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River regulation and associated geo-environmental problems: A case study of lower reaches of shilabati river basin, west Bengal, India

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Abstract
Since the very early civilization, rivers have been a vital source of livelihood for millions of people. Human use of river water had significant direct and indirect impacts upon fluvial environment in the form of river regulation. The processes of river regulation introduce short and long-term changes land-use and land-cover in morphology of the river basin. The present paper attempts to identify the spatial dimensions of river regulation in lower reaches of Silabati River and analyse the impact of human activities on morphology and ecological setting of the flood plains in parts of lower Silabati river basin, West Bengal, by using remote sensing and GIS techniques. The study is primary based upon field survey along with the consultation of toposheet and satellite imagery. The secondary information has been collected from Ghatal block development authority of the region. The key parameters considered for this change are interlinking channels, cross valley, meander scars, sinuosity index and water logged area. The study concludes that in-channel morphology is dominated by glides and relatively fast flowing features; whereas the effect of abstraction created in regulation section reaches is dominated by slow flowing pool type dynamics. The dynamics of the off-channel are also regulated by the human beings for reclaiming the land for agricultural purposes.

Keywords: river basin regulation, human intervention, landscape ecology.

Introduction

River has use long been an important element in human activities and socio-economic development. It is used for domestic, industrial and agriculture purposes. Farmers need more water for agriculture during summer when stream channels dry up. Generally dry climate and variable stream flow have resulted in need for a high degree of river regulation to provide supply with appropriate security at different times of the year. River regulation is the most common cause of alteration in the natural flow regime of rivers and streams. River and stream ecosystem refer to the whole system from headwater to the mouth and so include the channel, any associated floodplain system and also estuary or terminal lake (Chandra, S. 2003) [1]. So, the fluvial channels usually maintain specific physical characteristics, flow regimes and capacity for sediment transportation controlled by the hydrodynamic environment of existing river basin. The hydraulic structure developed across the flow path creates a strong perturbation of fluvial dynamic, changing the natural cycle of the river and intervening in the transportation and deposition process, together with a reduction of biodiversity by destroying the natural habitat of many species and turn into hazards (Mandal, and Sivaramakrishnan). Fluvial hazards include both flooding and river bank erosion. The regulation of river channels is primarily dependent upon the flow rate and slope of the river and the type of soil that make up its bottom and bank. This is because of the different conditions under which river is formed (diverse hydraulic regime flow rate depth), the deformation of the channel over the length of the river varies – in the upper reaches of bottom erosion, usually predominates whereas in the lower reaches sedimentation prevails. Prior work Adnan, s. (1991) [2]. Suggested that the task of the river regulation is carried out most successively by the joint application of two methods:

I. Regulation of the streams by construction of reservoirs that source discharge.

II. Regulation of the destructive erosion activity of water in a river channel by a regulating structure.

The effect of regulating and diverting the water resource has had a long term impact on the aquatic ecosystem of the river and stream and associated estuaries and floodplains which affect species diversity and abundance of a variety of aquatic and semi aquatic animals including the invertebrates fishes. The present study propose to analyse the impact of river regulation in the fluviomorphological structure and flood plain ecological setting in lower parts of Shilabati river basin, in West Bengal. The study area is the Ghatal Block located at the lower reaches of shilabati river catchment and administratively is located within Ghatal subdivision of Paschim Mednipur district of west Bengal. As a Ghatal block falls within the micro-watershed of Shilabati River, therefore from the hydrologic point of view, the effect of overland flow rather than the effect of the channel flow is a dominating factor as the channel storage capacity of small watershed is limited. More over a small watershed is play vital role to high intensity rainfall of short duration and changing the landscape pattern. The river banks are high and the river itself is narrow here. In winter season the rain fall very low and is further reduced its end by being taken off for irrigation the spring crop. But in monsoon the river become extremely vulnerable and therefore

flooding a huge areal extant. So, the impact of river regulation varies according to their magnitude:

I. On channel modification included widening, dredging and straightening of channel.

II. Release of water form storage for hydro-electricity generation or irrigation can abnormally rapid change in water depth and speed.

