FLOOD HAZARD AND RISK OF SOCIO-ECONOMIC VULNERABILITY IN NORTH BIHAR

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India's 40% of the land area is vulnerable to flood, whilst North Bihar itself shares 17% of the area. The major rivers such as Kosi, Gandak, Burhi-Gandak, Bagmati-Adhwara group, Mahananda always brings riverine flood during the monsoon season almost every year. Hence, understanding flood inundation character based on long-term flooding pattern data becomes essential information which further could be used to develop long-term flood management strategies in the North Bihar regions.

Keywords: Flood and Vulnerability.

INTRODUCTION

During the last few decades, hydro-meteorological hazards, namely floods, droughts, and extreme weather events are causing catastrophes around the world. Hydrological extreme events and their occurrences and magnitude are increasing due to global climate change. Its multitude of impacts are seen across the various sector and its subsectors such as agriculture (crops, livestock, fisheries and forestry), environment, ecosystems, health, economy and increasing vulnerability of these hazards can be attributed to rapid growth in population, unplanned urbanization, and other anthropogenic activities which affected almost 1 billion people worldwide. Floods are generally originated from fluvial, pluvial, coastal and storms sources and cause significant economic, environmental, and social effects. Flooding is the major threat posed by climate change, especially in Southeast Asia with 237 million people at risk by 2050s from China, India, Vietnam, Bangladesh, Indonesia and Thailand. Flood risk and associated human morality and infrastructure losses are also heavily concentrated in these countries because of the high vulnerability and coping capabilities of people. In Indonesia, the Philippines and Singapore, rainfall-related impacts of climate change, such as floods or rainfall-induced landslides, are becoming concerned. Moreover, river floods are projected to appear frequently and intense in some regions of Southeast Asia. The extremity of extreme rainfall-induced flooding in Chennai (India) in 2015 was attributed to the warming trend of sea surface temperatures (SST) in the Bay of Bengal (BoB) and the strong El-Nino conditions. An extreme weather event in Chennai in 2021 had recorded 210 mm of rainfall on a single day (6th November) due to the northeast monsoon which has been impacted by La Nina, a complex weather pattern caused by variations in ocean SST in the equatorial band of the Pacific Ocean. Hence, to reduce flood losses, one has to understand both current and future risks, develop effective strategies, and increase the resilience of communities to flooding. This needs innovative approaches and space-based tools to assess flood zones, risk and resilience.

RESULTS

Spatio-Temporal Precipitation Maps during 2000-2020

The rainfall anomaly maps based on CHRS PDIR-Now data from July to September. To assess the spatiotemporal rainfall variability across the Gandak (1), Burhi Gandak (2), Bagmati-Adhwara Group (3), Kamla-Balan (4), Kosi (5), and Mahananda river basin's catchment (6), we showed only for extreme rainfall years like 2004, 2007, 2008, 2011, 2017, and 2020. The rainfall anomaly maps were presented to identify the districts as well as the basins (1-6), which received intense rainfall. Rainfall anomaly maps for the years 2004, 2007, 2008, 2011, 2017 and 2020 are showing heavy downpours during particular years with respect to the rest of the years during 2000-2020. These results showed that during the year 2004, the majority of areas of the study region has received rainfall up to 200 mm. However, it is concentrated in the central part of the study region (i.e., Burhi Gandak, Bagmati-Adhwara Group, and Kamla-Balan basins) which further resulted in severe inundation in low catchment areas of North Bihar plain. The major district severely affected during the 2004 flooding event was Darbhanga, Madhepura, Katihar, and Khagaria. During the year 2007, it is shown that 6.4% of the geographical land of North Bihar districts got inundated due to severe rainfall occurred which were concentrated over the south-western part of the region (i.e., Gandak, Burhi Gandak, Bagmati-Adhwara Group and Kamla-Balan basins) with the rainfall of 100-200 mm, severely inundated Darbhanga, Katihar, Madhepura, and Purnea districts. During the year 2008, except upper catchment region especially in the western Nepal region, middle and lower catchment region has received rainfall up to 100 mm. This unprecedented rainfall has resulted in breaching of Kosi River near Kushaha bridge at 12 km upstream from Kosi barrage. Rainfall anomaly map during the year 2011 has shown that except Tibetan plateau, the whole study region has received less than 50 mm of rainfall and therefore, flood extent areas are limited to a few districts, such as Muzzfarpur, Bhagalpur, Katihar, and Khagaria. As per the rainfall anomaly map of the year 2017, it can be stated that the Northern Bihar region has received the distributed rainfall between 50-150 mm and concentrated over the western and southern region (i.e., Gandak, Burhi Gandak, Bagmati-Adhwara Group, Kamla-Balan and Kosi basins). The affected districts were Darbhanga, Madhepura, Khagaria, Saharsa, Katihar, and Bhagalpur. During the year 2020, the study area has received excessive rainfall between 50-200 mm that concentrated over the south-western part of the basin (i.e., Gandak, Burhi Gandak, Bagmati-Adhwara Group, Kamla-Balan, Kosi and Mahananda basins). Consequently, it was found that 17.7% geographical land of the study region was inundated and severely affected districts are Muzzafarpur, Darbhanga, Saharsa, Khagaria, Madhepura, Bhagalpur, Katihar, and Purnea. Notably, we found that during the year 2020, the maximum rainfall was occurred followed by the years 2004 and 2007 over North Bihar, Nepal, and Tibetan Plateau which subsequently led to flood-like conditions over downstream areas. The precipitated water traveled through a gentle slope from the upper (Tibetan Plateau and Nepal) to the lower catchment of North Bihar. The rainfall was concentrated mostly over the northern and south-west part of the basin as displayed.

