



The Use of GIS and Statistical Application in Flood Disaster of Atryee River Basin in West Bengal in India

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ABSTRACT: A flood is an overflow of water that submerges land that is usually dry and it is a natural phenomenon that occurs most commonly due to the overflow of water, heavy rainfall, etc. One of the World's most flood disaster-prone areas is the Indian Sub-Continent, and flood here is a very common annual feature in the Ganga-Brahmaputra-Meghna transboundary river system. One of the transboundary rivers like Atryee, a part of this Ganga -Brahmaputra river system, is facing a big problem due to its frequent floods. It creates problems when it undergoes the cultivation land and rural settlements. Every flood causes damage and makes the life of people miserable. This paper aims to suggest some ways and means for streamlining flood problems by using cartographic tools. The flood risk analysis of the studied areas has been prepared through a process of scientific cartographic techniques, by managing hydro-morphological data of the Atryee river basin. The methodology adopted in the present study is based on primary as well as secondary information including hydro-meteorology, morphology, topographical maps, satellite sensing data, and socio-economic data. In the last 45 years, Atryee keeps on changing its course and bank lines. Spatio-temporal shifting of such river channels is an important factor for the identification of flooding hazards in the community. After mapping using the findings of the land use and land cover (LULC), rainfall zoning at flood plain areas, and analyzing hydro-morphological data derived from the study, it offers significant information to understand flood risk vulnerability and it allows the support of flood disaster preparedness and management.

KEYWORDS: Flood-prone areas cartographic techniques, hydro-morphological data, Spatio-temporal, vulnerability, etc.

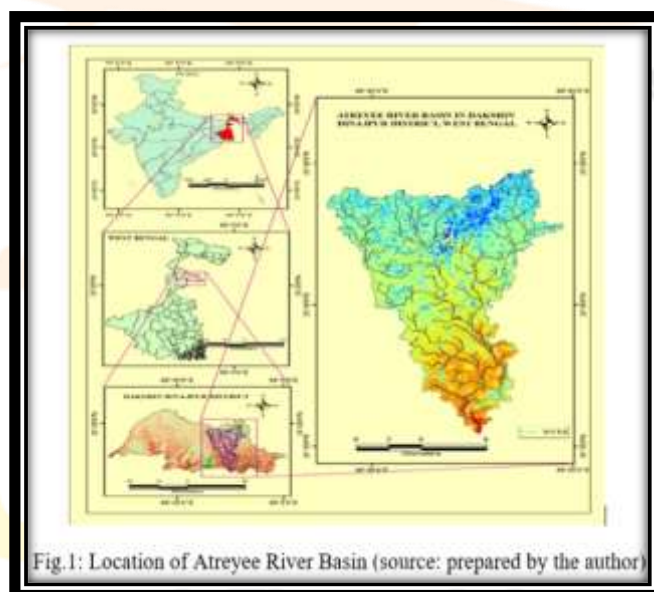
INTRODUCTION: Flood-prone areas in India have been increasing dramatically with the rising of population growth. Official records reveal that nearly 42.5% of the land, in the state of West Bengal, are susceptible to devastative flood hazard each year and 22.1 million people are gravely affected (Rudra, 2001) as a result of it. The consequences of flooding include the direct damage caused by flooding and the indirect disruption to society, infrastructure, and the economy (Pender & Faulkner, 2011). Floods sometimes can be due to excess water carried over from transnational and inter-state borders. It can be said as an example that the most densely populated and the poorest areas in South Asia with the largest concentration of disaster-affected people due to high-intensity floods are located in the eastern part of the Indo-Gangetic Plains (IGP) (Muhammed et al. 2004). Major contributing factors to flood in the northern parts of West Bengal are the local monsoon run-off, discharge from upper river basin areas, and also the outfall condition in the neighbouring countries. The rivers (Atryee, Punarbhaba) of the district Dakshin Dinajpur, originating in Bangladesh passes through this district and then join the River Ganges-Padma downstream in Bangladesh (Irrigation & Waterways Department). It is noted for all alluvial rivers that river channel change such as bank erosion, river bed accretion, and downcutting are common and natural processes and these incidents may increase the risk of bank erosion, flood, loss of agricultural land, nearby settlements, and developed infrastructures (Zhengyi et al. 2010). These hazards and losses can be prevented and reduced by providing reliable information to the public about the flood risk through flood inundation maps (Dimer, 2015). Flood inundation maps are very essential for municipal planning, emergency action plans, flood insurance rates, and ecological studies (Goodell & Warren, 2006). Cartography is the science, technique, and art of filtering and compiling spatial data into map information and communicating complex spatial relationships and interdependences by advanced visualization techniques (Buchroithner et al, 2019). Therefore, the benefits of such work are very much effective for the people living in the Atryee River Basin (ARB) and governmental organizations to reduce flood

