss Equation (RUSLE) are the most popular empirical models used globally for erosion prediction and control RUSLE developed by the U.S. Department of Agricultureis used as a decision support system in soil conservation and land use planning. RUSLE is the most widely used model because it can calculate soil loss on an annual basis and is compatiblewith ArcGIS environment and satellite data. The geospatial technologycan incorporate a large volume of information from multidisciplinary data sources for the development andintegrated water resource development plan. The study's main objective is to find out the soil loss of the basin area with the RUSLE model using GIS techniques. The soil loss equation's sub parts aim to include the topographic influence, rainfall erosivity, soil erodibility, cover management, etc. The proper management of the basin area can be done by minimizing the potential soil loss. This study is aimed to estimate the annual soil loss in the Bhagirathi Hooghly river in West Bengal, India.

After traversing a distance of about 3000 km and crossing the Indian states of Uttar Pradesh, Bihar, Jharkhand and West Bengal, the Ganges Rivers bifurcates into Padma and Bhagirathi rivers shortly after Farakka in Murshidabad District of West Bengal (Rudra, K.2018). Whilethe Padma River flows SE through Bangladesh, and after meeting Jamuna and Meghna rivers, empties itself into the Bay of Bengal, the other distributary, i.e., Bhagirathi River, flows within the Indian state of West Bengal. After meandering for about 150 km, it is joinedby a tributary Jalangi, near Nabadwip. After the confluence of the Bhagirathi and Jalangi, the Bhagirathi River is known as the Hooghly River, which empties itself into the Bay of Bengal after passing through Kolkata and Diamond Harbour (Mukhopadhyay, S.K.206). The complete stretch of Bhagirathi and Hooghly together is known as Bhagirathi-Hooghly River. The lower reach of the Bhagirathi was named as

Hooghly after the busy port town of Hugli during the Portugese rule. The vast stretch of Bhagirathi Hooghly river meanders over the districts of Murshidabad, Nadia, Purba Bardhaman, Hooghly, Howrah, North 24 Parganas Kolkata, South 24 Parganas, East Midnapore. Such a long stretch of river goes through many changes in its flow pattern and velocity. Huge tonnes of materials are being washed away due to shifting of the channel causing soil loss in many areas. Our focus is to identify the major areas of soilloss in this river belt.

Background

The Bhagirathi Hooghly River called as the Kati-Ganga in the Puranas, is a river that rises close to Giria, which is north of Baharampur and Palashi, in Murshidabad and is the western distributary of the Ganges.The main course of the Ganges then flows into Bangladesh as the Padma. The Hooghly River or the Bhagirathi-Hooghly, called 'Ganga' traditionally, is an approximately 260 kilometres long distributary of the Ganges River in West Bengal, India. A man-made canal at Farakka connects the Ganges to the Bhagirathi to bring the abundant waters of the Himalayan river to the comparatively narrow river that rises in West Bengal. The river flows through the Rarh region, the lower deltaic districts of West Bengal, and eventually into the Bay of Bengal. The upper riparian zone of the river is called Bhagirathi while the lower riparian zone is called Hooghly. Major cities that stand on the banks of the Hooghly river are Behrampore, Kalyani, Tribeni, Saptagram, Bandel, Chandannagar, Serampore, Barrackpore.

The vast majority of the water that flows into the Hooghly River is provided by the man-made Farakka Feeder Canal, rather than the natural source of the river at Giria. The Farakka Barrage is a dam that diverts water from the Ganges into the Farakka Feeder Canal near the town of Tildanga in Murshidabad district, located 40 km upstream from Giria. This supplies the Hooghly with water as per the agreement between India and Bangladesh. The feeder canal runs parallel to the Ganges, past Dhulian, until just above Jahangirpur where the canal ends and joins the Bhagirathi river. The Bhagirathi river then flows southwards past Jiaganj Azimganj, Murshidabad, and Baharampur. South of Baharampur and north of Palashi it used to form the border between Bardhaman District and Nadia District, but while the border has remained the same the river is now often east or west of its former bed. The river then flows south past Katwa, Nabadwip, Kalna and Jirat. At Kalna it originally formed the border between Nadia District and Hooghly District, and then further southbetween Hooghly district and North 24 Parganas district. It flows past Halisahar, Chinsurah, Naihati, Bhatpara, Konnagar, Serampor and Kamarhati. Then, just before entering the twin cities of Kolkata (Calcutta) and Howrah, it turns to the southwest. Two of its well known tributaries are Damodar and

Rupnarayan. At Nurpur itenters an old channel of the Ganges, and turns south to empty into the Bay of Bengal through an estuary about 32 kilometres wide.

Being the distributary of the main river, Ganga, Bhagirathi Hooghly river has been the most important navigable river since ancient times. It has been the most important river for transportation during Colonial rule. Presently the river feeds from Feeder canal, someof its important tributaries and also from the tidal waters. Our study is to focus on the annual soil loss that it faces along its entire stretch in West Bengal.

Objectives

There are some objectives of our study based on which we have accomplished ourresearch. These are:

- To calculate the amount of soil erosion more accurately using ArcGIS and RevisedUniversal Soil Loss Equation (RUSLE);
- To analyse the different input parameters of the RUSLE model;
- To identify the factor which is more dominant in terms of soil loss in the river belt.
- To identify the regions of soil loss along the Bhagirathi Hooghly river banks for theyears 2016-21

Study area

The study area for this research is the entire tract of the Bhagirathi-Hooghly River that flowsover the state of West Bengal, India. The latitudinal and longitudinal extent of the river is about $22^0$00'N to $25^0$00'N and $87^0$00'E to $89^0$00'E respectively. It is the western branch of the river Ganga and flows more than 500 km through West Bengal. The Jalangi and the Mathabhanga–Churni are two other offshoots of the Ganga, and those two join the Bhagirathiand Mayapur and Payradanga, respectively. The lower 280 km stretch of the Bhagirathi is tidal and known as the Hooghly River. The Bhagirathi remains delinked from the Ganga for about nine months of the year and receives water from 38-km-long feeder canal originating from the Farakka barrage. The river tends to oscillate laterally in its non-tidal r gime and has thrown several distributaries in the lower reach. The channels which had been important navigational route during the mediaeval and post-mediaeval period have gone dry. The total catchment area of the Bhagirathi-Hooghly River is approximately 141,600 square kilometers. The length of the Bhagirathi-Hooghly River in West Bengal is approximately 260 kilometers, starting from the point where it enters the state at Farakka Barrage and flowing through several districts such as

Murshidabad, Nadia, Purba Bardhaman, Hooghly, Howrah, North 24 Parganas, Kolkata, South 24 Parganas, East Midnapore. before finally emptyin into the Bay of Bengal through the Sundarba s delta.

The Bhagirathi-Hooghly River is a distributary of the Ganges River, located in India. The region through which the river flows has a diverse range of climate, soil, and topography.The Bhagirathi-Hooghly River flows through the Indian states of West Bengal and Bihar, and the climate in this region is typically tropical. The summer months from March to June are hot and humid, with temperatures ranging from 25 to 40 degrees Celsius. The monsoon arrives in June and lasts till September, bringing heavy rainfall to the region. The winter months from October to February are relatively cool with temperatures ranging from 10 to 25 degrees Celsius.The soil in the region through which the Bhagirathi-Hooghly River flows is predominantly alluvial, which means it is composed of sediment deposited by the river over a long period of time. The alluvial soil is rich in nutrients, making it highly fertile. This has led to the development of a thriving agricultural site in the region, with crops such as rice, wheat, and sugarcane being grown. The topography of the region through which the Bhagirathi- Hooghly River flows is mostly flat, with occasional hills and ridges. The river itself has a meandering course, and its banks are often lined with mangrove forests. The river also has several islands, including the famous Sunderbans, which is the largest mangrove forest in the world and is home to a variety of wildlife, including the Royal Bengal Tiger. The river deltais an important ecological zone that supports a diverse range of flora and fauna.

Materials and Method

- ***Data Sources***

For the present study, the data for estimating soil loss with the RUSLE model has been collected from different sources. The SRTM Digital Elevation (DEM) data has been collected from the USGS Earth Explorer to prepare the slope map and estimate the topographic influence of soil loss. The satellite image of Sentinel 2A which is of 10 metres resolution is collected from Scihub.Copernicus to prepare the land use and land covermap to show theland cover management. Soil texture map has been generated from National Bureau of Soil Science & Land Use Planning from which data on soil erodibility is derived. The gridded rainfall data is obtained from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) and spatially interpolated into grid points for the purpose of analyzing rainfall erosivity. The following techniques given below explains the basic concepts, how to calculate the parameters of the RUSLE model, and based on annual rainfall map, slope map, LULCmap and soil texture map, the RUSLE model's parameters have been estimated.

Table.1 shows the input data sources used for the RUSLE Model

Sl.No.	Data Type	Source	Description
1.	Digital elevation model	https://earthexplorer.usgs.gov/ (accessed on 15th May,2023)	SRTM DEM (Resolution 30metres)
2.	Satellite image	https://scihub.copernicus.eu/ (accessed on 16thMay,2023)	Sentinel 2A image (Resolution10 metres)
3.	Soil data	National Bureau of Soil Science &Land Use Planning	Soil texture map
4.	Rainfall data	Climate Hazards Group InfraRed Precipitationwith Station data (CHIRPS) (https:// data.chc. ucsb. edu/ products/ CHIRPS- 2.0)	Annual Rainfal lData (2016-21)

Methodology

The RUSLE is a scientific model developed by W.Wischmeier, D. D. Smith (1978). The RUSLE model is used for calculating the enduring average annual soil erosion on a surface slope emerged on runoff model, soil category, crop process, and topography (slope) and supervision practices. The average annual soil erosion per unit region and the year were quantified as per the following formula (Eq. 1) of RUSLE. The RUSLE is an empirical equation that enumerates the average annual soil erosion in tons/ha/year. The RUSLE model estimates soil damage for ground slopes in Geographic Information System (GIS) platform. A combined equation of geophysical and land cover factors to evaluate the yearly soil loss from a unit of property. It assesses erosion risk in the research area, which has its qualities and application scopes. Its global compatibility with GIS. model to predict soilloss because of its convenience.

The remote sensing and GIS technology enabled a more accurate estimation of the factors used for calculation. Each of the elements derived separately in raster data fo rmat and the erosion calculated using the map algebra functions.The framework for the RUSLE model calculation and expressed by an equation:

$A = [R] * [K] * [LS] * [C] * [P]$ (1)

where,

A=estimated average annual soil erosion (ton/ha^{-1}/year^{-1}), R= rainfall-runoff erosivity factor((MJ mm ha^{-1} h^{-1} year^{-1}), K= soil erodibility factor (t MJ^{-1} ha^{-1} mm^{-1}), L=slope length factor,S=slope steepness factor (dimensionless), C= cover management factor and P = supporting practices.

RUSLE Parameters Computation

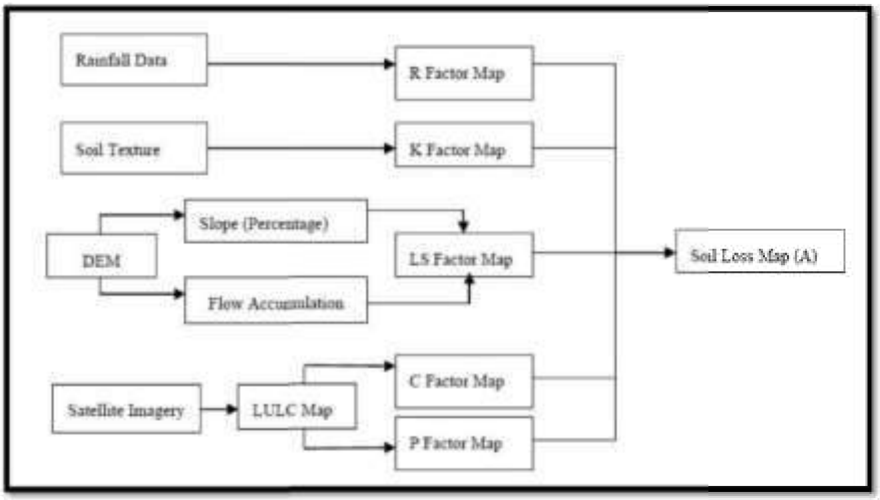

Fig.2: Flowchart showing the methodology adopted for the present study

Rainfall Erosivity Factor (R)

The rainfall erosivity factor (R) defines rainfall intensity and occurs through different rainfall conditions leading to erosion. Rainfall significantly influenced soil erosion as many studies have established the direct relationship between rainfall and soil erosion. The R factor quantifies the impact of runoff rate and the number of raindrops associated with the rainfall. The available gridded rainfall data from CHIRPS is used to create the rainfall map. For the Bhagirathi Hooghly river, the rainfall map is produced using the inverse distance weighted (IDW) interpolation technique. The R factor is calculated using the equation shown below, as shown.

$$Ra= 81.5 + 0.380\ Pa \qquad (2)$$

Ra is Average erosion index, P is Average rainfall (mm), and Subscript a stands for annual.

For the determination of R factor, rainfall data is collected for 6 years from 2016-21. After data collection, R factor was determined for all selected rainfall gauge stations using the equations. Then, the average R factor for each rainfall gauge station was inserted into Arc GIS. All the data points were interpolated spatially using Inverse Distance Weighted (IDW) found in the Arc GIS Spatial Analyst tool to IDW. In our study area, R is determined using annual rainfall data for each year from 2016-21.

Soil Erodibility factor (K)

In RUSLE, K is assumed to be constant throughout the year. K Factor depends upon organic matter, Soil texture and soil structure. Soil erodibility factor represents both susceptibility of soil to erosion and rate of runoff, as measured under the standard unit plot condition. The value of this factor is affected by infiltration capacity andstructural stability of the soil. So the K values run from 1.0 to 0.01 with highest values for soils with high content of silt or very fine sand.

The amount of soil erosion at the surface is indicated by the soil erodibility factor (K).Soil texture is the most crucial parameter to measure the K factor. Other factors are essential in determining the K factor in addition to soil permeability, organic matter, and soil structure.The value of K indicates the soil erosion rate per rainfall erosivity index (R). The NBSS and LUP was used to create the soil map for this study, and the K factor I calculated using the equation below:

$$K = 2.1 \times 10^{-4}(12 - OM)M^{1.14} + 3.25(s^{-2}) + 2.5(p - 3)/759.4 \qquad (3)$$

K is soil erodibility (tons/Y/MJ/mm), OM is Percentage organic matter, s is soil structurecode, p is Soil permeability code, M is a function of the primary particle size fraction givenby the following formula,

$$M = (\%\ Silt + \%\ Very\ fine\ sand)\ \_\ (100\%\ clay) \qquad (4)$$

In general, sandy soil has a low k value for a high infiltration rate, and clay soil has a low k value showing resistance to the catchment area. Silt soil has the highest K value as it crusts highly and generates a high runoff rate and amounts.

Percent silt (MS; 0.002-0.05 mm)

Percent very fine sand (VFS; 0.05-0.1 mm)

Percent sand (SA; 0.1-2 mm)

Percent organic matter (OM)

Soil structure code (s)

Soil permeability code (p)

Table.2 shows Attributes of Soil map used in RUSLE

Sl.No.	Class name	% Sand	% Silt	% Clay	M	Soil Structure code (s)	Permeability Code (p)	Soil Org Matter %
1.	Sand	90	6	4	9216	4	1	0.5
2.	Silty Loam	20	65	15	7225	2	3	1
3.	Silt	8	87	5	9025	2	3	1.4
4.	Loam	41	41	18	6724	2	3	1.5
5.	Sandy Clay Loam	60	13	27	5329	3	4	2
6.	Clay Loam	33	33	34	4356	2	4	0.8

Soil structure code(s): 1 - very fine granular 2 - fine granular 3 - medium or coarse granular 4 - blocky, platy, prism like Soil permeability code (p): - rapid (>150mm/hr) - moderate to rapid (50-150 mm/hr) 3 - moderate (15-50 mm/hr) 4 - slow to moderate (5-15 mm/hr) 5 - slow (1-5 mm/hr) 6 - very slow (< 1mm/hr)

Topographic factor (LS)

Topographic Factor is the combination of Length factor & Steepness factor. The influence of terrain on erosion is represented by Length slope factor which reflects the fact that erosion increases with slope angle & slope length. RUSLE consider the automated method to generate slope length factor. DEM is used to calculate LS Factor. Slopes of DEM in percentage were also generated using surface analysis under the spatial analyst function. The equation used to compute LS factor by DEM expressed as (Moore, 1986): LS= ([flow accumulation]×cell size/22.13)0.6×|[Slope] ×0.01745/0.0896|1.3×1.4 (5)

The topographic factor (LS) is calculated from the slope and flow accumulation. Theslope length (L) factor has been derived using the given equation:

$L = (\lambda/22.13)\ m$ (6)

Where,

22.13 is equal to the RUSLE unit plot length, m is a variable slope length exponent and λ is Horizontal distance between the origin of the overland flow and the point at whichthe slope gradient becomes so steep that deposition begins or surface runoff becomes accumulated in a defined channel.

In the present study, LS-factors were derived by using Shuttle Radar Topography Mission (SRTM) DEM data of the region using the spatial analyst extension of Arc GIS 10.8.We have rendered the slope in percentage and flow accumulation map from the SRTM DEM using the surface analysis and hydrology tools in the spatial analyst toolbox of ArcGIS. The flow accumulation corrected map is produced by assigning the value one to all the grids whose flow accumulation value is zero and keeping all the other values the same.

Cover Management Factor (C)

The C-factor is the most crucial parameter for crop management but is not present for all Indian crops. Thus, C-factor was used to estimate the rate of soil erosion in agricultural fields. The ground covered by vegetation canopy reduces the rate of soil erosion in the forested area. The values of the C-factor depend on seasonal changes as it varies with different parameters, such as crop types, rainfall, agriculture practice, etc. The C-factor was calculated based on the study area's LULC classification. The riverbasin is classified into five dominant land cover classes: water body, flooded vegetation, bare ground, crop land and built up. The maximum likelihood algorithm has been applied for the supervised classification. The cover and management factor is dimensionless which is an important factor for reduction of soil erosion and it depends on land use pattern of an area. The C factor is the ratio of soil loss from anarea with protective cover and management to soil loss in the continuous clean tilled fallowland. The values of C factor vary from 0 to 1 based on land use land cover types excludingareas of water body (Karaburun, A. 2010).

Conservation Support Practice Factor (P)

The conservation support practice factor (P) is the most important parameter in RUSLE method and it is a dimensionless factor defined P factor as the ratio of soil loss in a particular support practice to the corresponding soil loss with up and downslope cultivation. P-value ranges from 0 to 1, where the value 0 indicates good erosion resistant facility made by man and the value 1 indicate an absence of erosion resistant facility (Pandey et al. 2007). The values for different LULC classes have been crudely assigned in the raster calculator, and theP factor map has been prepared. P values range from 0 to 1, with higher values denoting ineffective conservation practices andlower values denoting effective conservation practices.

Results and Discussions

The soil erosion hazard map was created by using all the five RUSLE layers, rainfall erosivity factor, soil erodibility factor, slope length and steepness factor, cover management factor, and support and conservation practices factor. Five input factors are being calculatedfor each year from 2016-21. Based on the values of these parameters, we have calculated the average annual soil loss of Bhagirathi Hooghlyriver from the years 2016-21.