2. Objectives

i. To identify the spatial dimension of river regulation in lower reaches of Silabati river basin.

ii. To identify the human impact on riverine environment in the basin are.

iii. To identify alternative measure the maintaining the ecological balance in the study area.

3. Study Area

The Shilabati river basin is located 22^0 35'5''to 22^0 47'37'' north and $87^0$36'22'' east to $87^0$49'8''east in southern part of Gahtal subdivision of the Pashim Mednipur district of West Bengal, covering of an area of 229.91 sq. km. The basin falls under transition zone of undulating Chotanagpur Plateau in west to the greater Ganga plain area in the east. The study area Ghatal situated in lower catchment of Shilabati River, which originates from the Chotanagpur Plateau. The average height of this junction is 12m from mean sea level. The junction areas are characterized by a sequence of pools and riffles. The tidal bore of lower magnitude is an important phenomenon at the junction. The physical factors selected to study land degradation of the basin include its geology, soil, relief, slope, geomorphology, groundwater, rainfall intensity, green biomass cover etc. The study area has a tropical monsoon climate with mean annual rainfall ranging between 250 to 300mm. Excessive monsoonal rainfall is confined to a period between July to September. Mean monthly temperature is 26^0 C. The cyclonic activity on the head of Bay of Bengal from month of October to November is also causes of floods in this block.