risks in this study area. However, there is a close relationship between ecosystem for life and natural resources which are sustainable for livelihoods. Since the number of people living in flood-prone areas is increasing, the damages due to floods increase also. It will be a great benefit to the people to implement a flood management program that consists of flood risk analysis, vulnerability, and flood hazard mapping. In the present research, applying cartography helps to collect knowledge about hydro-morphological features of the study area as well as spatial information of landscape in two ways like erosion and deposition utilizing channel shifting for the last five decades. In this study, changing detection analysis is used to explain and measure the quantitatively spatiotemporal pattern of environmental changes of any region of the earth's surface (Das,2015). So, this study is very significant to identify such changes, and monitoring the changing detection with the help of computer-based cartographic technique flood risk of ARB can be systematically assessed to some extent.

OBJECTIVES OF THE STUDY: Flood hazards an annual feature is a regular risk to the life and property of people residing along with the ARB areas in Dakshin Dinajpur District in West Bengal in India. This paper aimed to identify map areas of flood risk based on several factors that are relevant in the study area. The present study aims to fulfill the following objectives:

- To explore some of the basic characteristics, causes, and controlling variables of the flood hazard takes place in the Atrayee River Basin in Dakshin Dinajpur district
- To understand how quantitatively spatial changes took place due to channel accretion and erosion with time by the application of GIS using remotely sensed data.
- To determine the flood-prone areas using the cartographic and statistical technique in the Atrayee River Basin and low-lying areas of the river basin.

STUDY AREA: The study is carried out in the Atrayee River Basin in Dakshin Dinajpur district, one of the marginal districts in West Bengal. The ancient district Dinajpur is believed to have been actively developed with influenced river enriched flood alluvial plain of river Atrayee, Punarvaba, Tangaon, Brahmani, Yamuna, and their many tributaries. The Atrayee river is the part of the Sub-Himalayan river system, consists of a combined catchment area of about 8873 sq. km, which is connected with the Ganga-Padma river system downstream where flood acts as the main carrier of huge sediments and other fluvial deposits (Govt. of W.B. Annual Flood Report,2016).The part of the study areas of the Atrayee river basin lies between 25°10'N and 25°30'N, and between 88°40'E and 88°50'E longitudes. The Atrayee River runs across the north to the south direction within this study area. The total length of the Atrayee is about 340 km, out of which 55 km of its course is within the administrative areas of West Bengal, which is selected for this study. The study area covers an area of about 262.65 sq. km. In the figure-1. The location map is shown below.



DATABASE & METHODOLOGY: The study is based on both primary and secondary data. Primary data are collected through direct field surveys and observations, whereas secondary data are collected from various Govt., private, public, and semi-public institutions in the form of data, charts, maps, diagrams, documents, topographic data, socio-economic data, and satellite data. The Topographical Map Index -78C, 1968-69 and &78 C/11, 1972 (the Source of both map S.O.I.), Satellite imageries-series of 7-band Landsat images, 30m resolution, taken in 1973,1987,2002&2018 years, georeferenced in WGS-84 spatial reference system (the sensor of data are RBV, MSS OLI &TIRS) are used for analyzing & assessing flood hazard risk in ARB. Besides, other associated maps, including administrative maps, geological maps, geomorphological maps, the population distribution has been studied. The adopted methodology framework of this study is shown in Figure no.2. It is carried out with a collection of necessary data in the Pre-Field stage and Field Survey stage for picking up the valuable information through field survey with designed questionnaires related to flood, local livelihoods of the people in the study area. The third stage, the post-field stage is carried out through different stages of the processing system in the laboratory by using different cartographic, statistical, and GIS techniques to get the result of the work. Finally, based on the Hazard Analysis and Vulnerability analysis, the Flood Risk analysis is carried out.