Concisely, it can be stated that the higher rainfall events were observed during 2004, 2007, and 2020 and were majorly concentrated over low catchment areas of Gandak, Burhi Gandak, Bagmati-Adhwara Group, Kamla-Balan, Kosi, and Mahananda river basin's catchment. Moreover, the composite rainfall data also showed that rainfall was concentrated in central and lower catchment areas. The districts which were adversely affected due to torrential rainfall are Paschim and Purbi Champaran, Madhubani, Darbhanga, Supaul, Araria, Saharsa and Katihar. Apart from these, some of the districts, such as Madhepura, Samastipur, Muzzafarpur, Purnea, Sitamarhi, Sheohar, Begusarai, Bhagalpur, Kishanganj, and Vaishali also witnessed high-intensity rainfall and followed by flood inundation.

Spatio-Temporal Annual Flood Extent Map during 2001-2020

During the last two decades (2001-2020), North Bihar districts witnessed major flooding events during 2001, 2002, 2004, 2007, 2008, 2013, 2014, 2017, 2019 and 2020. The present study has shown the year-wise spatiotemporal flooding events during 2001-2020. Five-year composite flood inundation maps exhibited a common region of North Bihar which were recurrently affected in the last twenty years (2001-2020). During 2001-2005 and 2006-2011, flooding took place over the central part of the region along the Kosi and Adhwara group of rivers and severely affected, Muzaffarpur, Darbhanga, Samastipur, Saharsa, Khagaria, Katihar, and Purnea districts. A total of 10490.5 km2 and 12594.8 km2 area was inundated along with Kosi and Bagmati-Adhwara group of rivers during 2001-2005 and 2006-2010, respectively. Notably, due to a breach near Kusaha in 2008, parts of Saharsa, Madhepura and Purnea districts were witnessed severe flood inundation, which can be seen in composite flood map during 2006-2010. During 2011-2015 and 2016-2020, an area of 8910.1 km2 and 24145.5 km2 were inundated, respectively and the latter one affected all most 19 districts in the North Bihar region.

Socio-Economic Vulnerability (SEV) and Flood Risk Map

Village level Socio-economic vulnerability (SEV) was assessed based on socio-economic factors taken from Census data collected during 2011. It was observed that districts present in central, eastern, and northern regions (i.e., East-Champaran, Sheohar, Sitamarhi, Darbhanga, Muzaffarpur, Katihar, Khagaria, Madhepura, Purnea, and Supaul) were under very-high vulnerability zone, whilst the north and central region (i.e., Sheohar, Madhubani, Darbhanga, Samastipur, Supaul Begusarai, and Saharsa) falls under high vulnerability zone. The central part of the northern plains area alone accounted for 19.11% (12,376.17 km2) of the inundated area under high to very high-vulnerability zone. Apart from this, the eastern part (i.e., Araria, Madhepura, Purnea, Katihar, Bhagalpur, and Khagaria) showed under the moderate vulnerable zone. Some districts such as West Champaran and Kishanganj are under the low and very low vulnerable zone, respectively. The analysis exhibited that a total of 10,976.36 km2 and 8139.76 km2 (20.24% and 15.01% of total geographical area) were estimated under very high and high SEV, respectively. The moderate SEV category accounts for 14,671.2 km2 of area (27.06%). Similarly, the low and very low categories have accounted for 9466.6 km2 (17.46%) and 10,969.1 km2 of land area (20.23%), respectively. The study also exhibited that among 23,632 villages in the North Bihar region, 4719 and 3571 villages are seen under very high and high vulnerability zones.