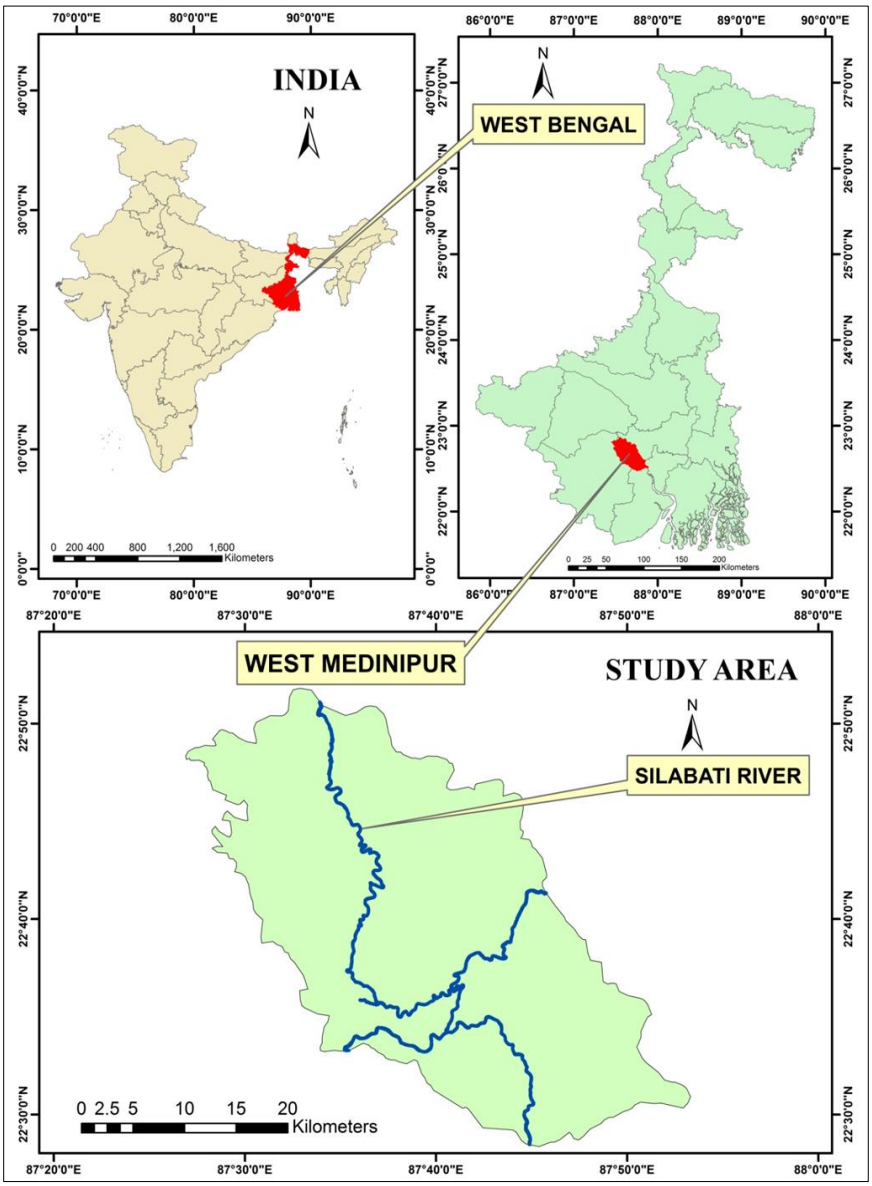

Fig 1: Study area Map

4. Data Base

The study is primarily based upon primary field survey along with the consultation of topographical sheet and satellite imagery. The secondary data along with their source are the toposheets from survey of India, climatic data (rainfall) ,ground water table, water yielding capacity etc.are collected from Ghatal sub divisional office, Gram Panchayat office of surrounding villages, Office of the Block Development Officer, District Magistrate office-Paschim Medinipur, Various published books, journals, memoirs etc. The primary data related tom flood plain of river rine environment, ground water table status are collected by conducting field work. Various methods are adapted for proper analysis and interpretation of the study area. The use of remote sensing and GIS technique has been integrated into mapping and analysis of such geomorphic process within natural hazard context; however the present study is conducted by the interpretation of remote sensing and GIS analysis along with geographical observation. The impact of bank erosion in the regulated river is described in the study area.

Table 1: Month wise rainfall chart (Shilabti development authority)

Month	Rainfall in mm.		
	2013	2012	2011
January	0	0	0
February	35.6	36.6	37.7
March	128.7	122.7	132.6
April	54	64	56
May	182.2	158.7	147.3
Jun	333.6	340.6	339.1
July	1092.7	1127	1198
August	356	355	361
September	442.5	338.6	498.6
October	52.8	78.7	69
November	31.6	35	38
December	0	0	10.2

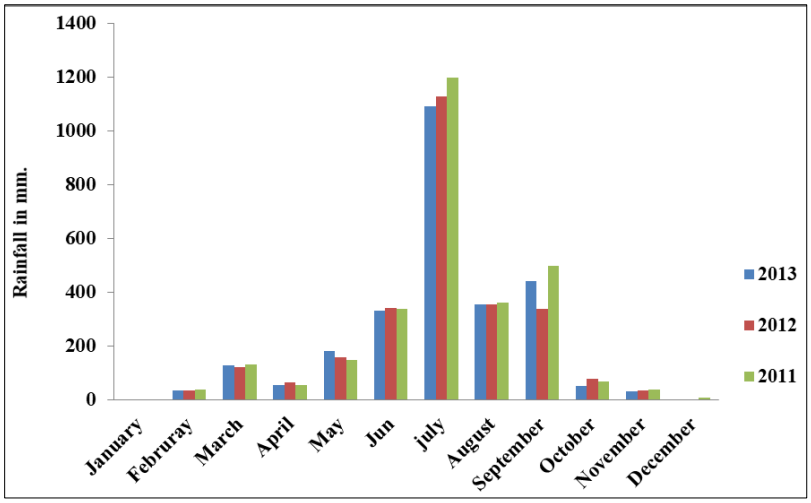

Fig 2: Month wise rainfall in various year of the study are

5. Methodology

The present work is concerned with investigation of Shilabati river basin of Paschim Mednipur district using satellite data, topographical sheet map interpretation along with the field observation. Precision Landmass (1971), Landsat TM (1972, 2005, 2006, and 2011) and topographical sheet no on 1; 50,000n scale of (1972-2011) have been used. The secondary information has been collected from the Ghatal subdivision office, district magistrate office of Paschim Mednipur. The visual interpretation is carried out to the identify map and geo-tectonic elements such as, ton, texture, size, shape, association have been used to interpret river regulation on the flood plain ecology. The analysis has been done with the help of field investigation at three stages, i.e. pre-field interpretation, post-field interpretation and field modification. The bank line and central line for different periods have been digitized and analysed using ARS GIS software. For the pattern identification as well as for the changes, channel sinuosity index (SI) have been calculated using following formula.