PHYSICAL SETTINGS OF THE STUDY AREA: The study of the geographical background of any region is important to understand the drainage system. Physiography originally means the study of natural phenomena. The whole area is featureless, level plain, gently sloping towards the southward direction. The average height of the area is about 25m above the mean sea level. Geomorphologically, the study area can be categorized as a fluvial deposited alluvial plain that is composed of deposits on residual soils or highly weathered basement rock. During a long period, the river Atreyee has been changed its course and its nature. Flat topography, heavy rainfall, geographical location, transboundary flows, and the impact of global warming including socio-economic and flood conditions have added complications in the ARB flood situation. The climate of this area is characterized by four seasons mainly. Firstly, the Pre-monsoon season extends from March to May, with the highest temperature and evaporation rates, accompanied by a thunderstorm. Secondly, the monsoon season is the most rainfall, cloudiness, and humidity extending from June to September. Rainfall floods occur during this period. Thirdly, Post monsoon season is from October to November, and it is characterized by high heat and humidity, with decreasing rainfall. Fourthly, Winter is characterized by dry and coolness and continues from December to February. The climatic characteristics of this study area have been shown by the graphical presentation of the Ombrothermic Diagram is shown in Fig.3. In the Dakshin Dinajpur generally, the annual average rainfall is ranged between 1500 to 2000 mm. The flood situation in this area mainly depends on the heavy rainfall in North Bengal Hill Areas and it is occurred due to high discharge carried by the streams in the upper catchment region. It is observed that the heavy discharge within a short period with the onrush of water through the river cause inundation and waterlogging in vast areas and also riverbank collapse is great havoc to life and property of the people in low lying areas in ARB.

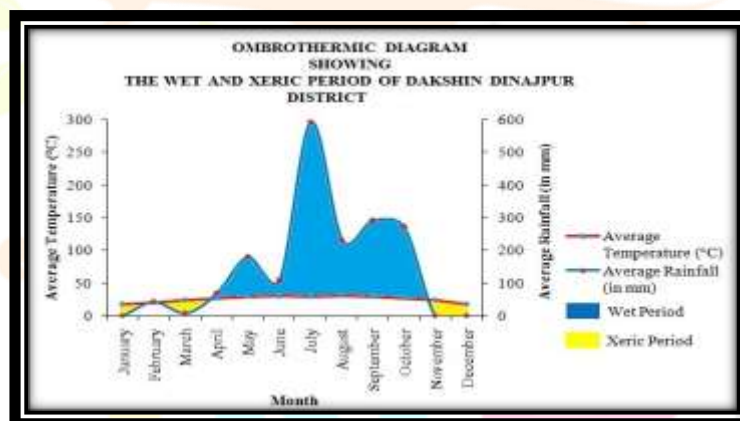


Fig. 3: Ombrothermic Diagram (2001-2020) of the Study area(Source: Data-IMD, G.O.I., prepared by the author)

DISCUSSION & FINDINGS: To fulfill the aims of the study purpose, the process of analysis of flood risk was conducted under the hazard and vulnerability concept under hydro-meteorological & man-induced controlling variables using a cartographic GIS framework. The Flood of the study area is considered to be associated with the accumulation of a huge volume of water during the peak discharge period and meandering courses of the river Atreyee. It is observed also flood is aggravated by anthropogenic activities such as building activity, deforestation, land uses changes, agricultural practices, etc. According to old records, the severe flood occurred in the year 1978,1987,1988, 1993,1999,2001,2005,2008,2013, 2017 and 2020 (Action Plan Control, Govt. of West Bengal). In this case study, it is found that floods are caused by one or more unfavorable meteorological and physical factors (Khullar.2008). Almost 1025445 people were affected, 59473.790-hectare crops were damaged, 13 cattle were lost, 10 human lives were lost; 41123 houses were fully and 60599 houses were partly damaged in the district in the 2017 floods (Bengal Annual Flood Report, 2017).