Rainfall Erosivity Factor (R)

The relationship between precipitation and sediment yield is described by rainfall erosivity, which measures the force of raindrops on surfaces and the rate of related surface erosion. Rainfall erosivity states the probable capability of raindrops to cause detachment of a soil particle, a process that is robustly reliant on rainfall intensity. Therainfall map has been prepared from CHIRPS gridded rainfall data of 2016-21. During the years 2016-21, the R factor values range from 480.41 to 985.66 MJ mm ha^{-1} h^{-1}.

The upper and lower part of the Bhagirathi Hooghly river buffer zone has higher rainfall than the middle portion throughout the years. In the lower reaches of thebuffer zone, the erosive power is clearly visible. There is a positive relationship between rainfall distribution and erosivity factor, as rainfall decreases the erosive power of the same is decreased in the drainage system.

Soil Erodibility Factor (K)

The rate of soil loss per unit of the rainfall erosion index is known as the soil erodibility factor (K). It is calculated on a typical soil plot and is often determined based on natural soil characteristics. This is a quantitative indicator of how easily soil particles can separate and be carried by surface runoff. Although soil texture is a vital aspect affecting erodibility, geological formation, permeability, organic matter and soil structure also play a significantrole in assessing the K factor. Based on rainfall erosivity (R) index, K values reflect soil loss rate. An erodibility value closer to 0 indicates less erosion prone soils; a value closer to 1 indicates more erosion prone soils.

The Bhagirathi Hooghly river basin is comprised of seven different types of soil namely clay, sity clay, clay loam, silty clay loam, sandy clay loam, loam and silty loam.The K values range for the years 2016-21 from 0 to 0.05 t MJ^{-1} ha^{-1} mm^{-1} . The rate of soil erodibility is very highif the soil texture is fine. Presence of organic matter into the soil is a dominant controlling factor of soil erodibility.

Topographic Factor (LS)

Determining slope length and steepness are a vital part of soil erosion prediction models In RUSLE, these factors represent topography's effect on erosion. The topographic factor isrepresented by slope length and slope steepness on soil erosion. There is a high probability of soil erosion with a higher slope factor in the region. This topographic relation is well established with the erosional factor. The flow accumulation is also considered with the slope for the topographic factor. The topographic factor increases with an increase in the slope and flow accumulation.

The LS factor in our study area for the years 2016-21 ranges from 5246.53 to 1.70. As the region is a flat plain with few undulations, the slope length and steepness does not have such dominant influence on the soil loss.

Cover Management Factor (C)

In order to assess how effectively soil and vegetation management systems can prevent or reduce soil loss, the cover management factor (C) is always used. Higher vegetation is related to the low possibility of soil loss. The C factor has a range of 0 to 1, with higher values indicating greater soil erosion and lower values indicating greater soil particle compactness. Here, the C factor varies from 1.28 to 0.12 for the years 2016-21. Therefore, all the vegetated areas in the study area are depicted low C values. Barren, fallow, and open bare lands without vegetation cover have shown higher C-factor values. The Bhagirathi Hooghly buffer zone has the highest area under crop land and built up, indicating the highest probability of soil erosion. Although the areas having high vegetative cover indicate less soil loss.The lower part of the basin has higher values indicating greater soil erosion.

Support Practice Factor (P)

The conservation practice resembles the support practice factor, which reflects the effects of practices on the reduction of surface runoff and consequently water-inducederosion The ratio between soil loss brought on by conservation practices and soil loss brought on by straight row farming up and down the slope is represented by the P factor, which shows the impact of support practices on the mean annual soil loss rate. The P factor shows the impact of conservation practices on the mean annual soil loss rate. The P factor, then, stands for the ratio of soil loss brought on by conservation practices to soil loss brought on by straight-row farming.The Bhagirathi Hooghly river buffer zone has a highest P-value for the lower areacompared to the other basin region. The P values range from 0.55 to 1.0, with the highest value being given to areas with no conservation practices.

The results are being analysed and explained about the input parameters i.e., R, K,LS, C andP factors from the following maps that have been prepared for each year from 2016 to 2021 shown in (figures 3-8).

From these five input parameters that have been calculated, we have generated theoutput map that is the soil loss maps of Bhagirathi Hooghly river for the years 2016 to 2021 using RUSLE model (equation.1) stated above.

