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Magnitude of Urban Flood in Kolkata Municipal Corporation and its Influencing Factors

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Abstract:- In last few decades the intensity and frequency of floods has been increasing in Kolkata Municipal Corporation which effects economy and society to large extent. The Inter-Governmental Panel on Climate Change (IPCC) overviewed the Global trends of different weather events and notes that the frequency of heavy precipitation events has increased over most land areas (IPCC AR4 2007). In last 100 year's rainfall data shows a cyclic pattern of rainfall intensification and high magnitude storm which led to intensive flood in Kolkata Municipal Corporation. Land use change in Kolkata Municipal Corporation and its surrounding results in reduction of water holding capacity as well a drainage congestion to contribute waterlogging.

Keywords:- *Flood Magnitude, Urban Flood, Google Earth Engine.*

I. INTRODUCTION

Urban flood is an emerging issue in the discussion of hazard management. Flooding is the most widespread weather-related hazard around the globe(C A Doswell, 2003) which affects water management, nature and ecosystem services, economic activities and human health(Moothedan et al., 2020) . 82% of world's humans are being affected by flooding phenomena , As because one third of the earth's area is susceptible to flood prone(Kumar et al., 2021). More than two billion of people were affected by flood issues throughout the world from 1998 to till now(Taromideh et al., 2022). Almost every city of worldwide is facing flood problems in different intensity and magnitude. 49.2% of the global population resides in urban areas, So societal and financial consequences of urban flooding are inevitably wide-ranging than other hazards(Chen et al., 2009). Many Asian megacities are also in floodplains and deltas are consequently exposed to the effect of climate-related hazards, such as sea level rise, cyclones, storm surges and flooding(Colenbrander et al., 2017). In India, every metropolitan like Delhi, Mumbai, Chennai, Bangalore had experienced flood in the last one decade which are mostly devastating. The climatic disorders of Kolkata municipal corporation (KMC) specially changing rainfall patterns in recent times are creating flood problems since long time. In 2007,there are 34 cases of death(De et al., 2013) due to terrible flood in Kolkata. At least 7 to 8 heavy rainfall events per year, leading to clogging of water in many places across the city Kolkata. If the rainfall exceeds 15 mm per hour then it became beyond the draining capacity of KMC(Bose, 2007). A saucer like terrain, sluggish natural drainage, cyclones, storm surges, tidal blockage of drainage channels cause flooding and water logging in the city.

Urban flood results in overwhelming of drainage capacity due to heavy rainfall(Rafiq et al., 2016). Mainly inadequate drainage system and lack of regular maintenance are caused for the floods in urban areas(Mark et al., 2001). Riverine floods, coastal floods and also flash floods can be prevalent in the urban set up but the term 'urban flooding refers especially to the flooding that occurs when rainfall, not only overflowing body of water- overwhelms the local storm water drainage capacity of a densely populated urban area' (NRDC,2023). Urban floods have the higher capacity of causalities and economic loss than other type of floods, as it effects urban settlements straightway(Sundaram et al., 2021). It has been predicted that worldwide urban property loss due to urban flood will be 712 billion dollars from 174 billion dollars per year(Tazmul Islam & Meng, 2022). There are several factors which are responsible for urban floods which can be broadly divided into three categories. The categories are geomorphic factors, anthropogenic factors and climatic factors (Fig.1). Unfortunately all these factors are prevalent in case of KMC which are treathening the flood condition of this region.From the last two decade flood magnitude of KMC is in very outrageous situation mainly in the late monsoon period. The impacts of the urban floods will be most relentless for those populations who are living in the eastern edge of the city , where population growth is very high over the past few decades(Rumbach, 2017). The problems of urban flooding need to be adressed by different stakeholders of urban planning to fulfill the goal of sustainable urban future.

In this paper,our aim is to identify the influencing factors of floods in the study area and the magnitude or extent of the flood events.Natural set up of KMC region coupling with anthropogenic influence and changing climatic phenomena triggered the flood magnitude of this region. Remote sensing and GIS tools has been used to identifiy the factors and Google Earth engine(GEE) platform has been used to mark out flood magnitude from 2016 to 2023 by using sentinel-1 SAR images.The key benefit of this research is to identify the urban flood factors in an urban area and also it shows the flood affected areas and its magnitude in KMC region.The findings of this study will be significantly beneficial for the citizens and the policy makers for flood-proof urban planning and management.