DISCUSSION

India's 40% of the land area is vulnerable to flood, whilst North Bihar itself shares 17% of the area. The major rivers such as Kosi, Gandak, Burhi-Gandak, Bagmati-Adhwara group, Mahananda always brings riverine flood during the monsoon season almost every year. Hence, understanding flood inundation character based on long-term flooding pattern data becomes essential information which further could be used to develop long-term flood management strategies in the North Bihar regions. The present study has utilized MOD09A1 satellite data to generate composite rainfall at every 5 years during 2001-2020. The study also reveals that during 2016-2020, on average half of the total North Bihar (~45% area) was inundated with a total area of 24,145.5 km2 which affected all most all 23 districts of the North Bihar region followed by extreme rainfall events. Flood impact assessment on varied land use classes was shown that ~45% of the agricultural land area was inundated followed by vegetation and settlement with ~22% and ~10% inundation, respectively. As per the long-term aggregated flood extent map, it was found that 18,640 km2 (~34%) area was inundated. However, it fluctuates year to year with a minimum flood area ~969 km2 (~2%) in the year 2013 and the maximum flooded area of 9607.45 km2 (~18%) in the year 2020. The fluctuation of area inundation is mainly attributed to rainfall received in upstream areas which can be seen in 2020 flood events. There was as such no study that was done for a longer period (2001-2020) for flood area mapping. However, some studies have been conducted by taking a single year that has been employed with MODIS NRT or SAR-based satellite data. The MODIS-based NRT based results indicated that ~9230 km2 (~17%) area was inundated due to the 2019 flood event over North Bihar. Moreover, the spatial pattern of flood in this study was quite consistent with previous studies. Flood extent map reveals that villages along Kosi, Gandak, and Burhi-Gandak rivers are more prone to flooding due to the availability of several major and minor river channels which activate during monsoons and contribute heavily to major streams to inundate low lying areas. Flood risk depends on a combination of the physical nature of flood severity and its interaction with a population or vulnerability. To study the risk of flood hazards, it is essential to study the severity, and spatial extent of these hazards as well as the socioeconomic ability of the region to anticipate and cope with the hazards.

However, some studies evaluated flood risk at district and block levels based on various indicators namely, major/minor river channels, road networks, hydro-geomorphology, sinuosity, demographics, flood report, and economic index. A significant rainfall contribution from the upstream Himalayan region makes this region highly vulnerable to flood. The present study revealed that villages of the districts such as Bhagalpur, Darbhanga, Khagaria, and Samastipur are considered to be at very high risk owing to their geographical setting as it is located in lower catchment areas with a gentle slope and several seasonal/permanent river channels. It was also studied that pre- and post-monsoon waterlogging zones are prominently present in these districts owing to lower relief zones. Flood not only causes population at risk but also agricultural loss and severe economic damages. The study also suggested that braided and meandering river channels play a key role in flooding patterns. Similarly, the flood risk map presented, exhibited that very high flood risk areas can be seen prominently in the central and northern part of North Bihar region whereas some of the areas from central, eastern and western parts of the region can be seen under moderate to high flood risk zone. These areas of higher risk to flood are mainly attributed to regional hydro-geomorphology such as the presence of lower relief zones, waterlogging zones, flood plains, paleochannels, oxbow lakes, etc. The study also exhibited that a higher degree of sinuosity is also a key reason behind the occurrence of severe flooding phenomena. Moreover, siltation deposition and lack of maintenance of sediments from dams and barrages are also reported to be major factors for increasing flood events and associated damages. Studies also projected that climate change-induced extreme rainfall intensity would be higher for the future and therefore, higher risk can be anticipated. However, Kosi fan areas, part of Mahananda basin, and western region are showing under in moderate flood risk which can be attributed to inactive flood plains as well as shallow to deep alluvial plains. Similarly, villages showing in Gandak and Burhi Gandak river basin are under low and very low flood risk category and primarily due to embankment structures, lower drainage density and lower sinuosity as well. However, low-quality structures or break-in embankments usually show higher flood damages across North Bihar. Additionally, deforestation at river banks and increasing urban compactness are some factors that could increase flood risks at river banks.