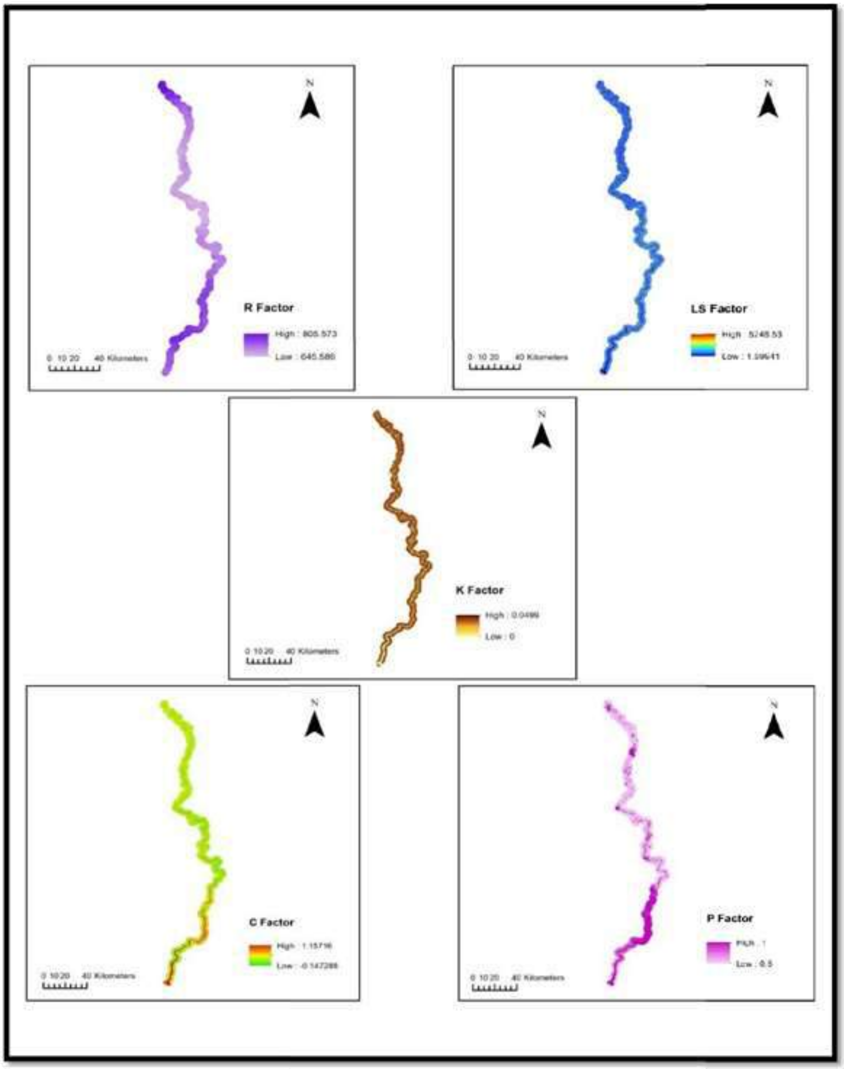

Fig.3: Five input parameters of RUSLE model for the year 2016

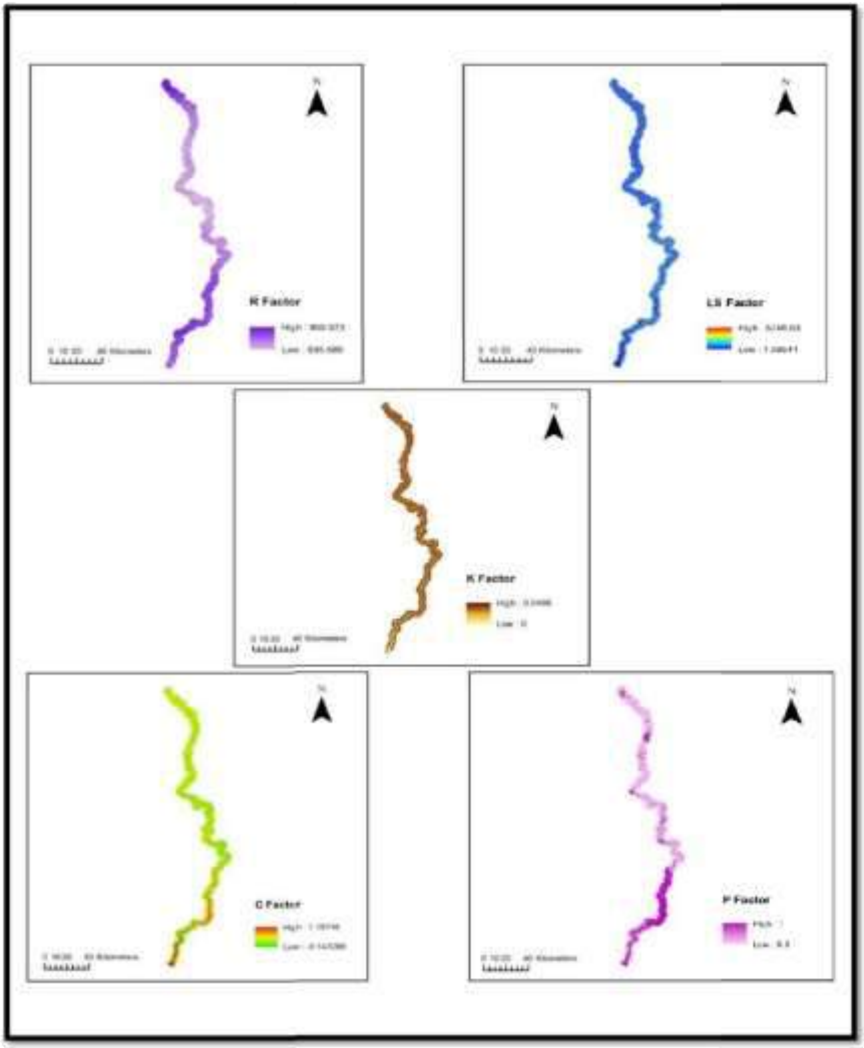

Fig.4: Five input parameters of RUSLE model for the year 2017

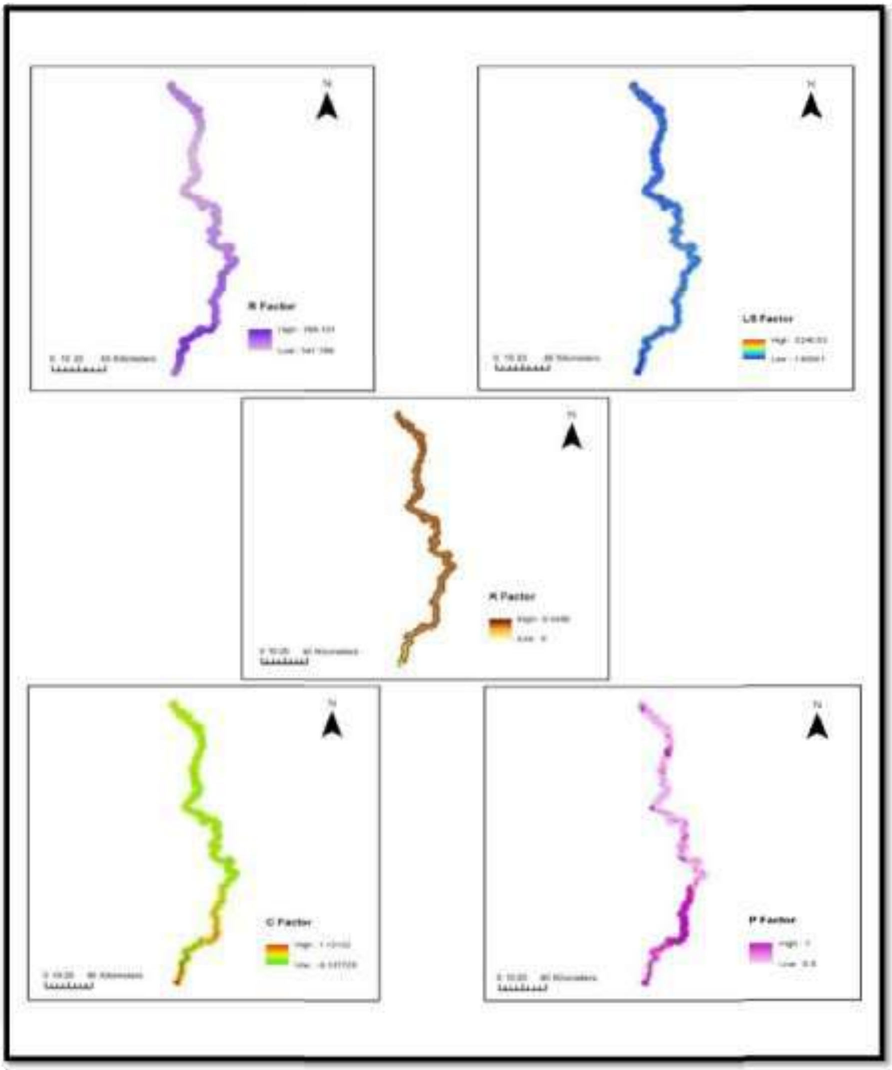

Fig.5: Five input parameters of RUSLE model for the year 2018

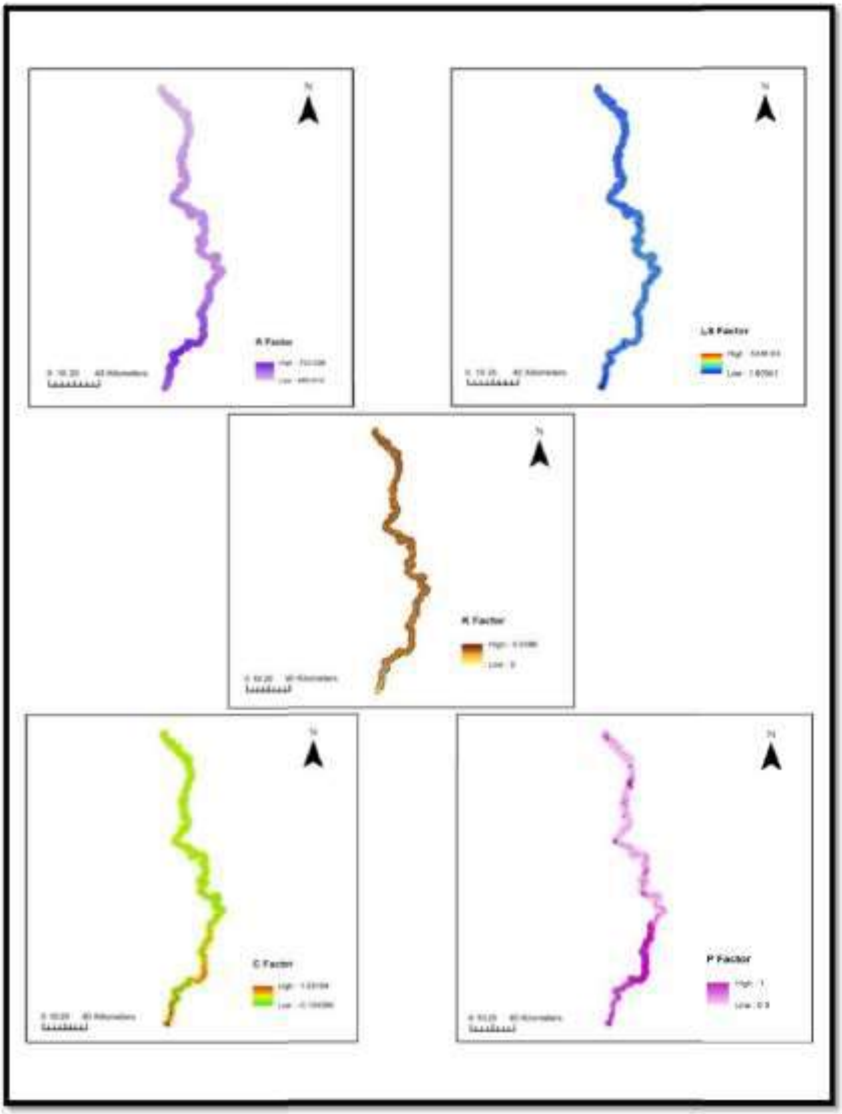

Fig.6: Five input parameters of RUSLE model for the year 2019

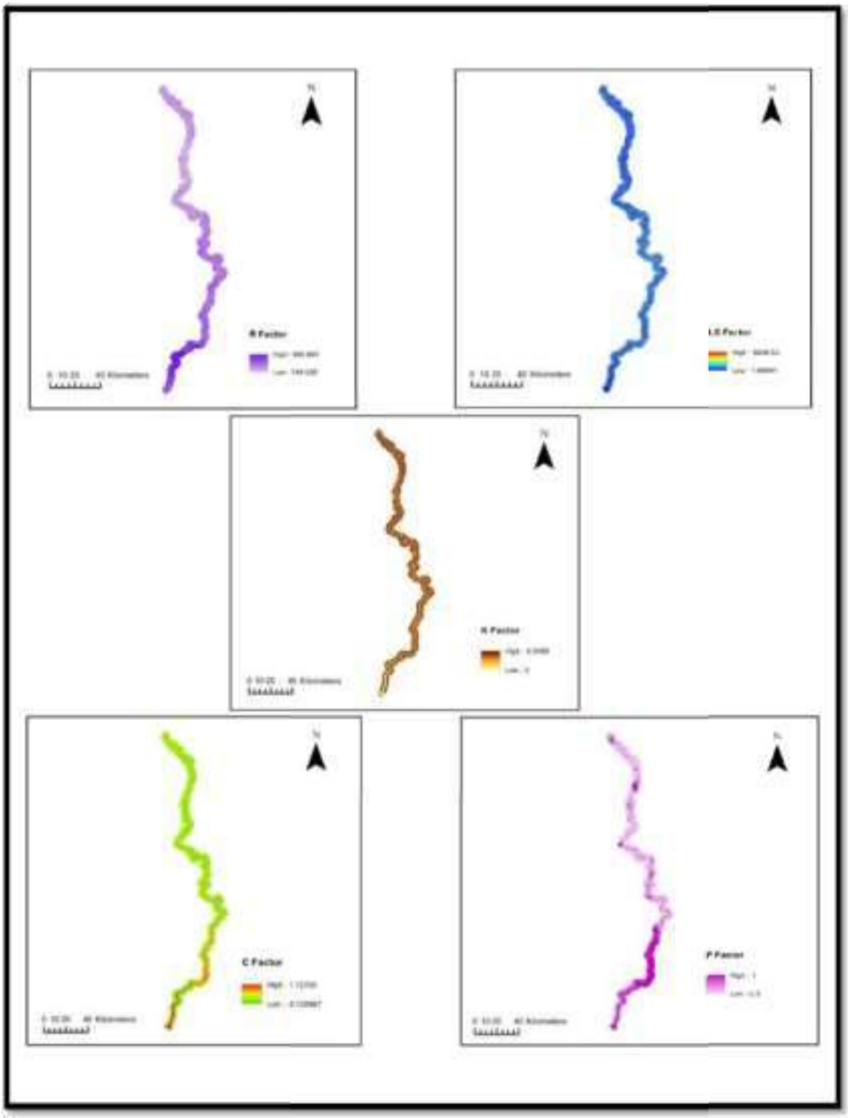

Fig.7: Five input parameters of RUSLE model for the year 2020

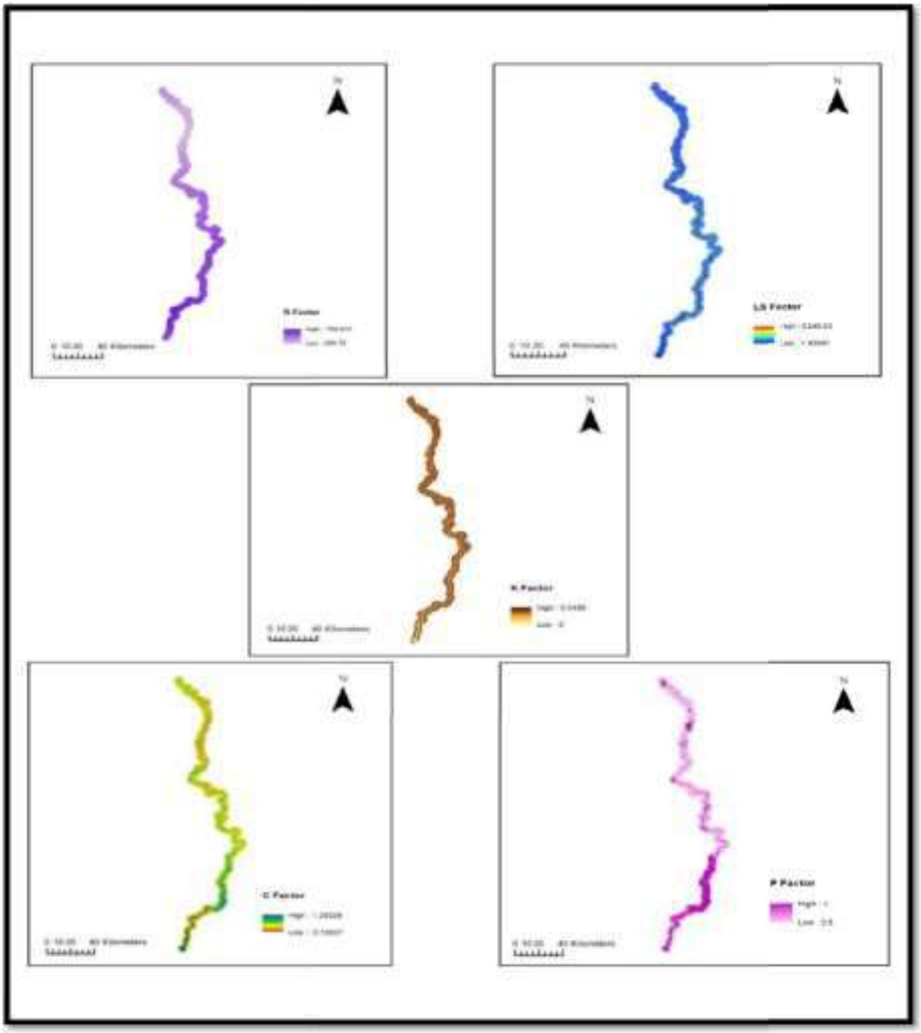

Fig.8: Five input parameters of RUSLE model for the year 2021

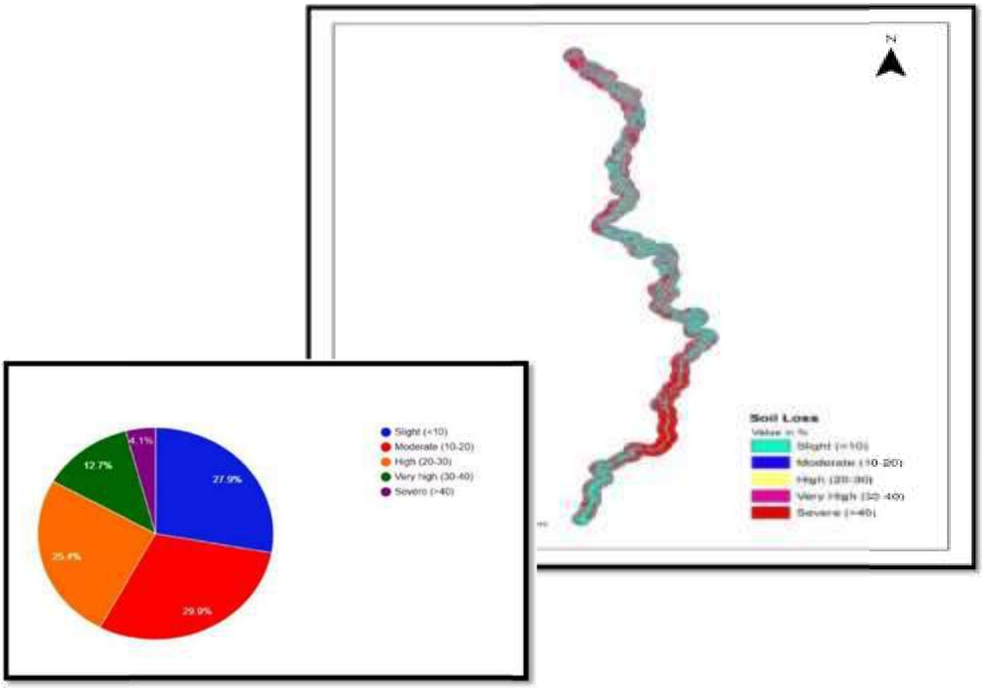

Fig 9 : Soil Loss Map by RUSLE Mode

The average annual soil loss was calculated using a raster calculator in a GIS environment by multiplying R, K, LS, C, and P factors. The output map that has been generated from the RUSLE model shows the soil loss of Bhagirathi Hooghly river in percentage for each yearsfrom 2016 to 2021.

These percentages have been calculated from the average annual soil loss that is valued in tons per hectare per year. The empirical soil erosion model map showssoil erosion from years 2016-21 in regions with a severe (>40%), high (30-40%), moderate (20-30%), low(10-20%), and very low (<10%) category, respectively. The red colour denotes severe soil loss in the region, magenta represents high level of soil loss, yellow colour represents moderate soil loss and blue represents less amount of soil loss.

In 2016, it is noticed that the average annual soil loss along the Bhagirathi Hooghly river belt was about 4.1% at severe level, 12.7 % at very high level, 25.4% at high level 29.9% at moderate level and 27.9% slight level. From figure.9, we can see that the lower part of the Bhagirathi Hooghly river buffer zone has the highest percentage of soil erosion and some patches in the upper part near Farakka has higher level of soil loss. Similarly, during the year 2017, The severe level of soil loss is 4.1% in the lower part of the region. The high to moderate level of soil loss is about 68% and here also the concentration is noticed in thelower part of the river zone especially over the districts of Kolkata and its lower reaches as seen in figure 11. During 2018 it is seen that the soil loss is lesser ascompared to the previous year. About 41% of the area has slight level of soil loss. Rest of the areas are experienced with a severe to moderate level of soil loss as noticed in figure 13. About 56.3%of the area is least affected by soil loss during 2019 and the major soil loss area is againvisible in lower reaches especially in Kolkata zone. In the year 2020, the percentage of soilloss has been reduced to 37.3% with a severe loss of 3.3% concentrated in the lower reachesof the river. As we can see from the year 2021 in figure 19, the percentage of soil loss is about 60% and is concentrated in various districts especially along Kolkata, Nadia and Burdwan. Hence from the analysis of the output maps of soil loss using RUSLE model, it is clearly visible that how the five input factors are responsible for influencing the average annual soil loss along Bhagirathi Hooghly belt in the state of West Bengal. The R, K, LS, C and P factors are comparatively higher in those areas of the study area where there is higher percentage of soil loss. In this way, we can compare all the input factors of RUSLE model to identify the average annual soil loss in tons perhectare per year.

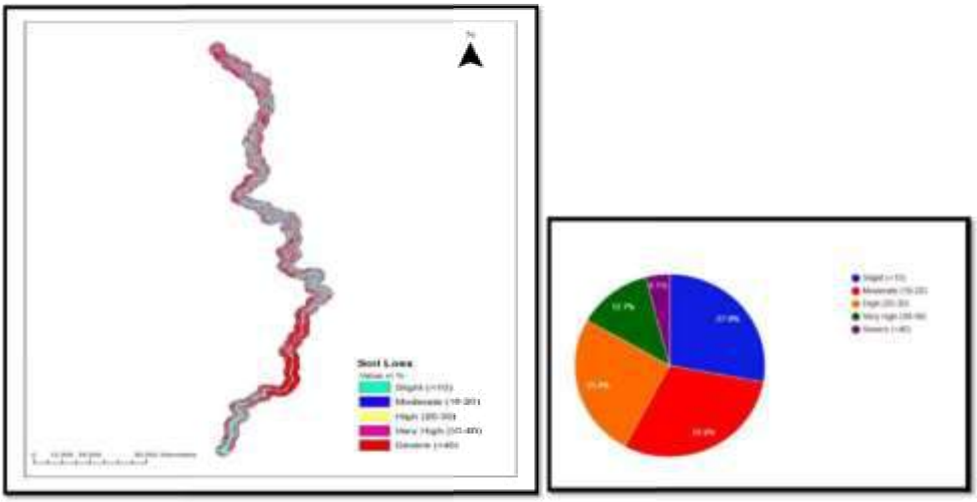

Fig.10: Soil loss estimation map of Bhagirathi Hooghly river in the year 2016

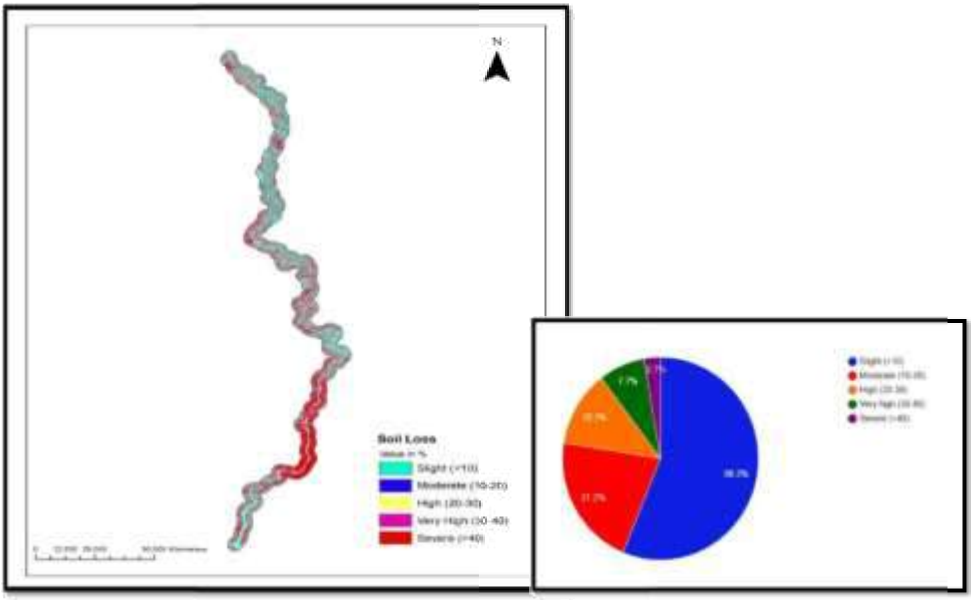

Fig.11: Soil loss estimation map of Bhagirathi Hooghly river in the year 2018

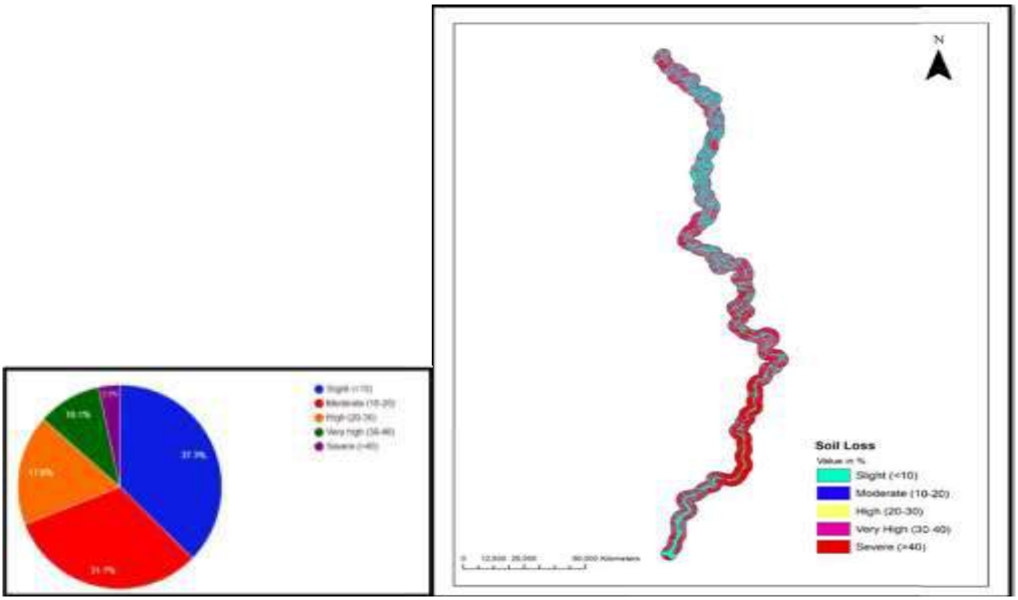

Fig.12: Soil loss estimation map of Bhagirathi Hooghly river in the year 2021

Conclusion

This research work demonstrates the use of an empirical soil erosion model such as RUSLEin conjunction with RS and GIS technology to estimate the soil loss along the Bhagirathi Hooghly region. Additionally, an effort was made to investigate the effect of changing land use/land cover on erosionrate. Additionally, it was observed that the amount of erosion varies significantly, according to the topography and land use/land cover. Furthermore, the results show that the rainfall erosivity component, cover management and support practices were the most significant variables in preventing soil erosion. Additional research is requiredto obtain the most accurate factor values within the study region, to accurately assess possible soil erosion. Overall, the findings of this research can assist in conducting proper erosion control measures in the seriously impacted areas.

The data collected from this research may help in establishing management scenarios and give alternatives to policy makers for controlling soil erosion threats in the most effective way. The empirical soil erosion model map shows soil erosion from years 2016-21 in regions witha severe (>40%), high (30-40%), moderate (20-30%), low (10-20%), and very low (<10%) category, respectively. Using the RUSLE model, we estimated annual soil losses in the Bhagirathi Hooghly river buffer zone. After observing the entire soil loss map of the Bhagirathi Hooghly river from 2016-21, we can clearly observe that the major soil loss has occurred on the lower reaches of the river. Huge belts of agricultural land has been lost through soil erosion.The river mainly meanders on the mature and old stage of the river where it erodes some portion of the land naturally. But severe tohigh level of soil loss occurs due to anthropogenic factors like built up lands, agricultural tracts, deforestation, aquaculture which causes the soil to loose its fertility and degrade.

As a result, it can be inferred that Remote Sensing, and GIS, in conjunction with the RUSLE model, play a crucial role in determining the input parameters for soil erosion modeling and resource management.Using these techniques, policymakers can develop management scenarios and determine the most efficient way to control soil erosion problems. Further land replenishment in these areas can improve the quality of land as it is necessary for agriculture and other purposes. Soil is an essential treasure which can be utilized in many ways. West Bengal having the population entirely dependent on agriculture needs to be more aware of this situation and necessary steps must be taken.

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RIVER CO-OPERATION: THE STORY OF INDIA-JAPAN

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Indo-Japan bilateral relations are developing on long term cooperation with short and mid-term mutual benefits. Water resources management, sustainable usage and their conservation isidentified as an important aspect between the two countries. Government of India and Japan signed several agreements and Memorandum of Co-operation (MoC) in last decade to deepen partnership and synergy in multiple projects. The usage of digital technologies to improve the operability, assessment and impact are also considered highly in last 5 years. In the stint to achieve and share expertise, a MoC was signed between Department of Water Resources, River Development & Ganga Rejuvenation under Ministry of Jal Shakti of Government of India and Water & Disaster Management Bureau under Ministry of Land, Infrastructure, Transport & Tourism in Government of Japan. It enables both the governments for long term cooperation in field of water and delta management & water technologies in order to increase the exchange of information, knowledge, technology and scientific allied experience, as well as implementation of joint projects between the two countries.

The Validation

Both countries has proved track record of cooperation in multiple sectors spanning from peace to commerce, culture to technology, taxation to defense, social security to nuclear energy. In river cooperation too, they have vivid testimonials on the ground to verify the impacts of this MoC are –

1. Mighty river _Ganga' flows from 11 states providing drinking water to 600 million and are severely impacted from river pollution due to multiple reasons. An ever-growing population, Inadequately planned urbanization and industrialization, together with lack of a robust municipal and industrial wastewater treatment network has left the river Ganges choking in effluents and toxic wastewater. Japanese major Toshiba Water Solutions (TWS) Private Limited based in India partnered with Government of India in2014 in _Clean Ganga Initiative'.Through active contribution in one of the largest industrial state – Uttar Pradesh, Toshiba Water Solutions (TWS) established 02 sewage treatment plants (STP) with a combined capacity of treating over 18 million liters per day (MLD), and laid down a 55km sewage network. In another key state –

Bihar, 60MLD capacity STP along with 55km of sewage network was constructed by Toshiba.Collectively, water re-use and effective water treatment technologies can help alleviate water crisis. Water management has the capability of addressing human interventions and the various natural events in connection with resources and the long-term water policy decisions on the environment and economy. Solution of water issues vested on infrastructure repair and maintenance of channels in water reuse and wastewater treatment.

1.Japan International Cooperation Agency (JICA) is funding the Mula-Mutha river pollution abatement project in Pune, Maharashtra in India worth cost of INR 1236 crores including its operation and management which will cost around INR 216 crores and INR 1020 croresrespectively. The tendering process of the project is completed in which the responsible Indian authorities i.e. Pune Municipal Corporation (PMC) assured the necessary cooperation to implement the transformation process.

JICA categorizes it in Category-B with the clear objective stated –

"To improve the water quality in the Mula, Mutha and Mula-Mutha rivers by augmenting sewage collection systems and sewage treatment facilities in PMC area. It also includes taking other measures required for the pollution abatement and thereby improving thesanitation and living conditions of people who reside in Pune City and in the watershed of the downstream area"

The water of this stretch is classified in Class-IV category by Maharashtra Pollution Control Board as one of the reasons is its non-perennial and severely impacted by untreated sewage water poured by Pune Municipal Corporation. The length of the stretch is merely 15 kms (under abatement by Japan) but will provide the potable water to the population 40 Lacs living in Pune and Pimpri-Chinchwad. The area is rich in economic activities and in dire need of the clean water for drinking purposes where Japan is sharing its expertise to provide solutions in India under technology sharing program.