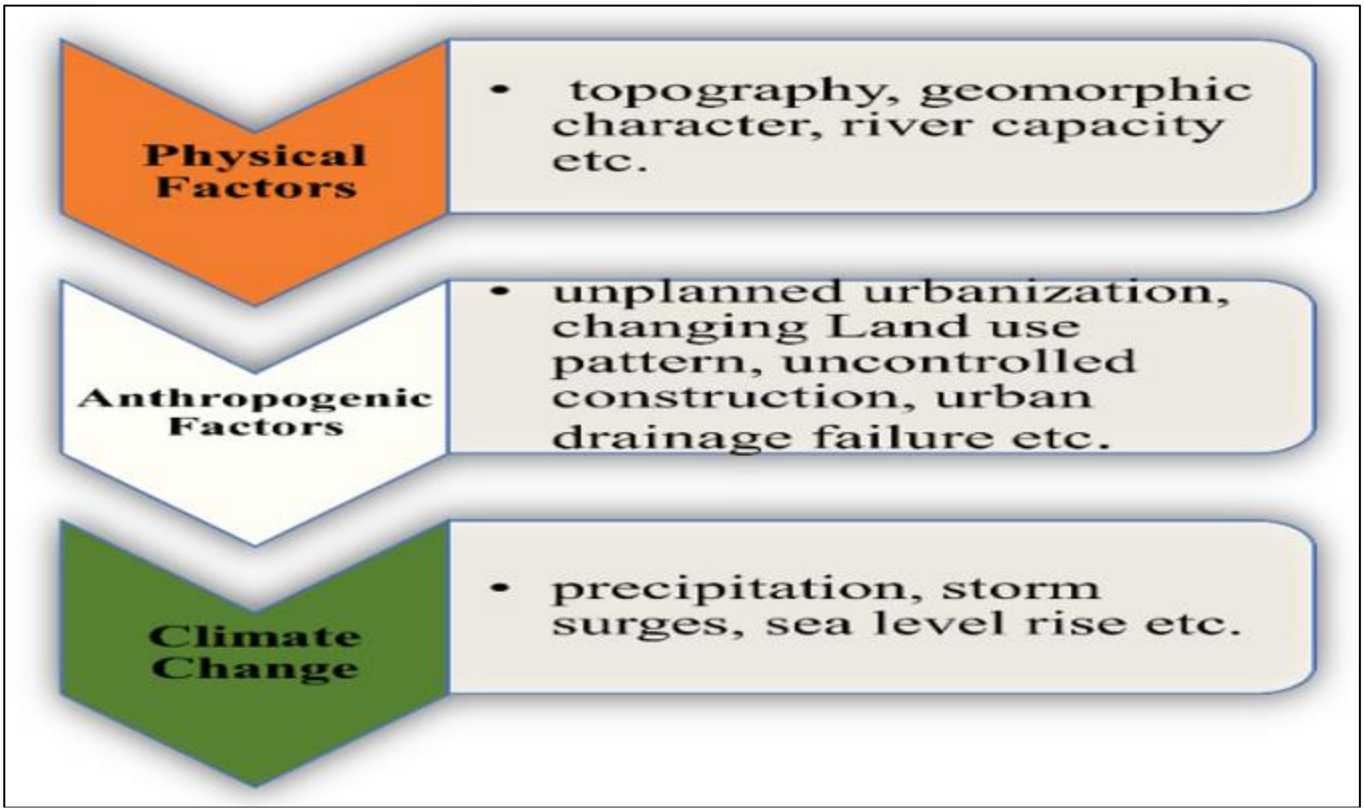

Fig 1: Responsible Factors for Urban Flood

II. STUDY AREA

Kolkata Municipal Corporation(Fig 2.) has chosen as our study area because it has an complex urban setting and also impacted by severe flood by several time. Some basic information about the study area is given below(Table1.)