The following cumulative factors cause severe floods in the study area:

Heavy Rainfall –It is observed that the occasional heavy rainfall in the ARB catchment amounting to 500 -700 mm within a minimum three-day period brings a big problem. It is found that comparatively high discharge of water coming from the upstream segment of Atreyee (Bangladesh) caused devastative loss of crops, human lives, and property in the monsoon period. It is very common in past

flood hazards. If the annual rainfall data & months having heavy rainfall of this area are analyzed systematically, it is seen that the gauge height of the river is increasing. With the help of the Scatter Diagram (Fig.4) based on the annual average rainfall of the last 5 years, it is observed that a strong positive relationship between the Atrayee river gauge height (Balurghat & Kumarganj Stations in West Bengal). The degree of correlation is fairly high and the determination value is found 0.6557. The value of the Coefficient of correlation is 0.809760355 and the relationship is indeed strong.

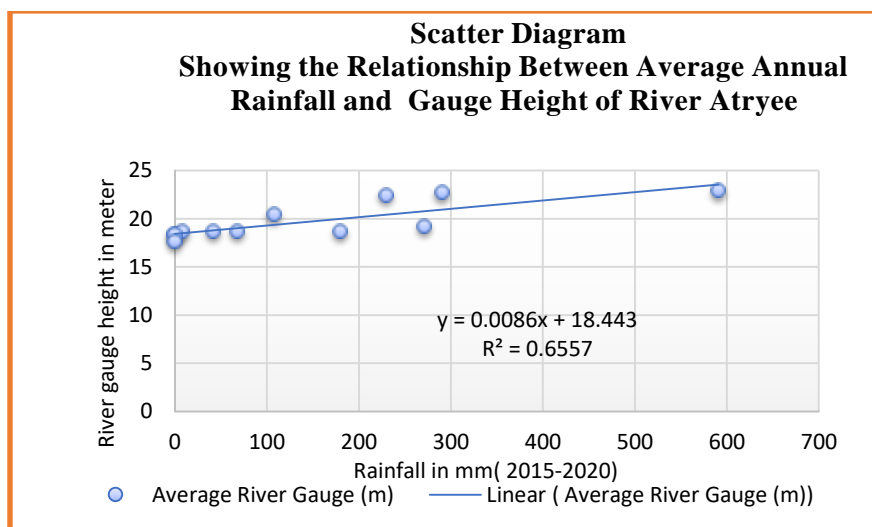


Fig. 4: Scatter Diagram (Source: Data-IMD, G.O.I., prepared by the author)

In Figure-5 the Relation between channel flow and rainfall for September 2020 has been graphically shown. It is observed that most of the floods in the study take place during August and September month due to heavy rainfall.

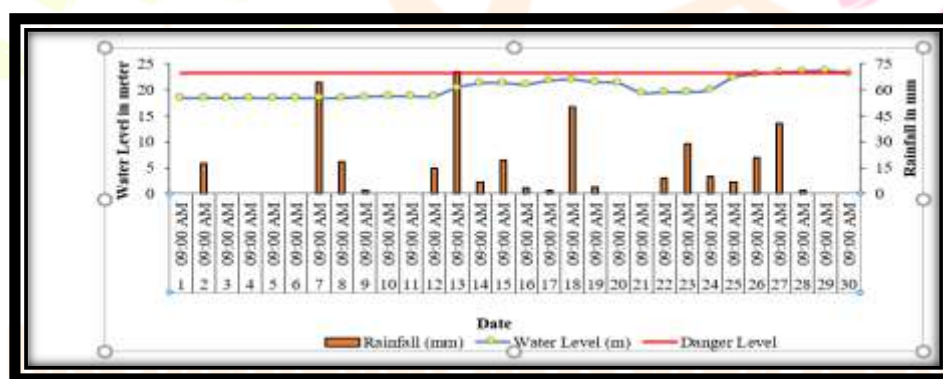


Fig. 5 Graphical Presentation of Relation Between Channel flow and Daily Rainfall