Nag River Pollution Abatement Project is another testimonial of growing Indo-Japan cooperation in river cooperation. It is a Category-B project of JICA in Nagpur, Maharashtra in India approved at a cost of INR 2117.54 crores. Its announced objective is –

"To prevent and improve the pollution of rivers and improve hygienic environment of residents in the catchment area of River Nag and Pili River in Nagpur city, by carrying out construction of sewerage treatment plants and public sanitary facilities, thereby contributing to the improvement of poverty and environmental issues …"

It is a river revival project announced for River Nag flowing through the city of Nagpur and a part of Kanhan-Pench river system. It is a highly polluted water channel consist sewage and industrial waste drains by Nagpur Municipal Corporation. The project is approved under the National River Conservation Plan and will be implemented by National River Conservation Directorate. Japan shows its interest in reducing the pollution level in terms of untreated sewage, flowing solid waste, and other impurities flowing into the Nag River and its tributaries.

One of the reasons behind this dirt that City of Nagpur has experienced very fast urbanization during last 50 years. It increased use of water which exponentially gives rise to sewage resulting in deterioration of quality of receiving water and distributing the ecosystem. This Japanese funded project is able to serve population of 27,00,000 people residing around the rivers.

India-Japan river cooperation is a type of multi-sectoral initiative where pollution abatement, preservation of water bodies, and rejuvenation of dried resource which upholds the flag of recreation.

The Approach

This Memorandum of Cooperation (MoC) signed between India & Japan is for development of a long-term cooperation in the field of Water and Delta management, and Water technology in order to increase the exchange of information, knowledge, technology and scientific allied experience, as well as implementation of joint projects between the two countries. This MoC will help in achieving water security, improved irrigation facility and sustainability in water resources development. The cooperation is an extension of India‘s Jal Shakti Abhiyaan in which preservation of water resources and rejuvenation of water bodies are taken up with the dedicated budget allocation in the Annual Financial Statement of Government of India. Indian government and industries are responding to the ace technologies in this field with utmost fulcrum available, to reincarnate the status and condition of water bodies. The perennial rivers are getting huge impetus from last decade in sense of disbursal of revenue, ramped efforts and multiple MoUs between India and Japan. It is pertinent here to mention that the Indus River basin in South Asia is one of the most intensively cultivated and utilitarian region on Earth. Also, it is the highly water stressed region lacking in energy security too. India-Japan river cooperation is a type of multi-sectoral initiative where pollution abatement, preservation of water bodies, and rejuvenation of dried resource which upholds the flag of recreation.

The Techs

Japanese technologies for sewage treatment and related facilities have special significance infor India as they offered multiple treatments in a single shoot. In 2019, 13 Japanese companies through JICA delivered presentations of their special technologies on wastewater treatment, membrane process, sludge treatment, sewer pipe replacement and toilet facilities. The main objective was to introduce Japanese technologies in India and to facilitate interactions with Government of India and prominent Indian companies. Post this event, several Indian companies took the training sessions and webinars with Japanese companies to upgrade, learn, and adapt the new thriving technologies like advanced oxidation process (AOPs), ion exchange,ultra & nano filtration adsorption/biosorption, and advanced biological treatment using algae, bacteria & fungi collectively. Nowadays, centrifuges are also used to reduce the amount of solids in wastewaters thereby reducing water pollution. The Japanese are using these techs in synchronous manner as per the requisite and usability of rivers in India.

Conclusion

Overall, if we analyze the trajectory of projects they are running with delays due to incapability of Municipal Corporations to equip themselves with the new technologies to treat water prior dumping it into rivers. The impetus was given to them by Central Government of India in their budgetary allocations as well as in the social campaigns to create awareness among the populace. But the social vigilant and civil societies are not enough conscious towards our own

‗going to dead rivers' or ‗dead rivers'. Indian society has to make it a mass campaign to save the rivers at most as possible.

India-Japan collaboration in river co-operation acting as a guiding light for the agencies working in India and they are considering treatment of water as prime component in abatement measures. The frequent and affordable reach to the equipment's/apparatuses is a rising issue as every district doesn't have enough capacity to install it locally. Although the resolution exists there only as there is famous idiom – Drop by drop makes an ocean. Japanese CAPEX and OPEX combinations in water treatment offer best in class water treatment facility. Also, the industry pioneers to develop and implement a cloud-based remote management solution for real-time water quality monitoring in STPs/CETP/WTP.

IoT-enabled automation is the future which helps in gauging and countering any possible redundancies and oversight by helping planners to assess the impact of treatment on the water'squality. India has to just adapt with the new techs, to resolve the old deeds, for the future needs.

FLOOD SUSCEPTIBILITY ASSESSMENT BASED ON HYDRO-GEOMORPHOLOGICALANALYSIS USING GEOSPATIAL TECHNIQUES ON SILABATI RIVER BASIN, WEST BENGAL, INDIA

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Abstract

The study assesses flood susceptibility on the Shilabati River Basin in West Bengal, India, usinghydro-geomorphologic analysis using Remote sensing and Geographical Information System. The study focuses on bed morphology and flow structure in spatial scales, highlighting the impact of hydro-geomorphologic development on flooding. The study uses Shuttle Radar Topographic Mission (SRTM) images to create thematic maps, including Topographic Wetness Index, Topographic Ruggedness Index, Stream Power Index,Stream Transport Index, and Flood Susceptibility Index. The results show that the lower catchment area is more prone to flood risk. The study suggests that geo-spatial techniques are a suitable tool for hydro- geomorphologic studies, aiding in flood mitigation.

Key Words: *River Basin, Flood Susceptibility, Hydro- geomorphological Studies, Geo-Spatialtechniques.*

Introduction

Floods are one of the most devastating natural hazards across the world [Asker et al.2022]. There arepossible several influencing factors of floods including climate change, human action and physicalphenomenon [Bui et al.2019]. It can cause direct or indirect effects on environment as well as socio- economic resources of a country [Tehrany et al.2019].An estimation shows thatmore than 34 million peoplewere affected by flood around the world. In 2020, approximately 6000 people were died due to flood. The effects of flood are more in developing countries then the developed countries [Tehrany et al.2019]. Flood is non-preventable natural hazard. Therefore, the effects of its can be minimized through appropriate prediction and forecasting [Clocke and Pappenberger 2009]. In recent decades, the study of flood assessment has been popularized in interdisciplinary and multidisciplinary domain [Tehrany et al.2015]. The Hydro- geomorphological analysis of the drainage basin and channel network play a major role to understanding the potentiality of flood of a river basin [Hajam et al.2013].

The word ‗Hydro-geomorphology' consists two words ‗Hydro' meaning ‗water' and‗Geomorphology' meaning ‗the study of landforms' thereby it is defined as the study of landforms curved out by action of water [Scheidegger 1973]. In other word Hydro- geomorphological characteristics of a river basin includes geological, hydrological and geomorphological attributes of the basin [Gurav and Babar 2019]. An integrated geospatial technique are now-a-days in use for convergent analysis of multi- disciplinary data and decision making for flood susceptibility assessment as it is a rapid and cost-effective tool [Hajam et al.2013, Nag and Kundu 2016]. The Remote sensing and GIS techniques provide a flexible environment to collect spatial and temporal data to understand the hydro- geomorphological system in any area [Kant et al.2015]

Aims and Objectives

The main two objectives of the present study are

- To analyze the geomorphological and hydrologicalattributes of Silabati river basin.
- To assessing flood susceptibility based on hydrogeomorphological attributes.

Database and Study Area

The Silabati river basin covering an area of 4088 Sq.km and it originated from part of eastern Chhotonagpur plateau in Purulia district of thestate of West Bengal in eastern India [Fig 1]. It islocated between 23°14'51.56''N to 23°24'56.55''N latitude and 86°28'34.09''E to 86°47'61.35''E longitude.

The river flows south-easterly direction through the Bankura and Paschim Medinipur district of West Bengal [Das et al.2020]. Total length of the river is 207 km and its joins Dwarakeswar river near Ghatal in Paschim Medinipur and drain into Bay of Bengal. The main tributaries of Silabati river are Joyponda, Ketia, Donai, Champayan [Ghosh et al.2022] The river basin is characterized by dendritic to sub dendritic type of drainage pattern which is controlledby relief, rock structure and regional slope of the area.

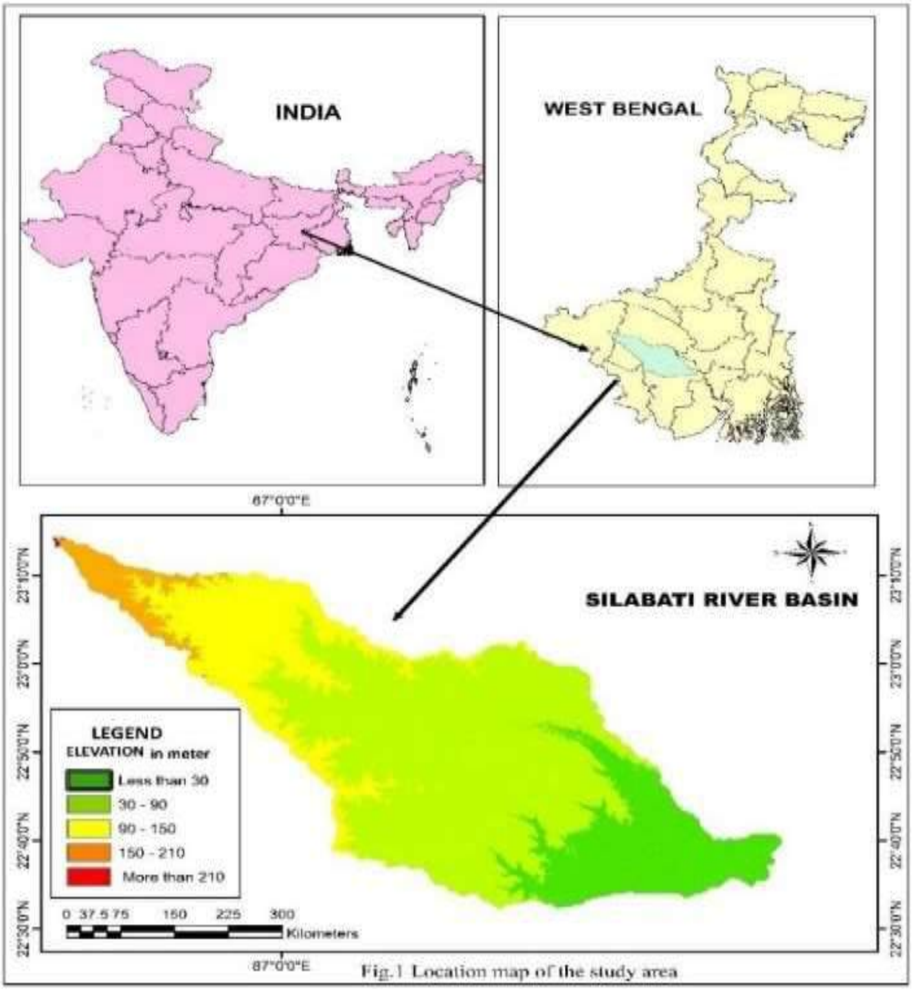

Fig 1: Study Area

The soil cover of the study area is characterized by sub- tropical humid climate. Most of the rainfall occurs in rainy season June to September due to south west monsoon. The average rainfall is 100-130cm [Das et al.2020]. Almost every year Silabati river foam up with rain, particularly Banka, Khipai and Ghatal areas in respective catchments.

Database

An attempt has been made in the present study to evaluate the flood risk assessment in the study area by analyzed topographic factors. which are directly and indirectly associated with hydrological characteristics of the area. Geo-coded satellite Imagery of Indian Remote sensing P6 LISS-III satellite data, SRTM DEM-1 arc of ~30m resolution(downloaded from USGS) and survey of India toposheets on 1:50000 scales were used to prepare contour, elevation, aspect, slope, hill shade, drainage, Topographic Wetness Index (TWI), Stream Power Index (SPI), Sediment Transport Index (STI), flood susceptibility maps by using ArcGIS 10.8 software. Another importantinfluencing hydrological factor is rainfall and heavydownpour is responsible for increasing potentiality of flood (Nataranjan et al.2021) Rainfall data have been collected from Indian Meteorological Department (IMD)for a period of 10 years (2010- 2020) of the study area.

Methodology

Flood is a vigorous natural hazards resultant as manynatural and anthropogenic causes. Thus, it is very important to understand the flood susceptibility of a study area. The basin area experiences heavy rainfall during southwest monsoon (July and August) due to severe low pressure and monsoon trough passes through the basin area. The required data for this study have been collected from different sources andseveral flood controlling factors are also assess for the study is shown below.

Flood Susceptibility Parameters

There are mainly Twelve factors flood susceptibility modeling in the study area. These are elevation, slope, aspect, relief, rainfall, LULC, drainage order and density, Topographic Ruggedness Index, Topographic Wetness Index, Stream Power Index and Stream Transport Index. All of these parametersare very important in determining and delineating flood- prone regions.

Result and Discussion

- ***Basin Relief***

Basin relief is an important factor to understanding the geomorphic process and flood risk assessment. It is noticed that the entire basin area is low elevated except some parts of upper catchment area innorthwest. The lowest basin relief 2m is observed in lower plain area whilethe highest basin relief area which is undulating surface of Chhotonagpur plateau as shown in fig3.

It is observed that high degree of correlation exists among basin relief and stream velocity and potentiality of flood (fig4).

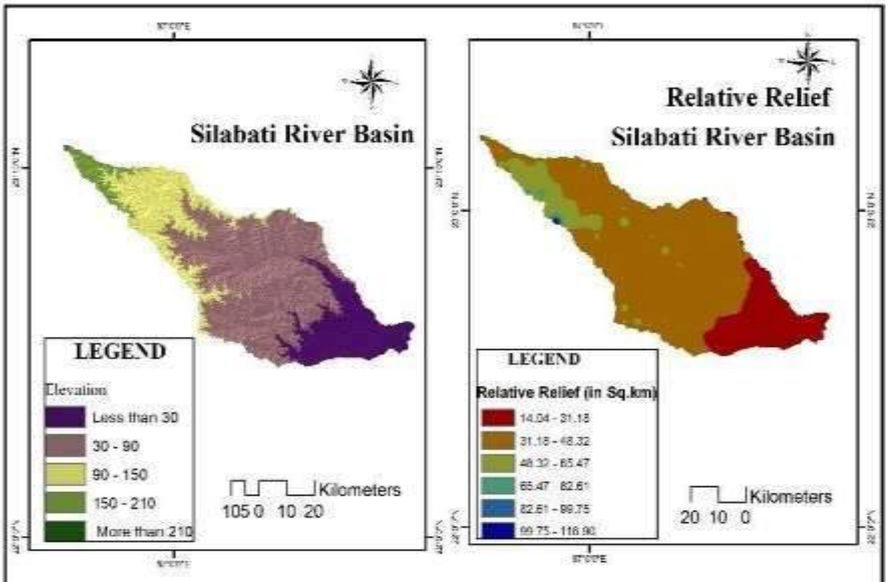

Fig.3 Elevation Map Fig 4 Relative Relief Map

- **Slope Area Analysis**

the slope of the basin area varies between gentle to moderate and influenced by different geomorphic and climatic factors such as erosion, transportation, deposition and rainfall - runoff characteristics of thebasin area. The slope generated shown (Fig5.a) a range varies 0% to 52% and overall direction of theslope is northwest to southeast. Then the slope wasreclassified into 5classes, 0 to 5°,5 5to 10°, 10 to 15°,15 to 20°and more than 20°. The relative percentage of gradient for individual slope class shown in fig5.among of the classes a large percentage of to 10° gradient of the study area fallswithin the slope class 0 to 5° and 5° to 10°. The gentle slope indicates flat terrain while higher slopeindicates steep terrain. Thus, the lower catchment area of the basin with gentle slope is highly susceptible to flood compare to upper catchment area with moderate to steep slope.

- ***Aspec***

Aspect map shows the direction of the terrain. It is playing an important role in predicting flood susceptibility of the study area. For this purpose, an aspect map has been prepared fromtheDEM image (fig5.b).

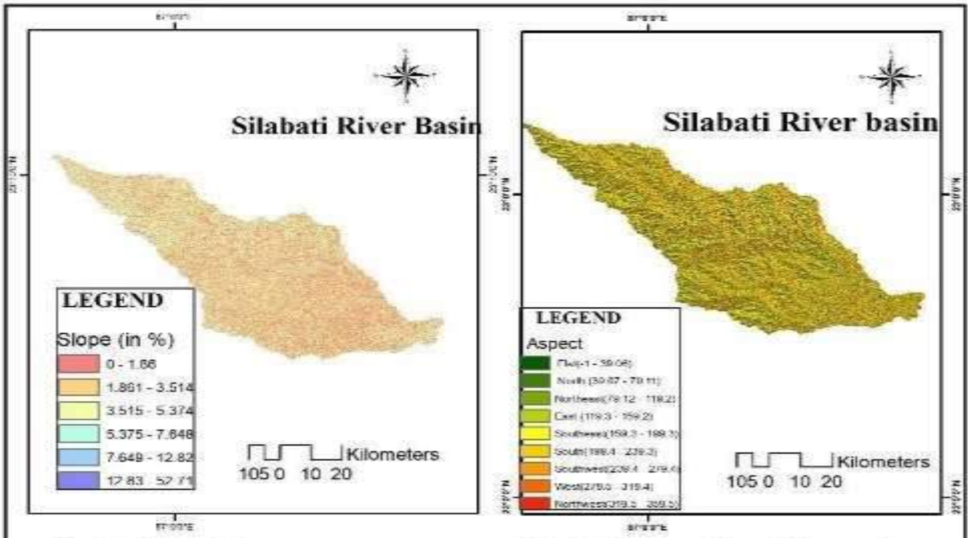

Fig.5.a Slope Map Fig.5.b Aspect Map of the study area

Table1 Showing Aspect classes

Aspect in Degree	Direction
-1to 39.06	Flat
39.07 to 79.11	North
79.12 to 119.2	North-east
119.3 to 159.2	East
159.3 to 199.3	South-east
199.4 to 239.3	South

239.4 to 279.4	**South-west**
279.5 to 319.4	**West**
319.5 to 359.5	**North- west**

Hydrological Characteristics of the study area

- ***Drainage Density and Stream ordering***

Drainage density defined as the total stream length per unit area. It indicates concentration of channels in a basin. A higher drainage density denotes a highly rugged basin area with high surface runoff while a low drainage density reflects poor drained basin with high water accumulation as well as sediment deposition and resultant into overland flood. The drainage density of Silabati river basin ranges between 0.01 to 3.32 sq/km (fig6.b). it indicates lower catchment area more susceptible to flood.