Table 1: Study Area Information

Location	Along the eastern banks of the River Hooghly in a N-S direction
Geographical location	22.5625°N and 88.3531°E
Total Area	206.1km^2
Elevation	Between 1.5m and 15m above MSL
Slope	0°- 2°
Climate type	Tropical wet-and-dry climate and *Aw* type under the Köppen climate classification
Maximum temperature	40 °C (104 °F)
Minimum temperature	9–11 °C (48–52 °F)
Average rainfall	1400-1600 mm per year
Total Population	more than 4.5 million
Floating Poupulation	60,00,000 per day
Population density	24,252 per sq. km
No. of wards	144
No. of borough	16
Total Length of Sewer Lines	brick sewer length 200 km and piped sewer length about 1784 km
Total Length of Open Drains	953 km.
Total slum population	1,409,721 Persons

Kolkata is an unplanned city which has started to evolve during 17th century.To accommodate the influx of population, kolkata has gradually grown(Singh et al., 2015) but from the last three decade it faced an explosive population growth. Due to this rapid growth, the city is experiencing swift conversion of land use and land cover characteristics. Kolkata is Being the 7th most populous city of india, facing various hydrometeorological issues from the last two decades. These hydrometeorological issues like flood will be threatfull to the citizen of the city in near future as the city lacking space for the retention of excessive surface water.

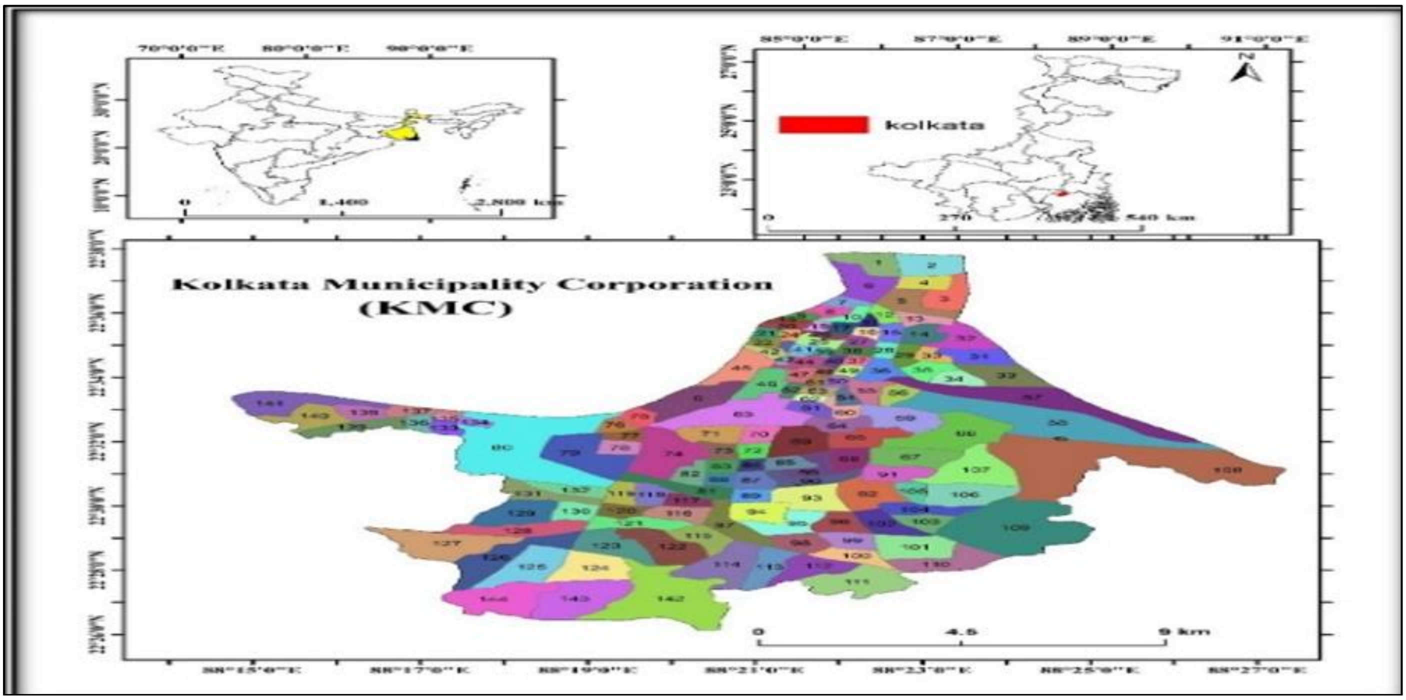

Fig 2: Study Area Map

III. DATA SOURCES AND METHODS

The synoptic view, repetitive coverage and real-time data acquisition by remote sensing technique making it very useful tool in any kind of research field. All data needed data for this investigation were collected from secondary sources mainly using remote sensing techniques.