(Source: Irrigation Deptt., G.O.I., prepared by the author)

Meandering Course & River Shifting: In the Meandering course, river, erosion will take place on the outer parts of the meander bends where the velocity of the stream is highest and it is observed that sediment deposition will occur along the inner meander bends where the velocity is low. Such deposition of sediment results in exposed bars called point bars. It is observed from field sites, many large longitudinal, and transverse sand bars are formed in the river bed extending 30 to 105mt. Shifting of the river channel is one of the relentless transformations of landforms that threatens the stability of the channel, which is also responsible for flooding ((Eaton et al. 2010; Rozo et al. 2014). The physical survey has been done at 23 different sites, cross profiles along the river are prepared and it seems that the base flow of the river is dependent on the alluvial deposits lying on the bed. At the same time, the satellite image of the Atrayee River basin is used also to visualize the extent of lateral channel shift, the river flow pattern, and its meandering course in this area.

Recorded data reveals that the entire course of the old basin of Atrayee has been shifted and changed many times earlier. The highly sinuous and meandering course of the river always obstructs the normal discharge of water and thus the velocity is reduced which delays the passage of water resulting in stagnation of water (Singh,2021). Normally River Atrayee obstructs its normal discharge of water due to its meander belts which are immediately overflowed during the monsoon. In Figure -6 lateral channel shifting of both side banks of five different years has been presented for identification and analyzation the Spatio-temporal changes of river Atrayee and it offers significant information to understand a future synoptic view of this river course changes in the study area. During the last few decades, the Atrayee has been attempting a westward push threatening breaches in left embankments. It is found from the calculation and evaluated field data that the shifting has been taking place due to erosional and depositional activities within the river

course. Sites like Safanagar, North Kumarganj, Gopalganj, Kureha, Belterra, and Patiram Prasadpur situated on the left side are found as highly erosive than the right sides.

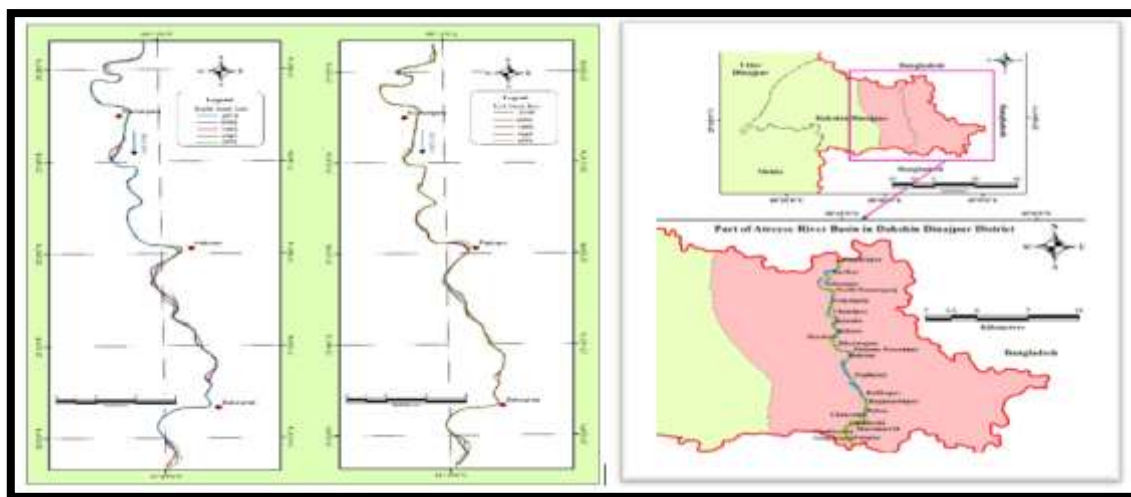


Fig. 6: Lateral channel shift of Atrerey between Kamdebpur (upperside) & Fatepur (downstream) West Bengal, in the years 1973, 1987, 1993, 2002 & 2018 (Source: The author)

From the survey as well as statistical calculation, topographical analysis, a cross profile of all sites on both side bank, it is observed that different type of human-induced activities has influenced channel flow pattern as well as shifting since the last few decades in ARB in the study area.