[SI= (channel Length/Straight Line Valley Length)]

Channel bar features have been identified through the visual interpretation of the satellite imageries. Bar areas have been calculated using Arc GIS for different time periods. The land use /landcover category was assigned a unique id.in the polygon coverage. The polygon coverage was transformed using sub modules available in the Ars GIS 8.0 version. Then on the basis of the field survey the problem of each landscape ecological unit (LEU‘s) in the micro region has been identified. Appropriate measures have also been suggested for sustainable land use planning and management. The study discusses the orientation of lineament mechanism of bank erosion orientation and development bar and channel shift in the reaches of Silabati river basin which are vulnerable to braches of the embankment.

6. Result and Discussion

The present study is an attempt to analyse the drainage and terrain characteristics of a typical drainage basin- the Silabati river basin that lies in Paschim Mednipur in the state of West Bengal .The entire drainage system reflects a meandering channel but the drainage pattern of the river shows variation according to local differences in slope and seasonal distribution of surface water. First, an ill-drained drainage pattern appeared in the source region of the river and another type of drainage pattern is developed of

the interfluvial areas where water shallow depression in prominent. The various properties of the basin have been deals with a sizable number of facts to examined their importance by using a variety of technique such as the channel pattern, meandering, floodplain sediment, serial avulsion and none equilibrium fluvial conditions leading to marsh flood out. The flood way zone of the river is highly meandering having a 'S' curve, pools, oxbow, point bars, meander scrolls, areas of death water, sand and gravel beaches are the main characteristics' feature occurring in this zone. The outflow zone occurs in the area of the Rupnarayana River where during heavy rains the channels flow is much more frequent than in upper segment of the river. This situation is caused heavy flood. As a result, one side of these becomes barrier to discharge excess flood water and in outer side as the internal areas of the river bed is lower than the river bank, resulting in critical problem of drainage.

The major cause of floods in the basin area is that a low pressure and depression prevails over the basin during the monsoons. These catchment areas are located in low pressure zone, thus the monsoon trough passes through the catchment area and causes heavy rainfall in the month of July and August. The Geomorphological factors are

I. Catchment size

Ghatal is a junctionpoint of kangsabati and shilabati river and the combination flow of Rupnarayan river.so in monsoon season two river carry on huge amount water and when meet junction point of Ghatal, water is overflow. Because catchment size of river is not enough.

II. Catchment shape

The actual width of the river shilabati is 50 m. the increase volume of water due tidal effect is one important cause for the flooding.

III. High sinuosity index

High sinuosity and very low gradient in the lower reaches of the Silabati River is one of main cause of flooding.

Table 2: Depth and Duration of flood water and inundated area in Ghatal Block and adjacent areas

YEAR	More than 30days		More than 15 Days	
	Area (sq.km)	Depth (m)	Area (sq.km)	Depth (m)
1959	100	2.00	184	1.50
1967	100	2.50	69	1.50
1968	350	2.50	308	2.00-1.00
1973	208	3.00	150	2.00-1.00
1974	61	3.00	102	2.00-1.00
1975	104	2.50	110	2.00-1.00
1976	55	2.50	104	2.00-1.00
1977	100	3.50	130	2.00-1.00
1978	710	3.50	356	2.00-1.00
1999	78	3.00	100	2.00-1.00
2000	80	3.00	121	2.00-1.00
2007	233	3.00	400	2.00-1.00
2013	245	3.00	275	2.00-1.00

Source: Ghatal Block Development Authorit

The area of the flood has been identified considering the opinion of stakeholders during the field survey. The flood of 1978 and 2007 were massive and cover 356sq km and 400 sq. km. of the basin. Another flood affected map has been collected from the Block Development Authority. There are some pockets in the basin (mostly riverslide flood plainarea) which are inundated every year.