Google earth engine catalog has used in this research for majority of datasets. In this study magnitude of flood has been derived from the sentinel-1 Level-1 Ground Range Detection (GRD) data in google earth engine platform (GEE). There are square pixels with few speckles effect in these images. Various multi-date images (pre-flood, during flood and post flood) have been acquired to monitor the flood events. After acquiring images, pre-processing steps were done which were mainly noise removal, radiometric calibration and terrain correction was performed by using the sentinel-1 toolbox. The pre-processing steps are given in the methodological flow chart (Fig.3). In this process VH-backscatter has been effectively used for flood inundation mapping.

In theory, a typical bi-modal character of SAR backscatter histogram is expected an over water plenty terrain. So, automatic thresholding method based on Otsu's method (Bangare and Patil, 2016) has been used to separate land and water from the images. The topographic characteristics of a region also influence the SAR backscatter which caused for difficulties in images' classification and interpretation. Thus, the terrain correction was done by using SRTM to minimize the errors. The study identified that the slope greater than 2^{o} in back-slope are likely to take place as surface water due to rise in the regional incidence angle(Moothedan et al., 2020).

- *OTSU Automatic Thresholding Method:*

Otsu automatic thresholding method comprises iteration of all the possible threshold values and for the pixel levels of each side of the threshold, a measure of spread calculation has done. In that case the pixels take place either foreground or background. The main focus is to get the threshold values where the spreads value is minimum for the sum of foreground and background. The partition of data which increase maximum inter-class variance and likewise, it minimizes the sum of interclass variance. BSS/p is the variance of inter-class where BSS (between-sum-of squares) is calculated by the below given equation:

$$BSS = \sum_{k=1}^{p}(\overline{DN}_{k} - \overline{DN})^{2} \quad (1)$$

In this equation DN represents Digital number of VH band and DN $_{k}$ is the mean digital number of the total dataset. As there are two classes in my study so p is 2 here. The variance structure of the dataset is described by the between-sum-of squares (BSS).

The threshold value curtails the BSS.

At the end, the calculated threshold value was assigned to every case and flooded and non-flooded areas are segmented from the images via the GEE platform.