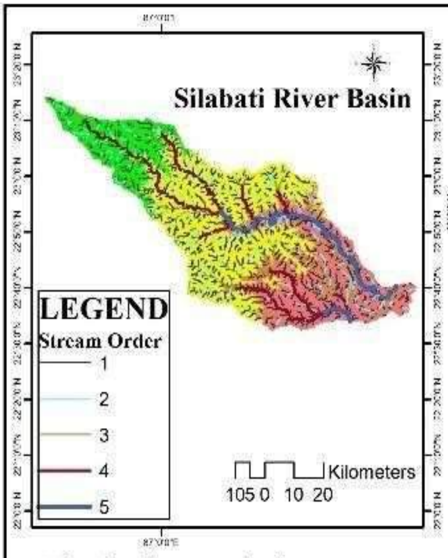

Fig 6.a Stream Order

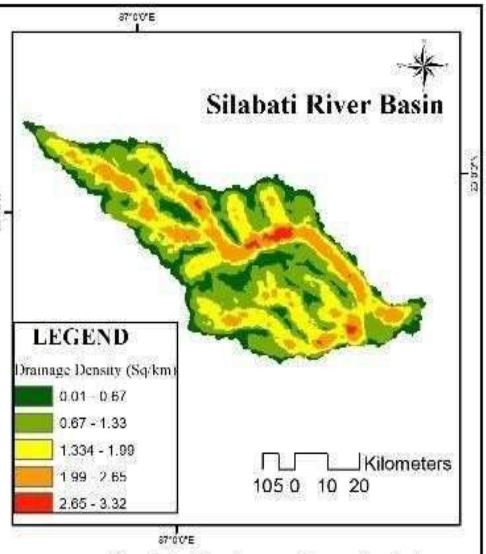

Fig 6.b Drainage Density Map

Table2 Total Number of streams

Stream Order	No. of Streams
1st order	34548
2nd order	16868
3rd order	6994
4th order	5926
5th order	2836

- **Topographic Wetness Index**

Topographic Wetness index (TWI) is the most popularmeasurement of water accumulation as well as flood mapping. Higher the TWI value greater chance toflood. It integrates the spatial distribution of runoff foreach cell in a DEM (fig7.a). It is expressed as following formula

TWI=ln (As/tan (β)   (i)

Where As represents the slope of area, tan(β)represents flow accumulation. In the present study TWI ranges between 4.27 to 24.97. It is shown that lower reaches have higher value of TWI (fig7.a)

- **Stream Power Index (SPI)**

SPI refers to capability of strems to modify topographical surface through gully erosion and transportation. It measures the erosive power of stream considering runoff potentiality. It is expressed as follows

SPI=$As \times tan\beta$ (ii)

where, As is the catchment area in sq/km and β is theslope in degree. In the present study SPI ranges between -11.81 to 11.84. In fig7.b shown that most part of the basin have no or lower surface erosion. Lower the value increase the potentiality of siltation.SPI is inversely related to flood potentiality.

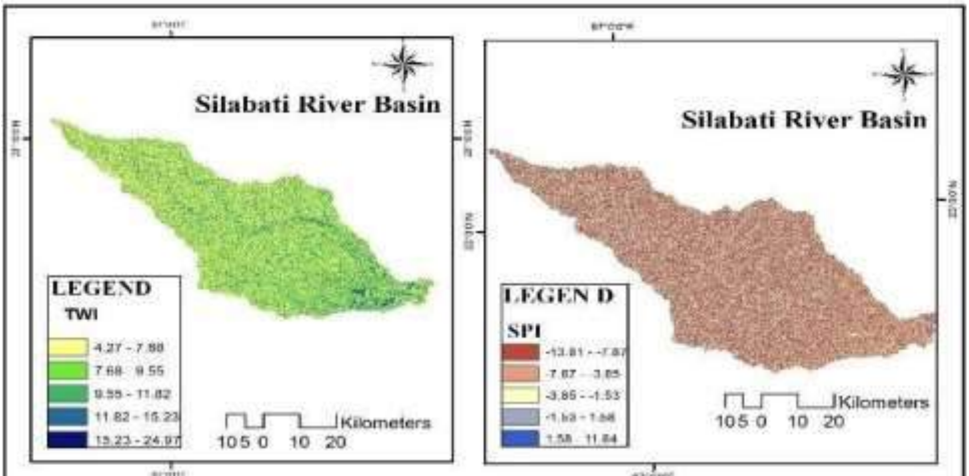

Fig 7.a TWI Map

Fig 7.b SPI Map

- **Sediment Transport Index (STI)**

This tool can be used to calculate the STI describedby Moore and Burch (1986). It refers to the effect of topography on erosional activities. The estimation of the STI as stated follows

$$STI=\left(\frac{As}{\quad}\right) 0.6 \times (\beta \times 0.0896)1.3 \ldots \ldots (iii)22.13$$

Where As is the unit contributing area (in/Sq.m) and β is the slope angle in degree at a given cell. Inthe present study the STI ranges between 0 to2254.36.

- **LULC Classification**

Land Use Land Cover classification have been prepared by maximum likelihood supervised classification. Consideration was given to 6 types of land use and land cover (fig.8). The map shown that most of the area of basin covered by agricultural land followed by water body, forest.

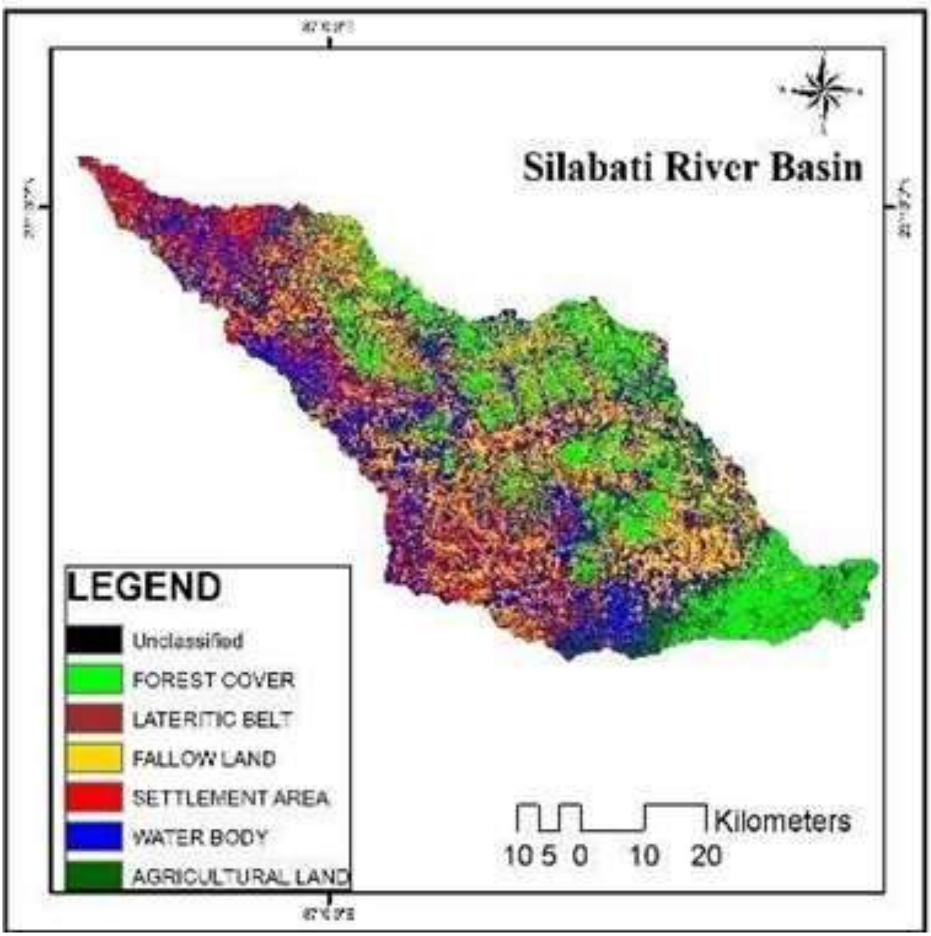

Fig 8: LULC Classification of the Study Area

Rainfall Distribution

One of the most important determinants of the flood is rainfall. In India several flood events occurred in each year due to Southwest monsoon. The average rainfall of the river basin 100- 120cm.Areas with high average rainfall have a high risk of flood. In the present study rainfall distribution map have been prepared based on collected rainfall data for the period of 2010-

2011 from Indian Meteorological Department (IMD). Themap shown (fig9) middle and lowerbasin receiveshigher amount of rainfall. It indicates these areas are more susceptible to flood.

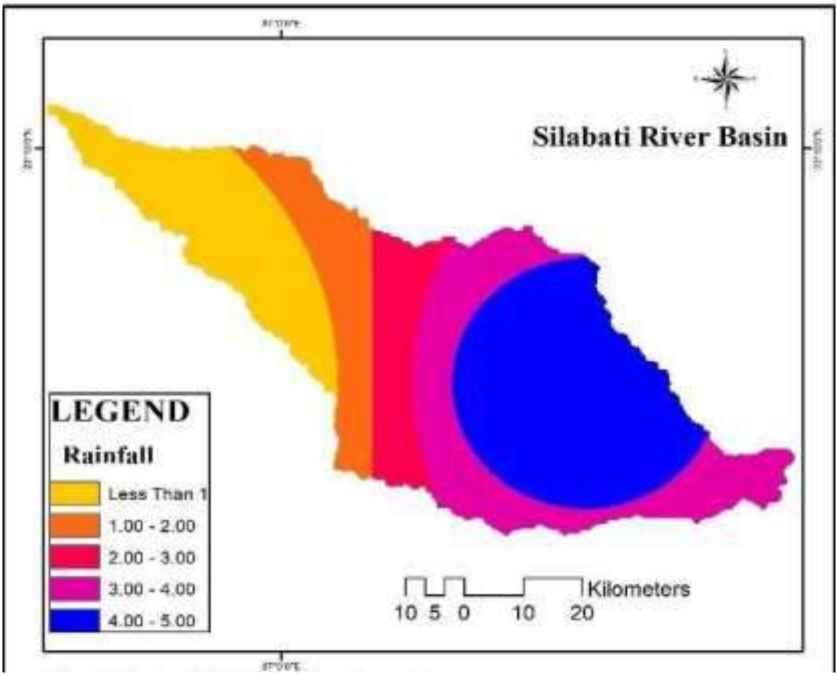

Fig 9: Rainfall distribution map

Flood Susceptibility

Flood susceptibility map have been prepared in ArcGIS software classified 5 major classes onthe basis of weighted sum as shown in fig10.

Conclusion

In the current research, hydro-geomorphological aspects are used to analyze flood susceptibilityin Silabati river basin in West Bengal, India. Severalindependent factors like elevation, slope, aspect, stream order and stream density, TWI, SPI, STI, LULC, rainfall were derived from geospatial data and used as input into the flood prone area mapping. As theresult suggest, the river basin occupies an area of 4088/Sq.km. Geologically, entire basin has two units, Pre- Cambrian Archean (Granite and Gneiss) in highlyelevated area

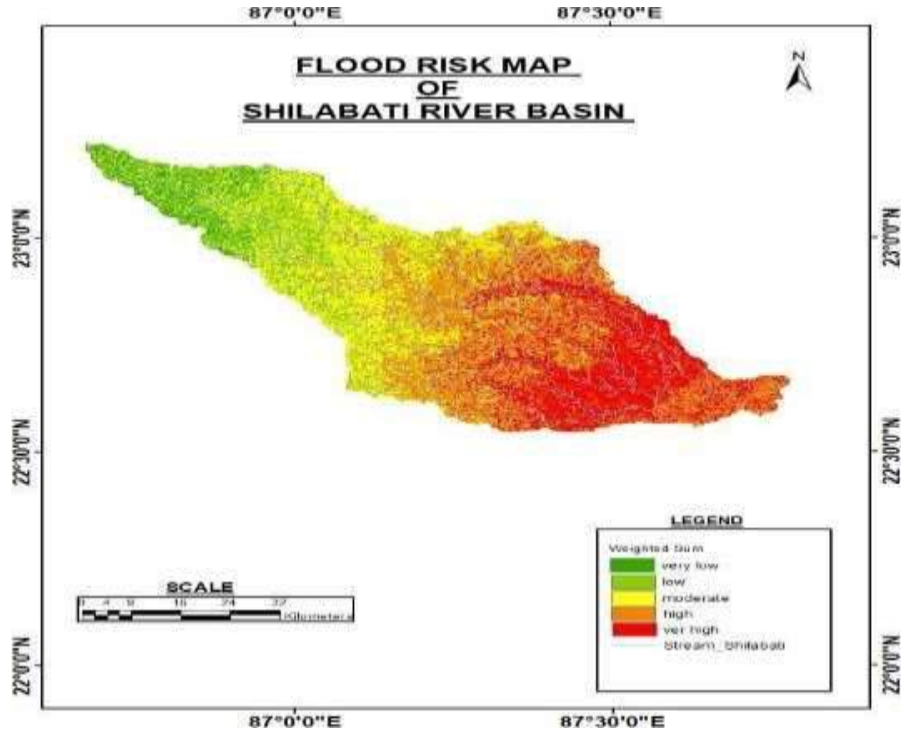

Fig10: Flood Susceptible Map

and alluvium formation in low elevated areas. As per flood risk map, the lower basin area is more susceptible to flood. In this area the river has lost her stream erosive power due to low channel gradient and huge sedimentation. Thus, ultimately increase water accumulation.Whenever, precipitation externally add as a form of water during southwest monsoon season theriver foam up and developed flood hazard.

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NAMAMI GANGE: ACING SUSTAINABLE DEVELOPMENT GOALS

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The Sustainable Development Goals (SDG), as adopted by nations worldwide in 2015, presents a trajectory of global development that focuses on improving quality of life through natural resource management. The integrated nature of SDGs implicates an environmentally led social development and economic prosperity model. Water flows through and connects all the SDGs. SDG 6 specifically calls for clean water and sanitation for all by 2030, which stresses on sustainable management of fresh water systems for ensuring availability of potable water. Rivers, in this context, are the largest fresh surface water system in the world. India is naturally endowed with rivers in which, Ganga is the largest river basin. With the objective of restoring the wholesomeness of River Ganga, the Government of India launched an ambitious programme of Namami Gange as a gradual, holistic and continuous effort towards improving basin management and governance. It entails sustained efforts for integration of institutional responsibilities, policy directions, stakeholder participation, scientific and traditional knowledge, technological possibilities, and funding prospects to abate pollution in the river and sustainably manage its natural ecosystem. The paper presents the synthesis of the strategies used in the Namami Gange programme to achieve the underlying targets of SDGs through basin approach of river rejuvenation and preservation. The Sustainable Development Goals (SDGs) were formulated as an indivisible set of goals and targets, with the environmental dimensions integrated into socioeconomic development plans. According to UN Environment, the "environmental dimensions" could refer to a total of 86 out of 169 targets that directly or indirectly seek to reduce environmental damage or emphasize the critical role of natural resources and ecosystem services in ensuring human well-being and prosperity. India continues to target and maintain its economic growth by introducing and implementing various policies and measures relating to sustainable development, climate change, resource efficiency, and air pollution.

Namami Gange is an umbrella initiative integrating previous and on-going efforts with the aim of pollution abatement, conservation and rejuvenation of the river Ganga and its tributaries. For effective implementation and proper synchronization with the State and Local Bodies, National Mission for Clean Ganga (NMCG), the implementing agency for

Namami Gange programme, was empowered as an Authority under the Environment (Protection) Act, 1986 for fast-track implementation and to formulate policies for long-term sustainability of the Ganga rejuvenation efforts. The work done under the programme has been duly recognised by Economic Survey 2018-19 as a key initiative poised to achieve the Sustainable Development Goals.

Mapping SDGs with Initiatives under Namami Gange Programme:

The initiatives undertaken in the Namami Gange programme have comprehensively addressed the key environmental parameters. The following section links the specific projects with the SDG targets that are addressed through their implementation:

SDG 2: Zero Hunger

Working to improve food and agriculture can have a substantial impact on combating climate change, bolster economic growth, and contribute to peace and stability in societies around the world. Climate change is putting greater pressure on the resources and increasing risks associated with natural disasters. Target 2.4 poises to ensure sustainable food production systems and implement resilient agricultural practices for improved land and soil quality. In order to mitigate the negative impact of the conventional farming in the Ganga plains, a joint project with Ministry of Agriculture and Farmers Welfares has been in progress to promote organic farming, which seeks to use swathes of green belts along the river for decontaminating the cultivable lands. The organic farming involves the careful handling of the environment and resources in such a way that the soil stays healthy - rich in organic matter, nutrients and microbial activity as well as provides a potential solution to the challenges being faced like depletion in soil fertility, water pollution as well as health hazards.

SDG 3: Good Health and Well-being

SDG 3 aims to ensure healthy lives and promote well-being for all. Target 3.9 aims to reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination. Putting in place trunk infrastructure lines for collection of wastewaters in certain cities and STPs in largely every city with higher degree of criticality in the Ganga basin has not only improved water pollution abatement but has also progressively and increasingly reduced the likely impact of water-borne diseases in the geography.

SDG 4: Quality Education

SDG 4 envisages inclusive and quality education for all. The target related to skill development (4.4) have been addressed under the Namami Gange programme through a cadre of ‘Ganga Mitra’ that focuses on leveraging their eco-skills and capacity building in rejuvenation efforts of River Ganga and its biodiversity. In order to ensure that skilled labourers and artisans have access to gainful employment upon completion of their vocational training. Collaboration with the Rural Development Departments have been established to provide work under Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) for rejuvenation of ponds and construction of toilets in the basin area. A team of dedicated Ganga Task Force has been put in place by raising a 529 member Territorial Army Unit, for four years to support in patrolling of ghats & river, public outreach, afforestation, water quality testing, among other pursuits. Finally, the Human Resource Development department has been on-boarded to raise environment literacy among common masses in 1438 Gram Panchayats in the five states of Ganga main-stem, which ensures knowledge is provided to promote sustainable practices (4.7).

SDG 6: Clean Water and Sanitation

Goal 6 of the 2030 Agenda for Sustainable Development recognizes the importance of ensuring the availability and sustainable management of water and encompasses a range of values for water, with sub-goals focused on equitable access to potable water (6.1), adequate sanitation (6.2), water quality (6.3), increase water-use efficiency (6.4), integrated water resource management including through trans-boundary cooperation (6.5), and the protection and restoration of water-related ecosystems, including rivers (6.6).

The Namami Gange programme has in its Vision Document identified an entire mission on sustainable agriculture practices that emphasises upon water use efficiency in the sector. This is also reiterated in the project approach of STP construction that relays importance on recycling and reuse of wastewater. Recycling further ensures that lesser fresh water is withdrawn for any industrial or municipal use (6.4). Provisioning of sanitation infrastructure to household level in being coordinated through Atal Mission for Rejuvenation and Urban Transformation (AMRUT) of Ministry of Housing and Urban Affairs in the Ganga basin States. Under the Swachh Bharat Mission, all the Ganga Grams have been declared open-defecation free. The adequacy of sanitation is also peripherally taken care in the Namami Gange programme (6.2). The cooperation of basin provinces is important to ensure that trans-boundary river space and associated wetlands and aquifers are managed in an equitable and sustainable manner. This has been highly emphasised in the National Ganga River Basin Management Plan and is being propagated in the implementation of the programme. International cooperation with Bangladesh on sharing of water at Farakka and with Nepal on Mahakali River reiterates India's commitment to practise integrated water resource management (6.5). The programme in totality is an effort to address SDG target 6.6 on protecting and restoring water-related ecosystems, including river, which reverberates with the larger ambition of restoring the wholesomeness of River Ganga. The overall improvement of river health will definitely augment the water quality levels of the region (6.3). Through SDG 9, countries have determined that investing in more resilient infrastructure, cooperating across borders, and encouraging small enterprises will all be critical to ensuring sustainable industrial development. Sustainability has been envisaged through the targets of resilient infrastructure (9.1), increased resource use efficiency (9.4) and increased scientific research (9.5). Industrial standards and quality output have been emphasised programme-wide. The design year of created infrastructures is for 2035 to ensure sustainability of use over longer period of time (9.1). Old, dilapidated and inadequate infrastructure have been rehabilitated and subsumed under the programme to create more resilient infrastructure and improve resource use efficiency (9.4).