The right bank of the river at Ghatal has been embanked by the high dyke (bandh) were left bank is open and there are no such construction. So during monsoon season left side flood plain of the river is inundated. It is because the right bank floodplain consist of 81 mouza with high population, small town, vast agriculture field were left bank is less populated for the save right bank flood plain. The every year flooded area is 38.30 sq. km which mainly covers the left bank floodplain

6.1 Channel Pattern

In the geomorphology the term 'river channel' refers to the through like form which contains a river and is shaped by the force of water flowing along it (Whittow 1984). Channels generally transport water and materials from the drainage basin in an effort to quality erosion. The channel pattern differs from one stream to anther stream due to difference in geological history, stream slope, discharge pattern, sediment load and time. The channel patterns mainly are meandering, braided and anastomosing. The study area of shilabati river basin was divided on the basic of channel curvature. This river has very high sinuosity index (1.8) and gradient of 9.5 cm/km from plateau (in the district of Puruliya to Garbeta), while the gradient from Garbeta to Ghatal town is 7.5. The gradient is Very low from Ghatal town to Dashpur village results in heavy piling up of floodwater. The high sinuosity index in these stretches will lead to pattern change.

6.2 Channel Shifting

The process of bank erosion and aggradations are the main cause for the shifting of river channel and evolution of different channel form. The channel shift in lower reaches of shilabati river basin is mainly associated with the flood. The effect of channel shifts mainly the loss of vulnerable arable land along the bank. Extension and downstream movement of meander with an acute angle are very common the lower part of shilabati river. One bank