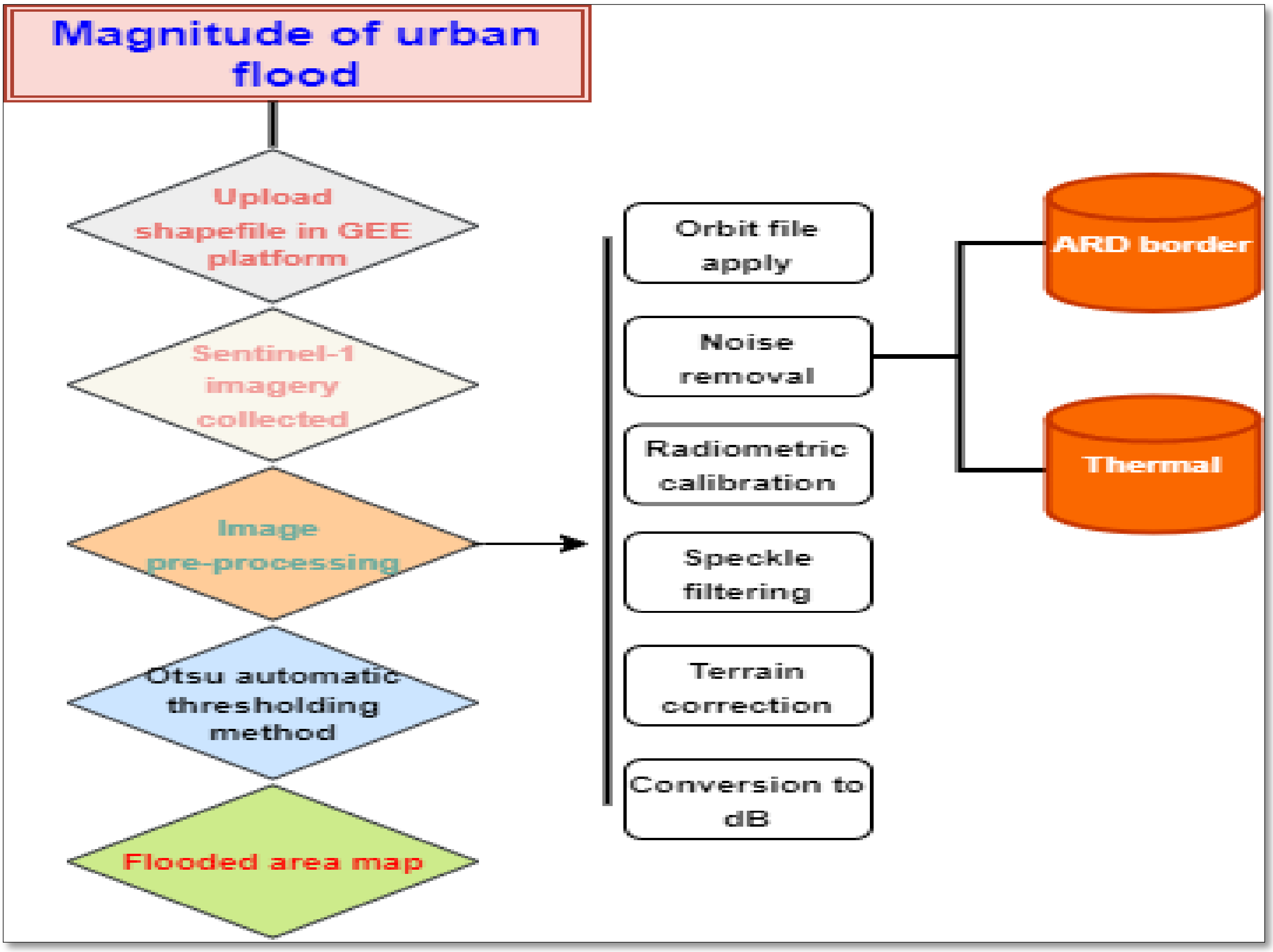

Fig 3: Methodological Flowchart

IV. RESULT AND DISCUSSION

Over the years, KMC experienced frequent flood incidents during the monsoon time.Inundation of different areas almost all the wards has become very common in every monsoon. There are several factors of urban flood which have previously discussed but the peculiar urban set up of KMC has elevated the issues of urban flood.The otsu autometic thresholding method has been applied to the images from 2016 to 2022. At the very first maximum rainfall day has selected from IMD gridded data, then post 15 days and pre 15 days of that day,s imagery has been selected to estimate the amount of flood.Presence of radar like reflecting surfaces, shadows and layovers are the major challenges for flood mapping in urban areas(Vanama et al., 2020).So, the autometic thresholding method has used on pre-flood images to extract the land surfaces which lead to over estimation of flood area. To avoid overestimation, the land surface acquired from pre-flood images has been masked out to identify the flooded areas from flood images and post flood images.

In this study, the SAR images from 2016 to 2022 is showing the flood effected area of KMC. It has been seen from the result that total flooded area is related with rainfall. In these given maps the blue colour is showing the waterbodies of the region and the red colour is showing the flooded area of the region. Every year during mansoon which is mainly may to october month KMC is facing heavy rainfall. This rainfall lead to waterlogging in massive way which causes flood in various places in the study area. In this study it is shown that if the rainfall reach 150 cm so the flooded area will be high. In 2017 and 2021 faced the most flooded area. 2021 faced the most flooded area,even the rainfall is lower than 2017.The main reason of this incedent is that 2021 gets the highest rainfall in the month of september which is the peak time of mansoon.In this time all the waterbodies and drainage are overwhelmed because of the middle of the season. The region already got rain in the last three month which is may, june, july.in the month of september the waterbodies and drainage has reached its highest carrying capacity so the high rainfall in september has failed to carry excessive water. So waterbodies and drainage take important role to retain or run out the excess water from the suffering region which may take effective role in urban flood mitigation.It is alarming to the policy maker and flood management team to manage the flood during late mansoon time.This Study will give the beneficial information to assess the flood hazards.

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V. CONCLUSION

Flood is one of the most destructive natural event that caused for massive loss in all over the world. It is assured that optical images is an efficient tool to monitor processes on the earth but it has drawbacks to keep track on floods caused by long rainfall. In this paper, the sentinel-1 images has been used to monitor flood events in KMC from 2016 to 2022.The images have been divided into flooded and non flooded zone by applying otsu autometic threshoding algorithm which is an effective method for flood event analysis.Findings of this research is that SAR images has massive imortance in the calibration and validation of flood inundation model.Google Earth Engine(GEE), a cloud based platform has an effective operational function for risk reduction and planning purpose.At the end,this study will be helpful for flood mitigation strategies and decisions making for future flood incedents.