Scientific temper and research is the backbone of Namami Gange initiative that keeps the programme contemporary (9.5). Significance of GIS framework has brought a paradigm shift in visualization of all crucial spatial and non-spatial information of Ganga basin. Further, decision support system developed with GIS domain helps in efficient decision making, execution and monitoring of projects as well as provides a platform for central repository of all data related to Ganga and geo-tagged assets. GIS Project on "Reconstructing the Ganga of the past from Corona archival imagery" being executed by IIT Kanpur has developed an Atlas of the Ganga River showing a comparison between 1960s and present, establishing the reference condition of the Ganga River and quantifying the changes in morphological characteristics and land-use /land-cover within the Ganga valley. This exercise will further propose a policy document on 'desirable' land-use within the Ganga valley.

SDG 11: Sustainable Cities and Communities

Urbanisation is the biggest driver of industrialisation. With India becoming urban at an accelerated pace, the population pressure is beginning to overwhelm and undermine nature's ability to provide key functions and services. The most constrained of these are fresh water systems that are mismatched with the replenishing capacity. It is, therefore, pertinent that SDG 11 be read together with SDG 6 to ensure better water management practice across the spectrum. Specific to the goal, with targets of integrated and sustainable human settlement planning and management (11.3), protect and safeguard the world's cultural and natural heritage (11.4), reduce deaths and property damage caused by water-related disasters (11.5), reduce per capita environmental impact of cities (11.6), provide inclusive access to green and public spaces (11.7) and provide access to sustainable transport (11.2), SDG 11 envisages to create cities that are safe, inclusive, resilient and sustainable.

Good river-sensitive urban plan requires consideration of all forms of water, including drinking water, wastewater, storm-water, groundwater and water for the environment. This approach is being increasingly adopted through 'Urban River Management Plan' for the 97 Class I towns in Ganga Basin that are aiming to create environmentally sensitive, socially equitable and economically viable plan that puts river at the centre of planning (11.3). In continuation to city approach, sustainable transport via the traditional river route is being explored through inland waterways on Ganga called "Jal Vikas Marg" (11.2).

Flood plains are integral part of overall river ecology and perform very important role in hydrological cycle, improving ground water recharge, providing base flow to the river during lean season and also protecting damage to life and properties during floods (11.5). Protection of flood plains is important for ensuring health of the river. NMCG 'Authority' Notification demarcates the bank of River Ganga and its flood plain as construction-free zone. NMCG has led a flood-plain demarcation exercise for Ganga from Haridwar to Unnao to identify no development zone and regulatory zone. The State Government has been on-boarded for implementation of the Authority order. This measure also reduces the adverse per capita environmental impact of cities by reducing pollution sources, pressure points and by maintaining natural ground water recharge functions of the floodplains (11.6).

The river Ganga plays an integral role in shaping the geography, economy and spiritual life of civilization across the 300,000 square miles of the basin plain and throughout myriad number of years. The river is also a goddess, a gateway to salvation, the mainstay of cities, a focus of environmental activism, and a fulcrum of dynasties and kingdoms across centuries that ruled it. This rich cultural and natural history of Ganga is being documented by INTACH through cultural mapping of architectural, intangible, built and natural heritage along 42 cities of Ganga basin. This project will further strengthen efforts to protect and safeguard the cultural and natural heritage of Ganga (11.4). Apart from this, the river front development and the ghat development projects being constructed across the important nodes of the river for people's congregation usher in much needed space in the city boundaries for use as public and green space (11.7).

SDG 12: Responsible Consumption and Production

The eight substantive targets of SDG 12 and their 10 corresponding indicators cover issues that relate to lifestyles and behaviour generally, and chemicals and waste specifically. These include targets on promoting universal understanding of sustainable lifestyles

(12.8); promoting sustainable public procurement practices (12.7); encouraging companies to adopt sustainable practices and sustainability reporting (12.6); substantially reducing waste generation (12.5); responsible management of chemicals and wastes, significantly reducing releases to air, water, and soil (12.4); and halving global per capita food waste (12.3). All these targets aim to achieve the sustainable management and efficient use of natural resources by 2030 (12.2) and implementation of the 10-Year Framework of Programmes (10 YFP) on Sustainable Consumption and Production (12.1). The 10YFP, adopted at Rio+20 Conference in 2012, is designed to develop, replicate, and scale up sustainable consumption and production (SCP) and resource efficiency initiatives at the regional and national levels, while decoupling environmental degradation and resource use from economic growth.

Under the Namami Gange program, efficient management of natural resources (12.2) holds the key to ensuring sustainable pattern of growth. This is reflected in initiatives like developing an 'Urban River Management Plan' to ensure a city-wide urban planning approach that places river at the centre of planning and 'Urban Wetland Management Toolkit' that directs city administrations to identify and prioritise wetland conservation measures within their respective boundaries. These initiatives have been piloted in the city of Kanpur in Uttar Pradesh and Bhagalpur in Bihar and a scientific scaling up is being envisaged in the remaining Ganga towns (12.1).

In order to achieve environmentally sound management of chemicals and wastes, and significantly reduce their release to water (12.4) by 2020, NMCG in its approach of tackling waste dumping in Ganga, has ensured construction of Sewage Treatment Plant for domestic wastewater and Common Effluent Treatment Plant for industrial wastewater to check unpolluted flow in the river. A classic case of this approach can be seen in the clamping down of 128- year-old Sisamau Drain in the city of Kanpur that was notorious for dumping an equivalent of 140 MLD of wastewater directly into the river water. Besides, to reduce the consumption footprint itself, projects like Okhla STP in the NCT of Delhi, when fully functional, will be able to generate enough power through bio-gas from the sludge, to be able to meet half of its power requirement. Zero black liquor discharge has been achieved in paper and pulp industries and molasses-based distillery. Estimated reduction in the fresh water consumption and effluent generation from this are about 45-50% as compared to 2012 standards.

Additionally, to substantially reduce waste generation through prevention, reduction, recycling and reuse (12.5) by 2030, within the broad ambits of sewerage projects, a component of recycle and reuse has been envisioned for treatment of wastewater and reuse of reclaimed water and sludge in active industrial and agricultural processes. This measure has been promoted in project procurement process (12.7) itself with the concessionaire being incentivized to recycle and reuse the treated water for non-potable purpose and the sludge for other uses apart from generating biogas-based power. The revenue earned from this venture is, further, independent of the Annuity and O&M charges paid by NMCG, which encourages companies to adopt sustainable practices first hand in project development (12.6). To this effect, a Memorandum of Understanding has been signed with Indian Oil Corporation to reuse treated wastewater from STPs in Mathura Refinery. On successful completion of the pilot, a policy directive is envisaged to be drawn based on the responses and challenges in implementation.

SDG 13: Climate Action

SDG 13 addresses climate change mitigation and adaptation but explicitly acknowledges that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change. Given that the SDGs were developed at the same time as countries were negotiating a new international agreement on climate change, the targets under SDG 13 are few and less detailed, namely strengthening resilience and adaptive capacity to natural disasters (13.1), integrating climate change measures in national policies (13.2) and improving awareness and institutional capacity on climate change (13.3).

In line with the identified targets, Namami Gange has constantly endeavoured to promote mechanisms for raising capacity for effective climate change-related planning and management through its various initiatives.

NMCG is working with IIT Delhi to map out high resolution climate scenarios for basin-scale water resources management. One of the major outcomes of this project will be improved understanding and scientifically rigorous estimates of climate change and its impact on water resources in the Indo-Gangetic Plain.

The Ganga River Basin Management Plan clearly identifies climate change measures to arrest and reverse the degradation of Ganga River (13.2). NMCG on 9th October, 2018 notified the minimum ecological flow in the River Ganga required to be maintained at different points in different stretches at all times, starting from all the head streams of river Ganga up to Haridwar in Uttarakhand and from Haridwar to Unnao in Uttar Pradesh. A mechanism for monitoring of e-flow regime has also been put in place with the help of Central Water Commission. A similar exercise has also been initiated for some of the other important tributaries viz., Yamuna and Ramganga. National Institute of Hydrology has submitted the study report for assessment of environmental flows in river Yamuna for stretch starting from Hathnikund barrage to Okhla barrage.

SDG 14: Life below Water

SDG 14 on Life below Water addresses a set of problems becoming increasingly serious for reasons related to their direct impacts and the indirect stresses they place on the environment. SDG 14 has seven substantive targets and seven corresponding indicators that collectively aim to preserve the health and wellbeing of marine ecosystems. There are references to interventions to increase the economic benefits from the sustainable use of marine resources (14.7), and the ending of subsidies contributing to overfishing (14.6). There are also targets on the conservation of coastal and marine areas (14.5), sustainable fishing (14.4), and the reduction of ocean acidification (14.3). Lastly, there are targets to protect and restore marine ecosystems (14.2), and to reduce marine pollution (14.1).

River Ganga culminates at Gangasagar in West Bengal where it meets the Bay of Bengal and along with its natural components of deposition like water and silt, the river is also a carrier of anthropogenic discharges. Within the Namami Gange program, solid waste management is highly emphasised both in urban areas and rural hinterlands. A blanket ban has been imposed on dumping of any solid waste on ghats and in the vicinity of river for up to a distance of one kilometre of the drains from the point of meeting the river. Screens have been fixed at regular intervals to check any plastic miscreant and trash skimmers are used at certain points on the river to ensure surface cleaning. These efforts ensure minimising plastic pollution that ultimately meets the ocean (14.1). The treated discharge of effluents is constantly monitored for adherence to prescribed limits of Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO) level, which precursory reduces ocean acidification levels (14.3).

For the conservation of fish & fisheries of river Ganga, a project has been awarded to Central Fisheries Research Institute (CIFRI), Barrakpore under which ranching of indigenous fish species along with capacity building & improvement of livelihood of fishermen (14.9) is being done. A Hilsa fish ranching station has been established at Farakka, West Bengal by CIFRI for the restoration of Hilsa Fishery around Farakka Barrage to enhance the understanding of the upstream migration of Hilsa fish in Ganga and to promote sustainable fishing practices (14.4) in the region. Essentially a saltwater fish, the Hilsa is found in the Bay of Bengal, but it travels upwards through the various rivers and its tributaries during the spawning season.

SDG 15: Life on Land

In many ways, SDG 15 attempts to achieve similar objectives to SDG 14, but with a focus on terrestrial ecosystems. Terrestrial ecosystems are linked to almost all the SDGs because they provide a basis for many essential goods and services. SDG 15 has nine substantive targets and 11 corresponding indicators to monitor progress. These focus on integrating ecosystems and biodiversity into governmental planning (15.9), preventing invasive alien species on land and in water ecosystems (15.8), eliminating poaching and trafficking of protected species (15.7), promoting access to genetic resources and fair sharing of the benefits (15.6), protecting biodiversity and natural habitats (15.5), ensuring the conservation of mountain ecosystems (15.4), ending desertification and restoring degraded land (15.3), and ending deforestation and restoring degraded forests (15.2). All these targets contribute to ensuring the conservation and restoration of terrestrial and freshwater ecosystems (15.1).

Integrating wetland conservation in Ganga River Basin Management and effective operationalization of State Wetland Authorities for conservation of wetlands (15.1) along Ganga have enabled conservation measures to be spelled out for scientific conservation of these endangered terrestrial ecosystems. Namami Gange programme has initiated a project based on the proposal received from Uttar Pradesh State Wetland Authority for development of detailed briefs and Integrated Management Plans (IMPs) for 101 wetlands situated in 27 Ganga districts in the State for up to five kilometres on either side of the river. A specific project is underway for rejuvenation of 9 kunds in Varanasi. In the State of Uttarakhand again, the State Government has identified 51 wetlands for creating a database of the wetlands and preparing IMPs for their conservation. This is in line with the Wetlands (Conservation and Management) Rules, 2017, notified by Ministry of Environment, Forests & Climate Change to operationalize State Wetlands Authorities and identify priority wetlands to be taken up for management and conservation. NMCG is also implementing Forestry Interventions in Ganga as per the DPR prepared by Forest Research Institute, Dehradun in order to positively improve the health and rejuvenation capacity of river Ganga. Since launch of the program, an estimated 20,000 hectares of land have been brought under plantation in Ganga basin States. This measure has sustainably improved afforestation cover (15.2) and combated desertification that results from flood and drought in the region (15.3). The Ganga Basin, in its upper reaches, is endowed with springs, which are an important source of water for hilly settlements especially during lean flow periods. Ensuring conservation of these mountain ecosystems (15.4), a rejuvenation programme is underway for which, Survey of India, Dehradun and IIT, Roorkee have initiated a scientific mapping of the springs of Tehri Garhwal district in Uttarakhand.

One of NMCG's long-term visions for Ganga Rejuvenation is to restore the viable populations of biodiversity of the river Ganga. To address the threats to the aquatic biodiversity of Ganga, Wildlife Institute of India (WII), Dehradun was awarded a project for developing a science - based aquatic species restoration plan for Ganga River by involving multiple stakeholders. A special programme is in place for conservation of Gangetic River Dolphin – the national aquatic animal of India. It is one of the four freshwater dolphins in the world. Gangetic river dolphins fall under Schedule I of the Indian Wildlife (Protection) Act and have been declared an endangered species by the

International Union for Conservation of Nature (IUCN). Through these measures, Namami Gange programme envisages protection and prevention of the extinction of threatened species (15.5). These initiatives have systematically ingrained ecosystem and biodiversity values into national and local planning and development processes (15.9).

SDG 17: Partnerships for the Goals

SDG 17 seeks to strengthen the means of implementation and revitalizing global partnership for sustainable development. SDG 17 has 19 substantive targets, which focus on implementing all development assistance commitments (17.2), mobilizing financial resources (17.3), knowledge sharing and cooperation (17.6), promoting sustainable technologies (17.7), enhancing policy coherence (17.14) and global partnership (17.16) for sustainable development, encouraging effective public-private and civil society partnerships (17.17) and enhancing availability of reliable data (17.18) will further develop measures of progress (17.19) and will improve domestic taxation (17.1).

The World Bank is financially supporting Namami Gange programme with a loan of $1 billion for helping NMCG build institutional capacity (17.9) for rejuvenating the river. It is also financing key infrastructure investments in the five main stem states- Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal. Through it various approaches of ensuring achievement of identified progress indicators under National Ganga River Basin Management Plan, NMCG is progressively moving towards achieving all the identified development assistance commitments (17.2). Under the Namami Gange programme, access to science, technology and innovation has been improved through global partnerships like India-EU Water Partnership wherein knowledge sharing on mutually agreed terms is practised (17.6). Technological partnerships with Israel, GIZ - Germany and OISCA - Japan as well as project partnerships with PTB – Germany, UK and Scotland have strengthened the mission in developing state-of-the-art solutions that are attuned to global practices (17.7). In order to conserve the ecological integrity of the Ganga River, and, reduce the direct dependency of the local communities on the river, the NMCG and Wildlife Institute of India (WII) initiated a project aimed at preparing a science-based restoration plan by involving multiple stakeholders and the local community as guardians of the river and called them “Ganga Praharis”. The purpose of this initiative was to establish a motivated and trained cadre of Ganga Prahari to support the local level institutions and monitor the quality of the natural resources of the river by mobilizing local communities at the grassroots (17.17). Further, to improve data collection and reliability (17.18), KPMG has developed a Project Monitoring Tool for online tracking of progress of projects sanctioned under Namami Gange programme. The monitoring of water quality of river Ganga is being carried by State Pollution Control Boards (SPCBs) in 5 Ganga main stem States at 97 Manual Water Quality stations. Central Pollution Control Board compiles the data collected by these stations and also uses a network of 36 Real Time Water Quality Monitoring Stations to substantiate the figures. This practice will definitely enhance the progress measures and the design of the programme (17.19). A repository of knowledge database has been created under Ganga Knowledge Centre that continuously endeavours to document best practices in the program and internationally and nationally recognised practices that have a scope of replicability in the basin planning. An outline of relationship of river and Sustainable Development Goals is attempted in Figure 1. An integrated River Rejuvenation program like Namami Gange can make a substantial contribution towards attaining these goals. The interventions of Namami Gange are also interrelated as is the case with SDGs.

Conclusion

While the Namami Gange Programme has progressively attempted to address impending goals under the SDG framework, efforts that have a long gestation period like change in microclimate and air quality, improvement in soil fertility, enhancement in water quality and increase in green cover will take time till their benefits are fully materialised on ground. Similarly, short-term efforts of cleanliness and sanitation require a sustained practice and behavioural change of the end-user. The programme continues to endeavour quality in efforts, consistency in practice and incremental growth in the outreach to stakeholders.

The NMCG and its legal framework have been crucial in promoting cooperation at the basin level and thus ensuring a progressive approach towards attainment of SDGs. However, improvements in governance at many levels (e.g. at District and State level) are critical, together with the needs for technical solutions and a coordinated basin-wide investment strategy. The District Ganga Committee and State Ganga Committee that have been put in place will have to ensure sustainability of efforts of NMCG at the local level. Only then can the larger goal of localizing SDG and leaving no one behind will be fulfilled.

ANALYSIS AND CHARACTERIZATION OF HYDROLOGICAL DROUGHT UNDER CHANGING CLIMATIC CONDITIONS BASED ON SWAT MODEL USING GEOSPATIAL TECHNOLOGY IN AJAY RIVER BASIN

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Introduction

Climate change is a worldwide process that offers substantial difficulties to our planet and its inhabitants. It refers to long-term changes in weather patterns induced by human activity, especially the release of greenhouse gases, which result in an increase in global temperatures and a variety of interrelated effects. This concept brief attempts to offer an overview of climate change, its origins, repercussions, and the need for sustainable solutions to alleviate its effects.

Changes in the timing, intensity, and distribution of rainfall are being caused by climate change, which is changing regional and worldwide precipitation patterns. Elevated evapotranspiration rates can accelerate soil and plant drying due to elevated temperatures and changed air circulation patterns. This raises the possibility of protracted, severe droughts, which would have a domino effect on socioeconomic systems, food security, and water supplies. In turn, droughts may increase the effects of climate change by changing the structure and operation of ecosystems, species composition, and more. Droughts have a significant impact on ecosystems, changing species composition, ecological structure, and ecosystem functioning. Droughts have serious socioeconomic repercussions, including crop failures, decreased yields, and increased vulnerability of rural households.

Drought is generally defined as a “prolonged absence or marked deficiency of precipitation”, a “deficiency of precipitation that results in water shortage for some activity or for some group”, or a “period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance” (Brouziyne, Y., Abouabdillah et.al)

It is a slow-moving phenomenon that affects many sectors of the economy and works on many different time frames. As a result, the climatological community has classified drought into four types: There are four types of drought: meteorological drought, hydrological drought, agricultural drought, and socioeconomic drought. When dry weather patterns dominate a region, meteorological drought occurs. Hydrological drought occurs when there is insufficient water supply, particularly in streams, reservoirs, and groundwater levels, frequently following several months of meteorological drought.