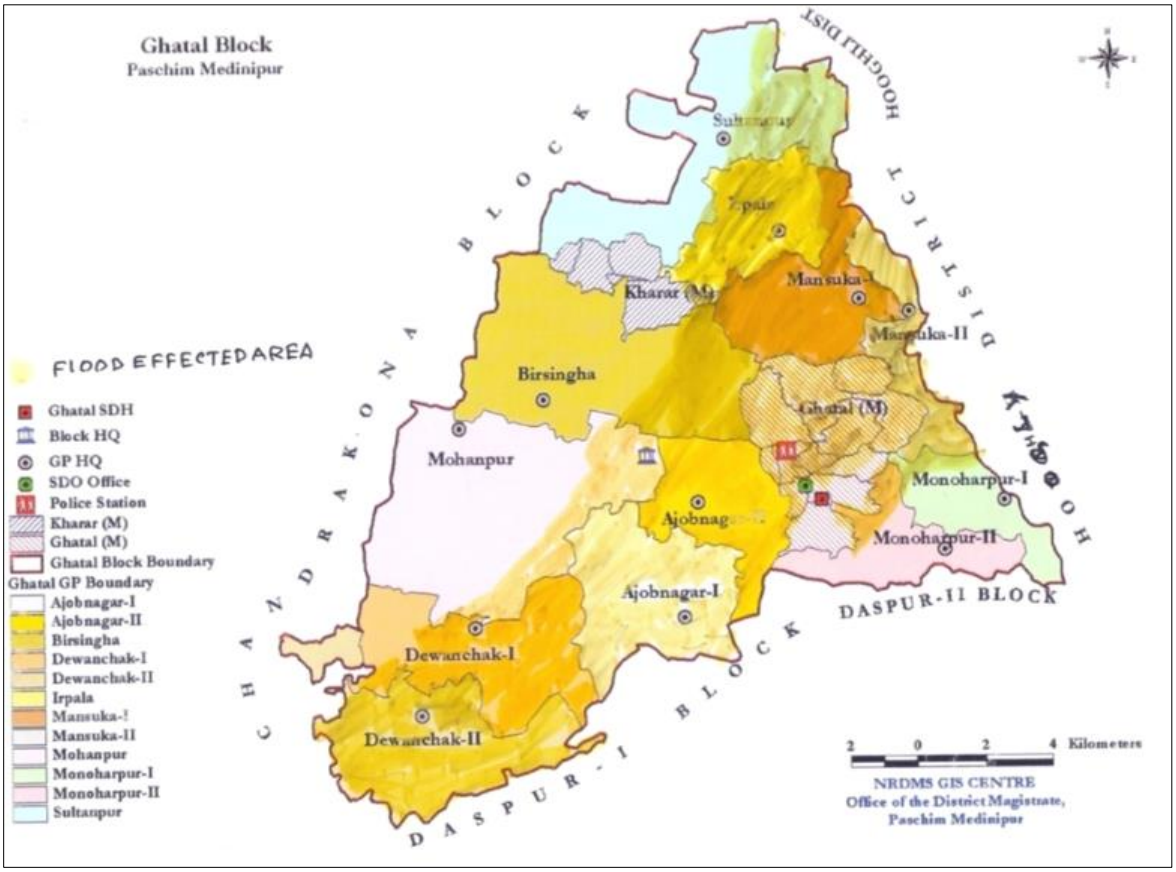

Fig 3: Flood effected area map, (Source: Block Development Authority)

is very high as well as steep, while the other bank is low and gently sloping with natural levee. These sides of river are mainly formed by accretion. Paleo-channels have formed the depression that is annually filed up by the water either overflowing from the river and its tributaries or by rain water during the monsoon season. It is significant that that the upstream and downstream section of the study area is associated with channel shifting over the studied period. From 1973 to 2012, the width of the upstream section has reduced ~300 m. In this similar fashion, the downstream section of the bridges has experienced with channel shifting along with the reduction of width (~700 m) of the channel. The changes of the channel properties and lateral oscillation may be for the several anthropogenic activities. Sand extraction in the upstream of the bridges causes the change in the channel morphology. Mainly wet-pit mining is dominant, and this changes the riffle-pool sequence of the reach. So the changes in fluvial processes are associated with the changes in the channel properties.

6.3 Dredging of sediment from river bed

The Shilabti River has a long history of its development, thus there is huge accumulation of sediment found in the channel bed, especially in the lower reaches. To increase the water carrying capacity of the river, even in the monsoon, the river should be dredged on regular basis.

6.4 Flow Regime of Shilabati River

Flow regime of rivers is generally thought to have function of determining and maintaining the shape of the channel. During the Field survey it was observed that the lower part of this basin has a high Sinuosity Index (1.8) and rate of bank erosion is very high. The thalweg orientation in meandering channel largely controls the severity of bank erosion. During the floods, the wag shifts and causes serve erosion. Summer flow in the mid and lower part of the river greatly increases due to large volume of water release from the reservoir to feed the irrigation channels. This is in contrast with pre-regulation period when summer flow would commonly be low. But the winter flow regime remains less altered by regulation, although there is some reduction of flow as reservoirs are replenished and there is decrease in the incidence of small to moderate floods. So, without natural flooding the river channel can decrease in size, reducing the water depth, Felling in pool and some other habitant.

6.5 Impact of River Regulation

This study demonstrates that the impact of river regulation is evident in a dominant region. In-channel morphology is dominated by glides and relatively fast flowing features, whereas the effect of abstraction in the regulated section creates reaches dominated by slow flowing pool type dynamic. The dynamics of the off-channel are also regulated by the humans for reclaiming the land for agriculture purpose. The Silabati river flood plains are formed by a combination of lateral (with in channel) and vertical accretion (over bank) process. Lateral accretion occurs when the bed load deposits tend to be relatively flat and featureless.