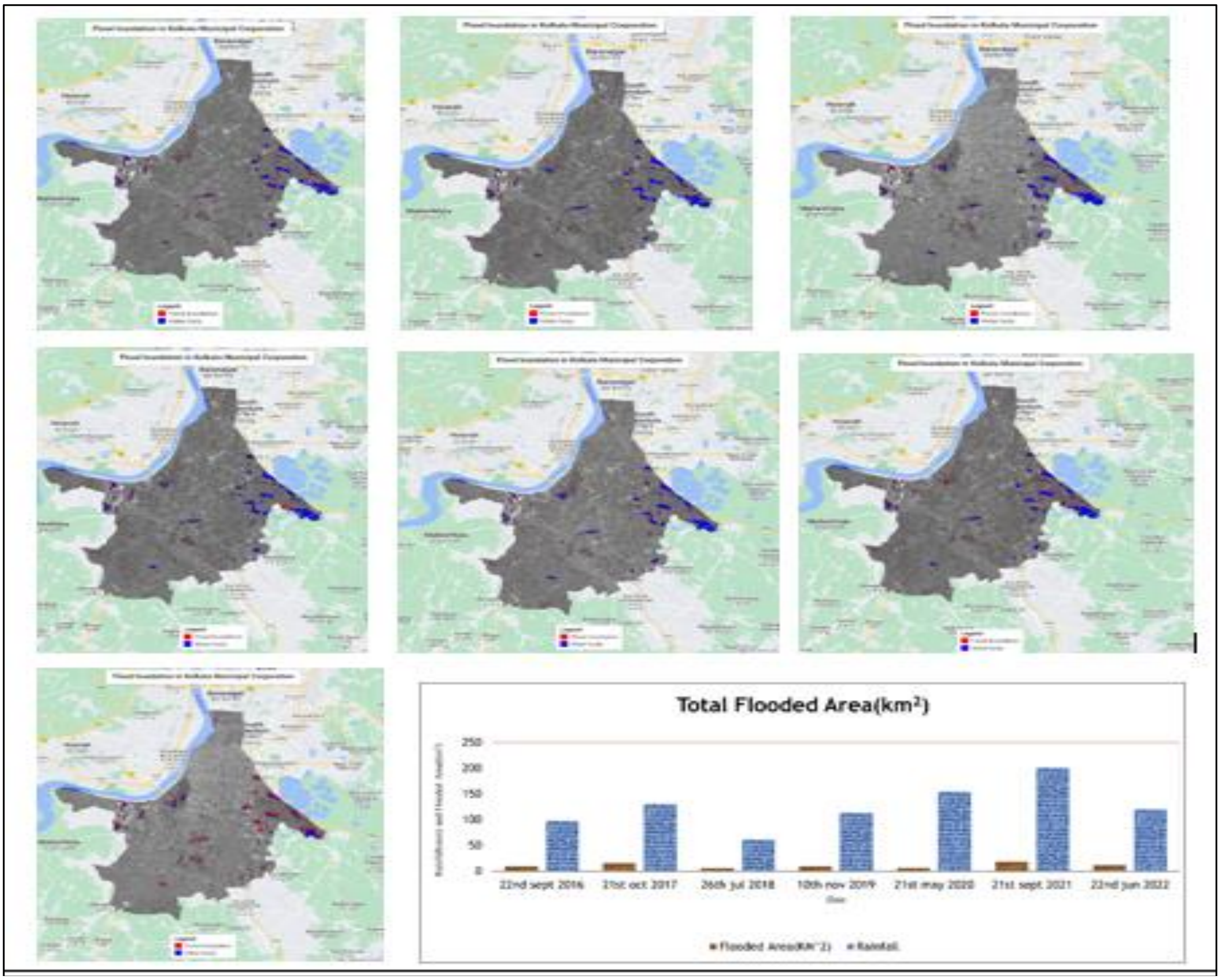

Fig 4: Total Flooded Area of the Study Region from 2016 to 2022

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