Hydrological drought occurs when the surface flow (river flow) and lakes or reservoirs levels decline below long-term mean (Mishra and Singh, 2010; Van Loon, 2015). It can be also termed as stream flow drought (Clausen and Pearson, 1995). Hydrological drought assessment at a catchment scale is often difficult due to limited observed data sets. Moreover, from a water resources management point of view, the duration and severity analysis of a hydrological drought is essential. The information on duration of hydrological drought is predominantly crucial for lives in an aquatic ecosystem (Humphries and Baldwin,2003), and quantifying the drought severity is more important for abstraction of water from a stream for different purposes (e.g., hydropower production, mining, and domestic use). Similar to the other categories of drought, the anomalies in atmospheric processes initiates the hydrologic drought.

Objectives:

This study primarily focuses on three main objectives:

- To estimate future climate and land use land cover scenario of Ajay Basin.
- To perform a hydrological model for stream flow estimation.
- To identify the water stress zone in the Ajay Basin.
- To predict future potential drought prone zone in Ajay Basin

Study Area

The Ajay river basin is situated between the coordinate's 23°200–24°300N and 86°150–88°100E. The Ajay River Basin is mostly in the state of West Bengal, in the eastern region of India. The survey of India toposheet no72L/6,7,8,10,11,12,15,16, 73I/13,73M/1,2,5,6,7,10,11,14,15 and 79A/1 in the scale of 1:50,000 and 1:36,360 cover the Santhal Parganas plateau and the Ajay river catchment, which is located there. It encompasses the Jharkhand regions of Deoghar, Giridhi, and Dumka; the Munger and Jamui districts of Bihar; and the West Bengal regions of Burdwan and Birbhum. The Ajoy River rises in the forested hills of Chakai Block in the Munger District of Bihar, flows through Jharkhand for 132 kilometres before entering West Bengal near Kalipahari, where it flows for 144 kilometres before entering the Bhagirathi, a distributary river that rises out of Bengal,near Katwa.

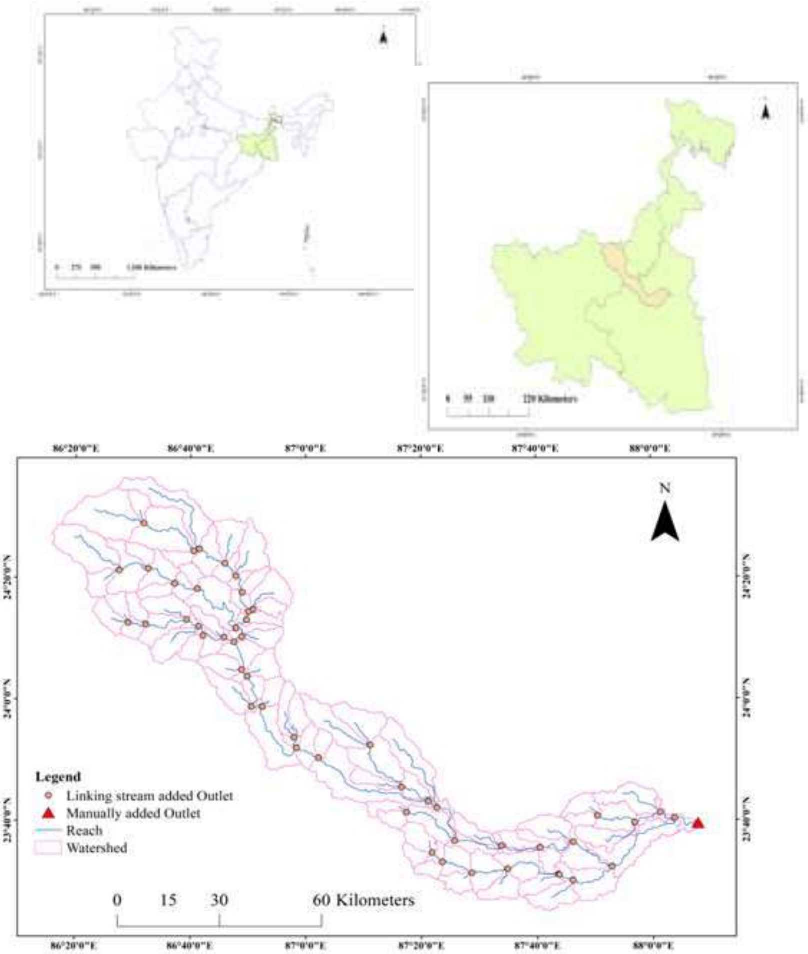

Fig 1 Location Map

It comes from a little hill in Bihar's south-west that is only 300 metres high. Afterward, it passes into Jharkhand until entering West Bengal at Simjuri, not far from Chittaranjan. Before ultimately entering the Katwa subdivision of Bardhaman district at Nareng village in Ketugram police station, it first forms the boundary between Bardhaman District and Jharkhand, then between Bardhaman District and Birbhum District. At Katwa Town, it then connects to the Bhagirathi River. The Ajay is 288 kilometres long overall, 152 km of which are in West Bengal.

Pathro and Jayanti in Jharkhand, as well as Tumuni and Kunur in West Bengal's Burdwan district, are the major tributaries of the Ajay. The Ajay's upper sections traverse mountainous terrain with latté rite soil. Alluvial plains are the sole place where the Ajay runs, and that is from Ausgram in Burdwan district. Up until recently, the Ajay valley was heavily covered in sal, piyasal, and palas trees. However, mining and other activities resulted in the loss of these forests.

The basin (Fig. 1), which has a basin size of 2881.65 km2, is located in the states of Bihar and Jharkhand between the longitudes of 86°16' E and 86°57' E and the latitudes of 23°57' N and 24°37' N. of general, and especially on uplands, the soils of the Ajay river basin are sandy and loamy sand, making them appear quite light at the surface. In the basin, the annual rainfall average ranges from 1280 to 1380 mm. In its lower reaches, the river flows on recently formed alluvium and is vulnerable to overflowing at very high discharge. The Ajay River has brief, showy, and unexpected floods.

High summertime temperatures in the Ajay River Basin are common, and during heatwaves such temperatures can rise significantly higher. Increased precipitation and cloud cover in the area during the monsoon season serve to chill the area down. After the monsoon season, the temperature slowly drops, with daily highs of 25 to 30 degrees Celsius (77 to 86 degrees Fahrenheit). In the basin, winter brings colder temperatures, with daytime highs of 15 to 25 degrees Celsius (59 to 77 degrees Fahrenheit) and lows of 5 to 15 degrees Celsius (41 to 59 degrees).

The southwest monsoon (June to September) is the main source of rainfall in the Ajay River Basin, which has a primarily monsoonal climate. The region receives 1,200 to 1,600 millimetres of rain on average each year, with variances occurring in different parts of the basin. Due to the monsoonal rainfall pattern, the river flow in the basin varies seasonally. Rainfall in the catchment region and tributary discharge control the hydrological regime in the basin. The basin's geography allows for the possibility of small-scale water storage and reservoir development. Water availability and storage in the area are largely used for irrigation. The Ajay River Basin in India is prone to both floods and droughts, with heavy rainfall in the monsoon season leading to flooding and water scarcity in the dry season.

The slopes in the Ajay River Basin range from gentle slopes in the plains to harsher gradients in hilly and mountainous regions. The altitude varies from 30 to 100 metres (98 to 328 feet) above sea level, with some summits rising to heights of several hundred metres to over a thousand metres (3,280 feet to 3,937 feet). The location and regional geological features determine the precise slope values.

Materials & Methods

4.1 Data Used:

The study is primarily based on secondary data acquired from different sources, which are following:

4.1.1 DEM

Elevation map has been generated from SRTM DEM with 30m resolution from 2014 which is collected from USGS Earth Explorer. (Fig 2.1)

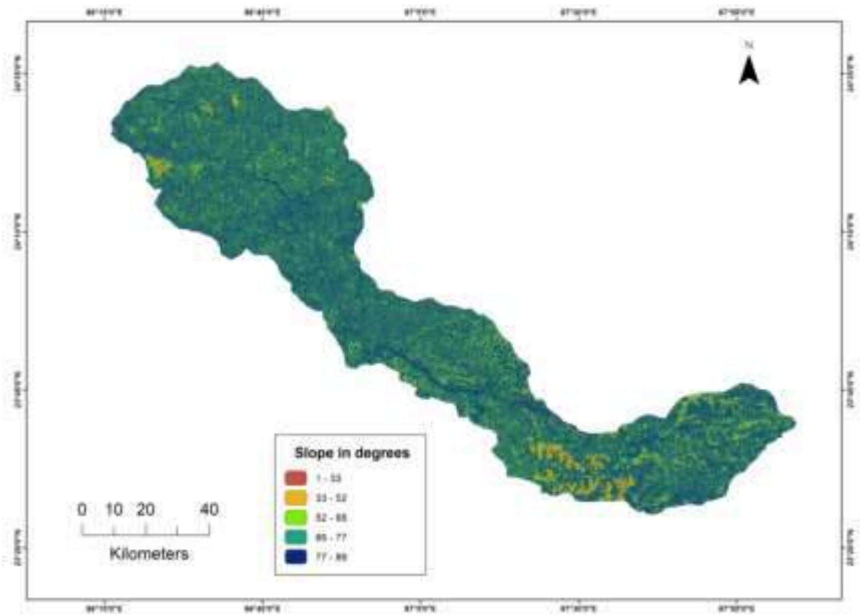

Fig: 2.1. Slope Map

4.1.2 Land use Map

A maximum likelihood algorithm (MLC) of supervised order classifier was used in the ArcGIS 10.8 programme to produce a LULC map in the chosen study area. In this study, seven major LULC classifications were determined based on visual analysis of Google Earth. For each of the LULC classes, more than 100 signatures have been collected to improve classification accuracy. For this study LULC map has been prepared for two consecutive years e.g., 2010 & 2020(Fig 3.1,3.2).The LULC maps has been prepared using Landsat 5 and Landsat 8 Satellite Image with 30m resolution. The supervised classification method has been used to prepare the LULC map.

4.1.3 Soil

he soil map has been extracted from National Bureau of Soil Survey & Land Use Planning. There are total 7 classes of soil. Mostly the region is covered by loamy soil, clay loam and sandy clay loam (Fig 2.2)

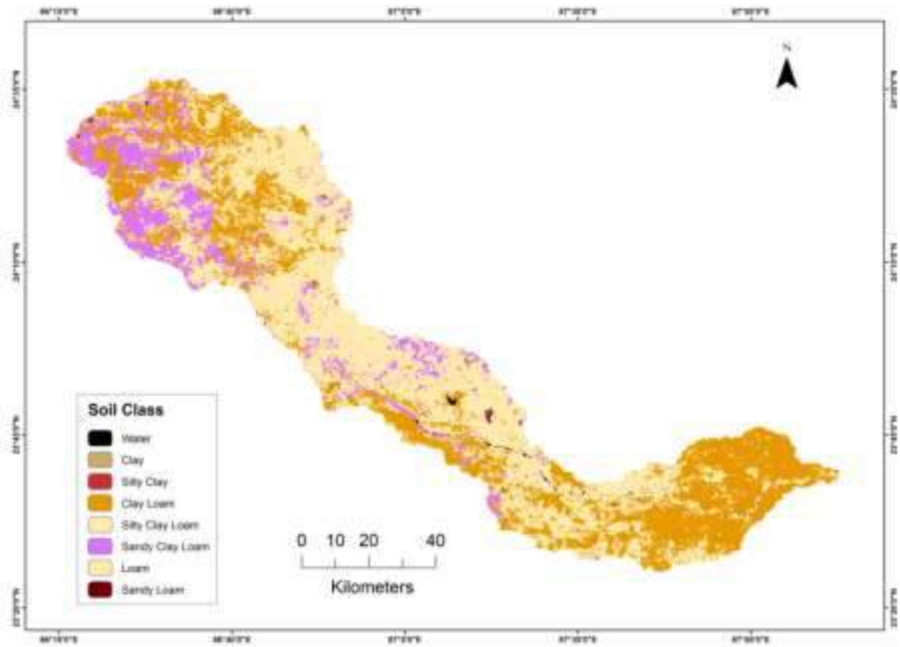

Fig: 2.2. Soil Map

4.1.4 Hydro-meteorological Data:

Projected climate data of Rainfall and temperature has been acquired from MIROC 5 climate model with RCP 4.5 scenario, IPCC assigned Coupled Model Inter-comparison Project, Phase 5 (CMIP5) database.

Sl. No.	Data Type	Source	Description
1.	Digital elevation model	https://earthexplorer.usgs.gov/ (accessed on 15th May, 2023)	SRTM DEM
2.	Satellite image	https://earthexplorer.usgs.gov/ (accessed on 16th May, 2023)	LANDSAT 5 (TM) LANDSAT 8 (OLI/TIRS C2 L2) image (Resolution 30 metres)
3.	Soil data	National Bureau of Soil Science & Land Use Planning	Soil texture map
4.	Rainfall data	MarkSim GCM - DSSAT	Annual Rainfall Data (2010-30)

4.2 Soft wares Used:

To conduct the study primarily three software has been used which are QGIS 2.8, ArcGIS 10.3 & 10.8, Arc SWAT 2012 and Google Earth Pro.

4.3 Methodology

4.3.1 Molusce Model:

The MOLUSCE plugin for Quantum GIS is user-friendly and designed for analysing, modelling, and simulating land use changes. It combines methods used in forestry, urban analysis, and land use/cover change analysis. MOLUSCE predicts land use transition locations and simulates future changes using Monte Carlo Cellular-automata model techniques. Sample data Sub-module Randomly selects user-specified sample points, which will be used for model calibration and validation Define Model Sub-module Four modelling methods are supported: Artificial Neural Networks (ANN), and Logistic Regression (LR), Multi-Criteria Evaluation (MCE) and Weights of Evidence (WoE).(Gismondi)

In this study CA-ANN model is applied to generate future LULC map of Ajay river basin. Two classified pictures were utilised in a 10-year interval (2010 & 2020) to prepare the anticipated LULC map in the CA- ANN simulation tab based on the Monte Carlo Algorithm. The two geographical variables NDVI and slope are employed. In this CA-ANN model, 500 number of iteration were demarcated to simulate the LULC mapping. The kappa validation value is 0.70751.

4.3.2 ArcSWAT Model:

The ARCSWAT model is a comprehensive hydrological modelling tool that combines the Soil and Water Assessment Tool (SWAT) with ArcGIS' Geographic Information System (GIS). It has various characteristics and capabilities that make it an important tool for watershed management, including hydrological modelling, land use/land cover analysis, climate change assessment, scenario analysis, and water quality evaluation. It models water balance, stream flow, sediment yield, and nutrient transport within a watershed while taking into account various hydrological processes.

SWAT splits a watershed into HRUs (Hydrologic Response Units), and all processes are estimated at the HRU scale. It employs the Soil Conservation Service curve number approach to record the rainfall-runoff connection and the SWAT model's daily water balance.

$$SW_t = SW_0 + (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})$$

Where,

SW_t: the daily final soil water content (mm H_2O)

SW_0: the initial soil water content on day i (mm H_2O);

t: the time (days);

R_{day}: the amount of precipitation on day i (mm H_2O);

Q_{surf}: the amount of surface runoff on day i (mm H_2O);

E_a: the amount of evapotranspiration on day i (mm H_2O);

W_{seep}: the amount of water entering the vadose zone from the soil profile on day i (mm H_2O);

Q_{gw}: the amount of return flow on day i (mm H_2O).

SWAT demands a large number of geographical and temporal input data sets. SWAT, being a semi-distributed model, must process, aggregate, and spatially analyse this data using GIS technologies. As a result, the model was integrated with GIS software as a free supplementary extension ArcSWAT for ArcGIS to enable its use.

4.3.2.1 Model Set Up:

For the research region, the whole database needed by the SWAT model has been created, and the model has been set up. With the use of DEM and ArcSWAT2012, we are able to define sub-watersheds automatically. To manually generate the mask and extract the ajay sub-catchment region from the model, a DEM file is loaded into the model. In the current study, the catchment area's exit was identified, the watershed was drawn, and all the parameters were computed for each sub basin . The watershed is reported to have a total size of 6105 km2. The research area has a maximum elevation of 89 degrees and a lowest elevation of 0 m. There are 101 sub basins in the watershed.

With the use of SWAT, we are able to incorporate soil and land use maps into the model, analyse slope characteristics, and establish land HRUs for every sub-watershed. For defining the land use layer, a land use category is employed, and a soil look-up table is used to define the kind of soil to be modelled for each category. Using the infiltration rate of the soil, the soil map divided the database into the 7 soil texture classification.

Additionally, the LULC map has been divided into 6 separate groups.The slope map is now divided into 5 classes, ranging from 1-33,33-52,352-66,66-77,77-89 in degrees.The data layers for soil, slope, and land use have then been combined. Within the watershed, the distribution of hydrologic response units (HRUs) has been identified. The watershed of the Ajay river generated 304 HRUs in total. A threshold percentage of 20% has been imposed for all land use, soil, and slope classes in order to exclude minor land use, slope, and soil.

The model needs daily temperature and precipitation data. The user may add the locations of weather stations to the current project using SWAT, and weather information can be assigned to the sub-watersheds. Here, daily rainfall data from 9 rain gauge stations from the same 30 years (1976 to 2005) have been used, together with daily maximum and lowest temperature data from 5 stations from the same 30 years. The Arc SWAT toolbar's "Write Input Tables" option is used to load weather data. With the help of this tool, users may add the locations of weather stations to the current project and link weather information to the sub-watersheds. Every sub-watershed has a gauge associated with it for every sort of loaded meteorological data. The initial input values for the watershed must be established before SWAT can be conducted.

4.3.2.2 SWAT Stimulation:

The SWAT Simulation menu enables users to complete the input configuration for the SWAT model, launch the SWAT model, carry out sensitivity analysis, and carry out auto-calibration.

4.3.3 TVDI:

The Temperature Vegetation Dryness Index (TVDI) is a drought indicator based on a scatterplot of Land Surface Temperature (LST) vs. Vegetation Index (VI).(Tang et al. (2010)) used contextual information from this connection to analyse soil moisture content and drought monitoring. The primary benefit of these approaches is that they represent moisture conditions rather than soil moisture, which is especially beneficial in vegetated regions. It is especially important when the goal of the research is to determine plant water availability rather than soil moisture value at some depth. The TVDI is used to estimate the drought effect of the Ajay river basin.

Temperature vegetation dryness index can be calculated as (Gao et al. 2011)

$$\text{TVDI} = \frac{\text{Ts} - \text{Tsmin}}{\text{Tsmax} - \text{Tsmin}}$$

Where,

Tsmin is the minimum LST given the NDVI along the wet edge (K)

Tsmax is the maximum LST given the NDVI along the dry edge (K)

Ts is the LST in any given pixel (K)

Result and Discussion

5.1. Future Prediction of LULC:

Using the 2010 and 2020 LULC maps (Fig 3.1,3.2) as input, the CA-ANN model is utilised to generate future LULC maps for the years 2030. In the study area from 2010 to 2030(Fig 3.3) , model results indicate a sharp decline in agricultural land area and a rise in range land. An expansion of mining area is observed. Due to urbanization the rate of population density is increasing therefore the percentage of built-up area is also higher in

2030 compared to 2010 and 2020.Decrasing rate of agricultural land indicates poor soil conditions and fertility and the effect of climate change will lead to water scarcity therefore lowering the agricultural potentiality of the region and negatively affect the livelihood of people in the study area.

5.2. Future prediction of hydro climatic parameters:

This study shows the characterization of hydrological drought in Ajay Basin with changing climatic conditions. SWAT Model has been used to generate the flow accumulation, watershed delineation, stream network and sub basin delineation.