Population Growth and Human-induced Activities: To understand flood risk, one has to understand the different components behind the flood hazard and their interrelationships to make informed decisions. The alteration of the physical environment, be it through natural processes or human activities will always have some sort of impact. Floodplains are usually very fertile agricultural areas as floods carry nutrient-rich silt, sediment and distribute it across a wide area. It is observed that spatial-temporal pattern of environment and land-use change in flood-prone regions takes place and such landscape ecology helps to examine how water bodies, forest cover, exposed fallow land, etc. of the previous decades has been converted into growing agricultural cropland and settlement build-up areas area with the growing demand of people in recent time. From the change detection analysis, it is clear that anthropogenic activities such as building manufacturing, channel manipulation through the diversion of the river course, construction of bridges, embankments, agricultural practices, deforestation, etc. all are very significant factors for causing the flood in the river basin areas. The study of change detection is used here to explain the measure quantitatively Spatio-temporal pattern of environmental land use land cover changes due to channel accretion and erosion with time in the study area during the past few decades (1973 & 2018). In Figure 7 the map of LULC of the study area has been shown and on the other hand, the year-wise land uses classes data is presented in Table-1. Remarkable changes had been taking place in forest cover, built-up areas, and agricultural land areas. In the year 1973, the area of forest cover was 220.581 sq. km and it is reduced to the area of 55.5642 sq. km in the year 2018 due to several anthropogenic activities.

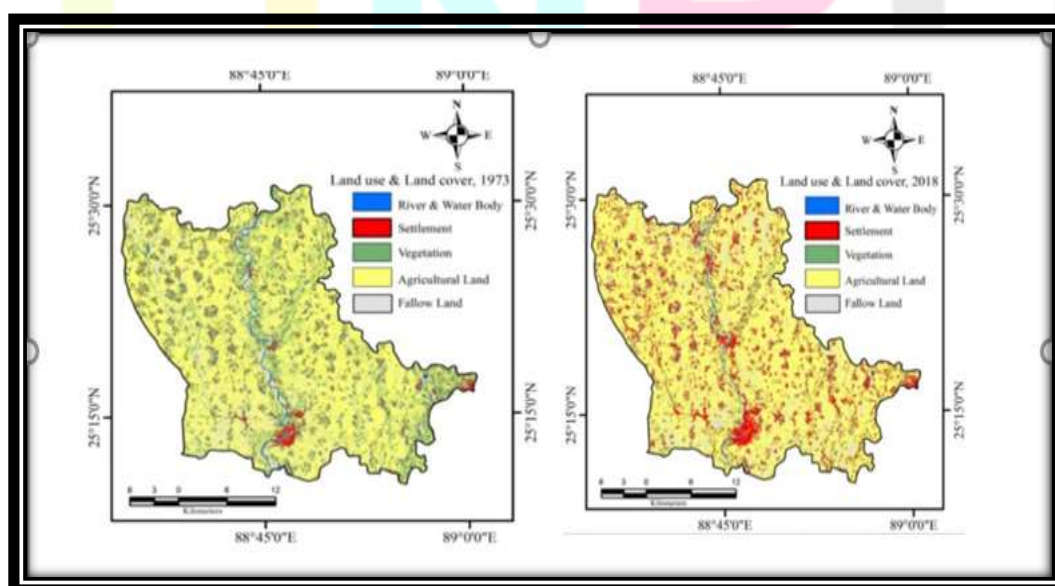


Fig. 7: Map showing Land Use & Land Cover (1973 & 2018, Source: The author)