The vertical accretion deposits also accumulate in paleo-channel and cut-offs. All the factorsare related to the changes in the

morphology of river and help in managing problems with land and designing maintains programme. The study suggests that in Silabati river under the flow condition present during survey, flow regulation altered the dominant type of wetland present significantly reduce the size of the wetland and effect the horizontal distribution of types by reducing habitat connectivity. The channel dynamics need to be addressed in order to ascertain the problem of floodplain habitats.

6.5.1 Impact of Arable Land

Arable land along the river is extensively used for agriculture practices and settlement in this basin. Increasing population density and construction of embankments brought more and more land under cultivation and other usage. While 30 percent are not at all depend on the cultivation the rest 70 percent is directly and indirectly involved with this agriculture practice. But during flood season, any change in river coarse bringing enormous loss tocropland. The main problem of this region is inundation, causing the damage to kharif crops ie. Paddy and vegetables. Fertility of soil often increase when the river deposits new silt and clay, on the hand coarse sand deposits in the agriculture field could convert it to a agriculture waste land for a prolonged period (Kishor, G. 2004) [3].

So erosion and deposition along the channel are recurrent and complex phenomena in the active flood plain because of changing the river channel or river regulation. An investigation of the spatial configuration of landform and land use within riparian tract was made, it also examined that how spatial pattern of agriculture, forest and other land uses measured at both landscape and class levels (fig: 4) related to land quality fromlandscape ecological perspective. The result indicates that the land form and land use is closely associated with both proportion of land quality and the configuration

Table 3: Landuse/Land cover classes' statistics.

S. no	Landuse/landcover classes	Area in hec.
1	Agriculture	28815.31
2	Dense Forest	48375.58
3	Low dense Forest	59388.17
4	Blank Forest	99007.39
5	Wet Agriculture Fallow	57060.86
6	Dry Agriculture Fallow	49844.71
7	Sand	530.7988
8	River Water	11223.58
9	Gully	51258.3
10	Stagnant Water	4888.066

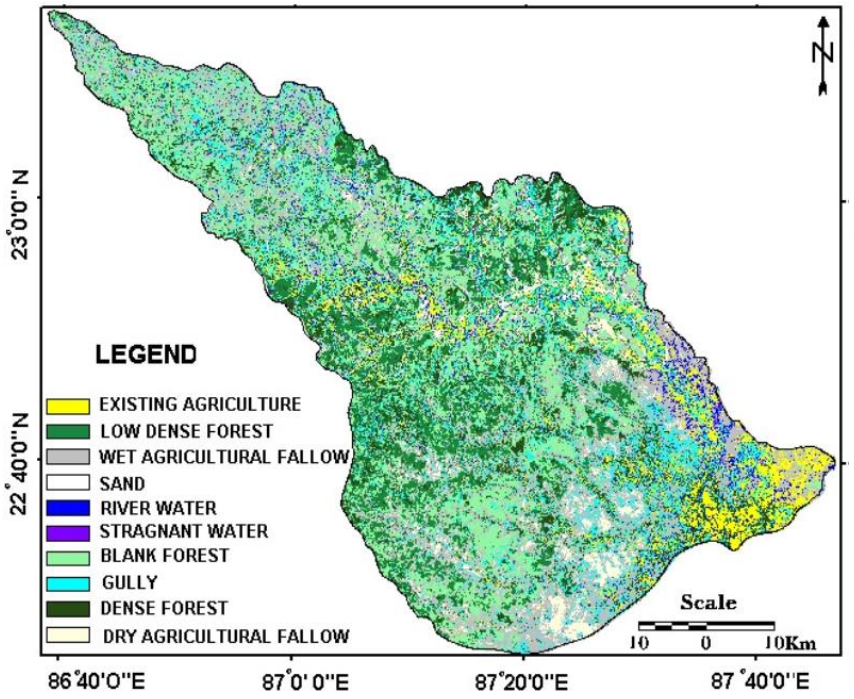

Fig 4: Landuse/ Landcover map based on satellite image

6.5.2 Land degradation: Land degradation is one of the long-term consequence of channl process in the study reach.it is caused by overbank deposition, water logging and gully formation which affect the arable land for a consideration period of time.