SWAT Stimulation has used to generate Evapotranspiration (ET), Potential Evapotranspiration (PET) and Precipitation over the sub basin area. It projected the future trends in climatic factors from the year 2010 to 2030.A future prediction or possible scenario can be determined from the results.

5.2.1. Rainfall: Water that has been discharged from clouds as rain, freezing rain, sleet, snow, or hail is known as precipitation. It is the key link in the water cycle that ensures atmospheric water is delivered to the Earth.

In the study area, 30 (2010, 2020, 2030) years of rainfall is calculated. Due to climate change the rainfall pattern of the study area experienced a decreasing trend which indicates drought situation in future.(Fig 4.1,4.2.,4.3)

The lower reach of the basin receives higher precipitation whereas in the upper reach some pockets such as Nawada point and Patharda Pahar receives higher amount of precipitation.

5.2.2. Evapotranspiration: Water moving from the ground surface to the atmosphere through evaporation and transpiration is collectively referred to as evapotranspiration. Evapotranspiration is the sum of water evaporation from the soil surface, the groundwater table's capillary edge, and land-based bodies of water into the atmosphere. Transpiration, or the water transfer from the soil to the atmosphere via plants, is also a component of evapotranspiration. Transpiration is the process through which plants absorb liquid water from the soil and expel water vapour into the atmosphere through their leaves.

In the study area 30 years evapotranspiration has been calculated (Fig 5.1, 5.2, 5.3). It has been observed that the rate of ET is higher lower reach and some pockets of upper reach due to the presence of hills. The portion of the basin receives moderate amount of ET. Changing climatic conditions negatively affects ET. In future map, the rate of average ET projects a decreasing trend in lower reach of the basin.

5.2.3. Potential Evapotranspiration: Potential evapotranspiration involves both potential soil evaporation and plant transpiration. Only when the amount of water available for this process is non-limiting does it happen at the potential pace. The rate of evaporation is influenced by climatic factors, including the solar radiation, wind, the air's vapour deficit, and temperature.

The 30 years of PET calculation shows an increasing trend towards future .The rate of PET determines the aridity of a region. Higher rate of PET signifies drought conditions. In the ajay river basin PET is higher in the middle portion (Fig 6.1) and it shifted towards lower reach of the basin (Fig 6.3).Future prediction map of PET shows potential drought scenario in lower reach. To predict the water stress zones the main factor needed is aridity. Aridity is determined by evaporation, precipitation and evapotranspiration. In ajay basin it can be seen that that rate of precipitation is decreasing towards the middle to lower part of the basin whereas it increased in upper part of the basin. Due to climate change inducing factors the overall rate of precipitation is decreasing. In upper part of the basin the presence of nawada pahar influences the higher rate of precipitation. The changing pattern of PET also determines the potential aridity of the Ajay basin. If the rate of PET is higher than ET the region will get drier over the time which can be seen in the study area.

5.2.4 Water Yield: Water yield is an estimate of freshwater input (for example, rain, snow and snowmelt) flowing into streams and rivers. Higher water yield represents higher soil moisture whereas lower water yield represents drought conditions. In the study area higher rate of water yield can be observed in lower portion of the basin which consequently decreases through time. Due to climate change the water yield will eventually decrease with time therefore drought prone areas will increase in quantity.

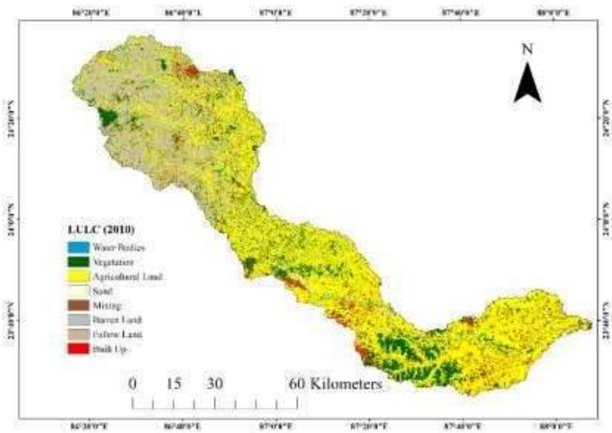

Fig: 3.1 Land use and Land cover map of 2010

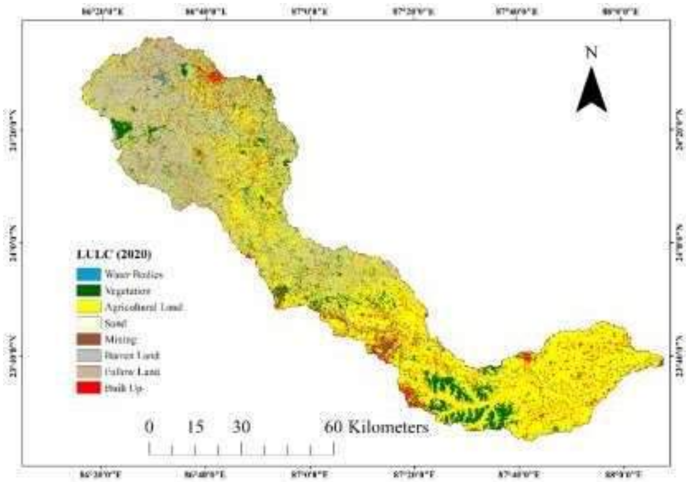

Fig: 3.2 Land use and Land cover map of 2020

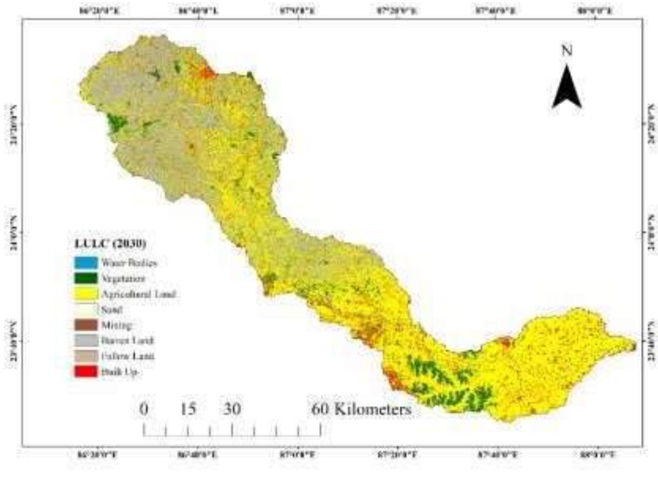

Fig: 3.3 Land use and Land cover map of 2030

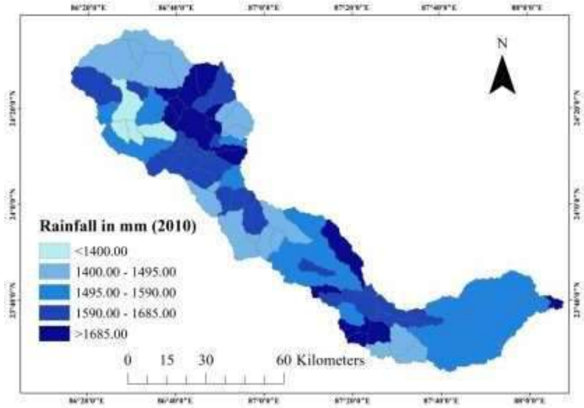

Fig: 4.1 Rainfall Map of 2010

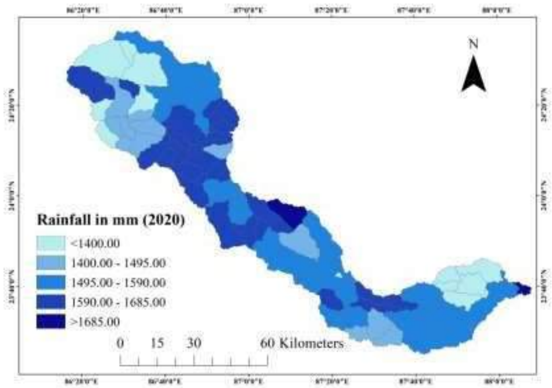

Fig: 4.2 Rainfall Map of 2020

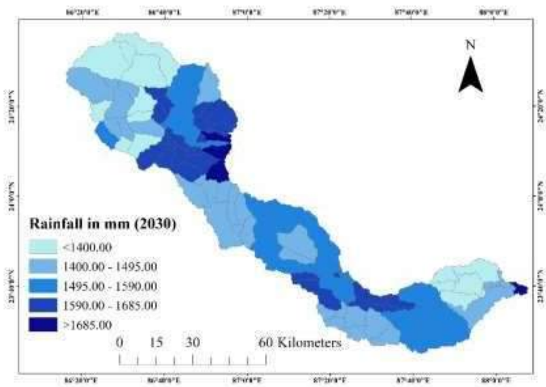

Fig: 4.3 Rainfall Map of 2030

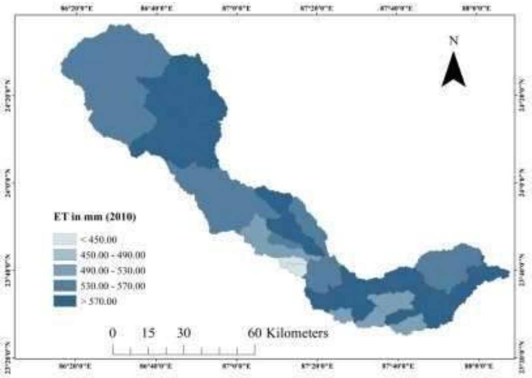

Fig: 5.1 Evapotranspiration map of 2010

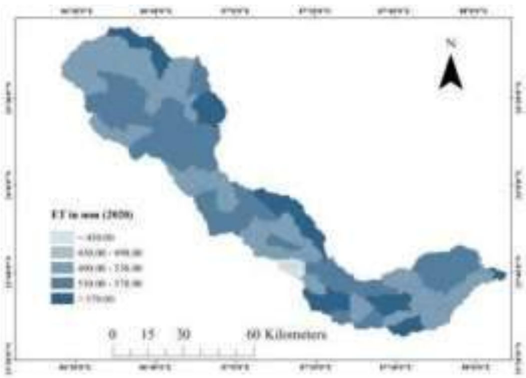

Fig: 5.2 Evapotranspiration map of 2020

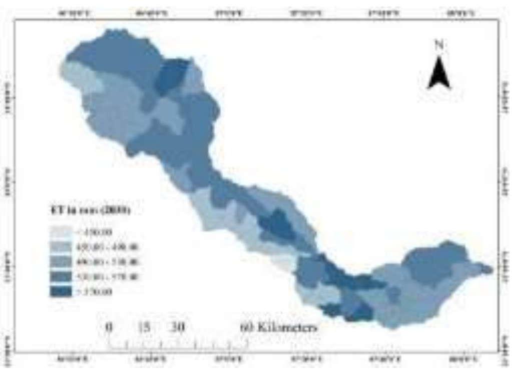

Fig: 5.3 Evapotranspiration map of 2030

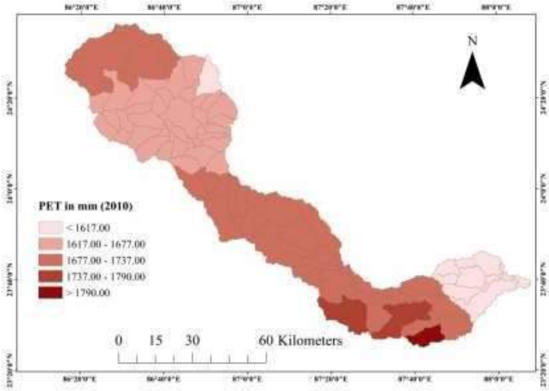

Fig: 6.1 Potential Evapotranspiration map of 2010

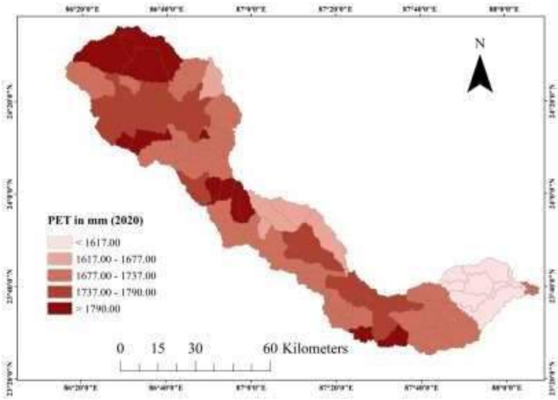

Fig: 6.2 Potential Evapotranspiration map of 2020

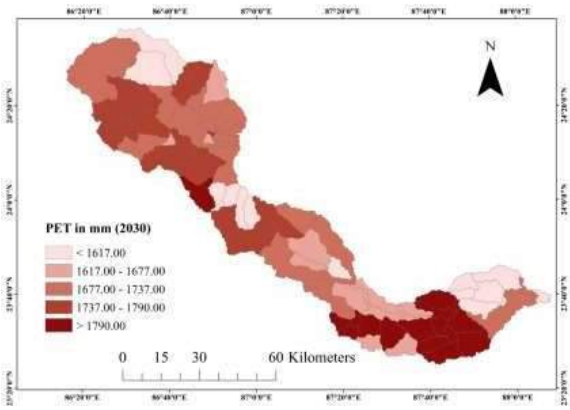

Fig: 6.3 Potential Evapotranspiration map of 2030

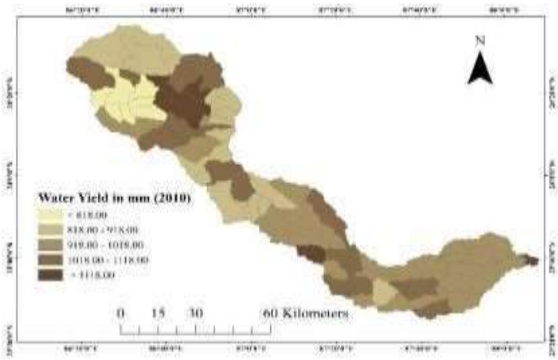

Fig: 7.1 Water Yield Map of 2010

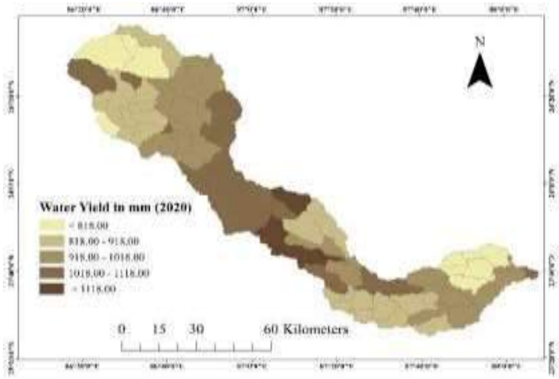

Fig: 7.2 Water Yield Map of 2020

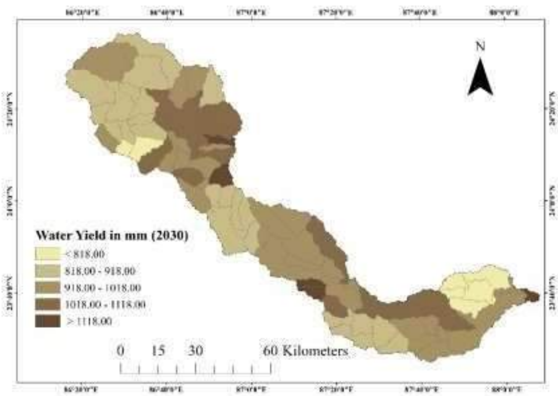

Fig: 7.3 Water Yield Map of 2030

Analysis of TVDI:

TVDI stands for indirect soil moisture status estimate based on remote sensing. TVDI is used to evaluate the effects of the drought on the Ajay River basin. From the dry (1) and wet (0) pixels of the derived information (LST and NDVI), it is determined (ranges from 0 to 1). For the proposed command area, NDVI and LST have a fairly positive correlation. The Ajay River basin has TVDI values ranging from 0.14 (lowest) to 0.37 (highest) (Fig. 5). High and low values correspond to the river basin's high and low water stress/drought zones, respectively. Higher TVDI value can be observed in western part of the basin which Jharkhand region and in some pockets of middle portion of the basin due increasing mining activity. TVDI value is comparatively lower in the eastern part of the basin.

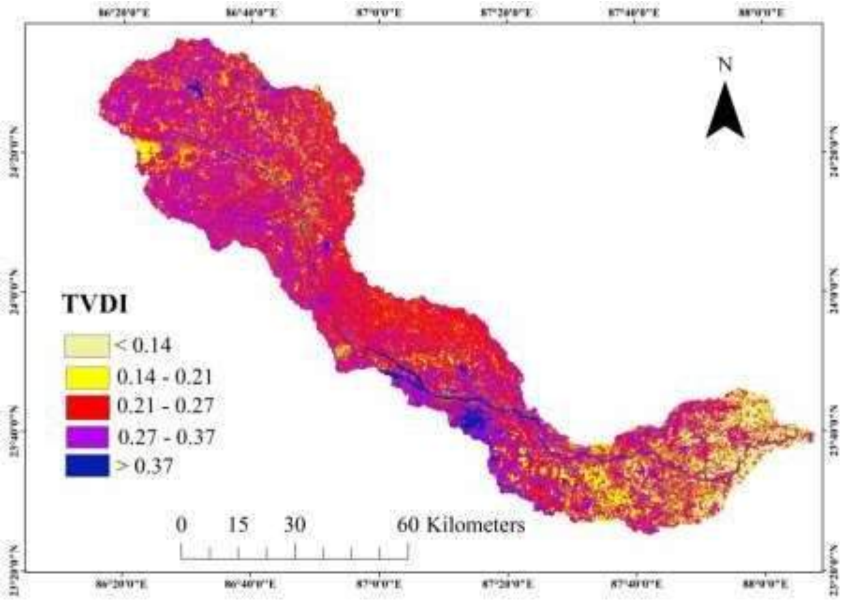

Fig: 8: TVDI map of Ajay River Basin

Conclusion

In this study the analysis and characterization of hydrological drought under changing climatic condition has been performed using three models e.g., MOLUSCE, CMIP 5 and Arc SWAT. CA-ANN model was simulated and predicted effectively for the LULC changes in theAjay River basin for the year of 2030 by using MOLUSCE Plugin. Twenty-one years rainfall and temperature has been taken for CMIP 5 model. Watershed delineation, stream flow stimulation has been carried out in Arc SWAT. The interrelationship between future land use and hydro climatic parameters is determined in this study. It has been observed that the with changing climatic conditions hydro climatic parameters e.g., rainfall, ET, PET, water yield are altering drastically. The effect of climate change can be seen in decreased rate of rainfall, lower ET a constant increase in PET which further enunciate the potentially increased drought prone areas. Future prediction indicates an increased percentage of barren land and decreased rate of agricultural land. TVDI shows the relation between land surface temperature and vegetation which indicates the potential drought prone zones of Ajay River basin in future. The study shows the potential drought prone zones of Ajay River basin. Mostly lower reach of the basin is becoming a water scare region lower rainfall, higher PET and lower water yield which can be determined as an effect of climate change. Therefore, increasing drought like condition will negatively affect the land use such as decrease rate agricultural land and increasing barren lands which lower the potentially agriculture and quality of crops which will eventually affect the livelihood of the people of the Ajay River basin.

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