1973			2018		
Land-use type	Area Sq. Km.	Area in %	Area Sq. Km.	Area in %	Difference in %
Waterbody	19.1763	2.04	25.7949	2.74	+2
Settlement	39.609	4.21	118.521	12.61	+24
Forest	220.581	23.47	55.5642	5.91	-49.5
Agriculture	597.3984	63.57	677.5893	72.10	+24
Fallow	63.0531	6.71	62.3484	6.63	-0.5
Total Study Area	939.8178	100	939.8178	100	100

Table 1: Table showing the change of areal coverage of different land-use types(1973 &2018) (Source: The author)

Irregular Dredging of Kharies: The irregular dredging of deposited sedimentation from the river, as well as river adjoining kharies, is another important factor of flood occurrence in the study area. Faulty agricultural Practices and Deforestation: It is observed from the study that unchecked population growth not only brings gradual encroachment of settlements towards the channel as well as low-lying areas but also helps in increasing deforestation and faulty agricultural practices. These all have a direct impact on flood occurrence in the riverine belts.

FLOOD RISK ANALYSIS: Flood risk may be generally termed as the possibility of losses, in life, health status, livelihoods, all types of property, and at the same time the consequences that influence the local community in the river basin areas. So, the determinants of the flood risk are hazard characteristics of the flood is multiplied by the vulnerability and is divided into the coping capacity to expose to the flood. Therefore, the risk of flood is based on the relationship between three elements. Flood Risk = Flood Hazard characteristics X Vulnerability /Coping capacity_(Based on Saltbones 2006 and Shook 1997) Flood hazard Characteristics in the study area are referred to the nature of flood frequency, flow and velocity, inundation period, and a maximum height of water level in the river surrounding areas and locality. On the other hand, vulnerability indicates consequences that may be produced due to the damaging effects of a flood. There are several types of vulnerability, arising from various physical, social, economic, and environmental factors. Coping capacity is the ability of community people by using available skills and resources to face and control flood hazards. The capacity to cope requires continuing awareness, resources, and good management, both in normal times as well as during hazard periods. Regarding this study, the characteristic of housing that is kachha, Semi-pucca & Pucca three types are found in the study area. Kachha house is a more vulnerable factor to exposure with the flood. A Flood Risk Matrix based on only two components (weightage value of Gauge Height during monsoon & weightage on building types) from field survey data is prepared to show the different zone of flood risk in the study area. The given figure -8 is showing the flood-prone areas in the study area.



Fig. 8: Map showing Flood Prone Areas in the study

STRATEGIES :

So, the main objective of the policy of risk reduction is that people living in ARB areas are better protected from risks of disasters and cope with the consequences of flood disasters. The strategies to reduce the risk are the following:

1. Effective risk reduction projects should be identified and implemented
2. Improved community capacity in dealing with flood disasters and risks supported by effective, integrated, and people-focused early warning systems to ensure people receive timely warning
3. Increased analysis and evaluation of hazards, vulnerabilities and risks
4. During hazard situations food security should be strengthened and it can enhance community-based disaster reduction initiatives

5. Policy, effective planning, response, and decision-making frameworks are to be strengthened at all levels of Govt.&Non-Govt. organizational, institutional, etc.



PhotoVoice: Inundated Agricultural Land and Residential Areas in the Study Area During Flood (2017&2020, Courtesy: Author)

CONCLUSION: It can be concluded that as Flood risk management is, a multi-disciplinary area, covering a wide range of monitoring, evacuation, search and rescue, relief, reconstruction, and rehabilitation, therefore, identification of more erosion-prone areas along the Atrayee river through regular monitoring of satellite data is needed more. Based on the study it can be said that Flood Risk Analysis is a better mitigation tool than flood control in the study area. Historical river discharge records alone are not enough to determine flood trends because of factors such as human modification including the rechanneling and other changes to river hydraulics as well as increasing sedimentation of riverbeds from deforestation, agricultural activities, and other non-climatic factors such as river dredging. All these activities affect the flow regime and river levels (McGuine et al., 2002).

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