Land sliding (Affected Gram Panchyat)

Fig 5: Land Sliding of Shilabati River at Haldighat under Dewanchak – II Gp

Fig 6: Land Sliding of Shilabati River at Simulia under Dewanchak - II Gp

6.5.3 Back Water Effect

Back water effect of shilabti river cause flooding in his tributaries, ie, the jaiponda Puratan, Ketia, Kubai, and Tamal, Donai, Ketan. The back water effect of jaiponda is the main cause of flooding lower reaches of shilabti river basin.

Therefore high water level and large number of sediment deposits of Shilabti River cause the flood. 6.5.4 Socio-Culture and Live hood Impact:

Human impacts upon the river directly or indirectly in many ways, which alters their natural flow regime in the river. Alternations of the flow regime therefore have also significant social, cultural, economic and health impact on the human population, which live along the river and depends upon the riverine environment for livelihood.

Although the socio-economic impact in areas upstream of the dam site has received global attention, little attention is paid to these impacts along the downstream reaches where usually a much larger area and greater population is affected. Loss to residential buildings: This is another structural measure to be followed by local people.

According to the housing act, people should construct their houses at a distance from the river bank. During the floods, large discharge of surface flow of water destroys many houses. In the last few years some residential buildings are partly or completely damaged by floods and erosion in the study area.

Table 4: Damage of Household

Year	Full Damage	Part Damage
2010	8	18
2011	3	7
2012	0	5
2013	1	9

Effect on Transport and Communication

When the flood condition is very dire in nature, then nothing is available whether public or private transport. People have to move quite a distance either for maintaining their regular livelihoods or for their job or education purpose.

Actually bus transport totally stops during flood time. As the region comes out from inundation, it takes some time to get back to normal condition.

Table 5: Damage of Road

Year	Grad(jam)	P.s road(jam)	Katha Road(Mt)
2010	500	300	1700
2011	300	450	1100

2012	275	212	300
2013	200	250	700

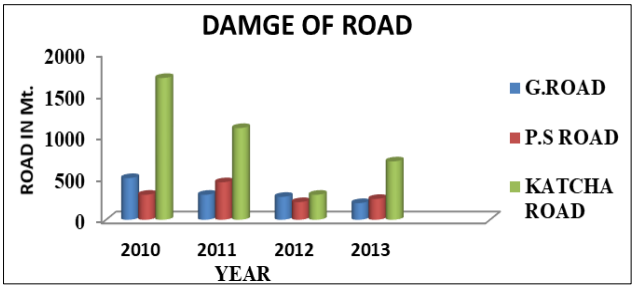

Fig 9: Damage of Road

7. Conclusion

Flood in Shilabati River is a regular and recurrent phenomena.it has occurred in the past and will continue to occur in future as well. The flow in the Shilabti River is influenced by the river regulation to provide for irrigation.

The study reach is highly populated and enriched by agricultural practices, small towns and moderate to high level of communication. Hence, during massive inundation period resource loss is its maximum level. To mitigate the flood condition, some initiatives had been taken such as Ghatal master plan, Shilabati project, etc. But it is the reality that after Shilabati dam construction the channel course has changed much especially in terms of its hydrology. As a result the channel is dried up in the lower regime during non-monsoon season where the bank-full discharge sometimes spilling of discharge to the floodplain occurred by high monsoon rainfall and release of water that is beyond the channel capability. Increasing connectivity across the floodplain has made the channel morphology dynamic that crosses the limit of its nature and become worse in some urban places. So it is high time to take major initiatives to save the floodplain fertility and to rejuvenate the channel flow.

Author's Contributions

We are solely responsible for the conception and design of the study. We fully and independently both carried out of the empirical analysis and interpreted the results of the manuscript. Conception and design of study: UD and DC; analysis and interpretation of data: UD, and RB; drafting the manuscript: UD; critical revision of the manuscript for important intellectual content: UD, RB .In addition, we are also fully responsible for any concept and ideas within the paper.

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