Flood risk evaluation becomes even more important when climate change induced extreme weather events are intensifying the flood events. According to the data provided by IPCC 2021, there have been more than 999 natural disasters in the last 20 twenty years, of which 951 were related to weather resulting havoc situations in lower catchment regions. This has caused a lot of damage to the economy. Considering all these factors, it can be stated that flood hazard, vulnerability and risk estimation are very important to reduce the loss of life and property by incorporating high resolution satellite data and 1-D, 2-D, and 3-D hydrological and hydro-dynamic models. Several studies have coupled high resolution satellite data with numerical models to evaluate flood risk. Studies have indicated that without including the socio-economic data with the meteorological, geomorphological, geological, and historical flood data, the flood risk assessment will be considered as unfinished work. The present study has employed MCDM approaches for flood risk mapping, which has used very limited input parameters. The socio-economic data were utilized from the Census 2011 survey report which is a decade-old dataset. As the latest Census dataset are not available, the derived SEI from Census 2011 dataset may be underestimated the vulnerability. Accordingly, the risk map of the present study may be underestimated flood-related vulnerability and risk. The availability of updated socio-economic data could lead to evaluate flood risk zone more efficiently. Nevertheless, the derived flood risk maps would be helpful to develop a flood preparedness plan during the mitigation process and risk assessment.

CONCLUSION

The present study has demonstrated the utility of multi-temporal satellite images of MOD09A1 in understanding flood inundation dynamics (i.e., flood progression and regression) during 2001-2020. Furthermore, the potential of satellite-derived flood frequency map and socio-economic data in assessing flood hazard, vulnerability, and risk. The key findings suggested that flood events of 2007, 2017, 2019, and 2020 were the major disasters due to heavy downpours which inundated 6.4%, 5.8%, 13.8%, and 17.7% of total North Bihar's geographical area, respectively. Flood frequency exhibited that nearly 7% and 8% of the area of North Bihar is categorized under very high and high hazard category. As per the composite flood inundation over 2001-2020, ~34% of the total geographical area was affected and among the LULC category, agricultural land and settlement were adversely affected. Census of India (2011) based composite socio-economic vulnerability map showed that the central part of North Bihar region and preferably region along the rivers are having greater vulnerability which is further proved based on flood risk map. The flood risk map also showed that the central North Bihar region along the river was categorized in high to very high flood risk zone, affecting 6305 villages.

Based on the capability of space-based data and its cost-effectiveness in flood disaster management, satellite data are useful for monitoring flood patterns as well as flood occurrences. The MCDM approaches can help disaster managers in the state to take mitigation measures for prioritizing susceptible zones and flood mitigation measures. The digital spatial database on the spatial distribution of flood hazards prepared for the North Bihar state will serve as important baseline information for taking up flood mitigation activities and also assist in taking flood insurance measures in flood-affected regions. The inundation map and associated impact and risk information will help decision-makers to provide an operational service for flood management.

REFERENCES

Blöschl, G.; Hall, et al. (2019), Changing Climate Both Increases and Decreases European River Floods. Nature 2019, 573, 108-111.

Boyaj, A.; Ashok, K.; Ghosh, S.; Devanand, A.; Dandu, G (2018), The Chennai Extreme Rainfall Event in 2015: The Bay of Bengal Connection. Clim. Dyn. 2018, 50, 2867-2879.

Chandrababu, D (2021), Record Rainfall Wreaks Havoc in Chennai. Hindustan Times New Delhi. 8 November 2021. Available online: https://www.hindustantimes.com/india-news/record-rainfall-wreaks-havoc-in-chennai-101636310510384.html (accessed on 25 November 2021).

Haltas, I.; Demir, I.; Yildirim, E.; Oztas, F (2021), A Comprehensive Flood Event Specification and Inventory: 1930-2020 Turkey Case Study. Int. J. Disaster Risk Reduct. 2021, 56, 102086.

IPCC, (2021): Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK, 2021.

Kulp, S.A.; Strauss, B.H. (2019), New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding. Nat. Commun. 2019, 10, 4844.

Loukas, A.; Garrote, L.; Vasiliades, L. Hydrological and Hydro-Meteorological Extremes and Related Risk and Uncertainty. Water 2021, 13, 377.

Samela, C.; Manfreda, S.; Troy, T.J. (2017), Dataset of 100-Year Flood Susceptibility Maps for the Continental U.S. Derived with a Geomorphic Method. Data Brief 2017, 12, 203-207.

Shivaprasad Sharma, S.V.; Sharma, S.; Roy, P.S. (2017), Extraction of Detailed Level Flood Hazard Zones Using Multi-Temporal Historical Satellite Data-Sets-A Case Study of Kopili River Basin, Assam, India. Geomat. Nat. Hazards Risk 2017, 8, 792-802.

Tripathi, G.; Parida, B.R.; Pandey, A.C. (2019), Spatio-Temporal Rainfall Variability and Flood Prognosis Analysis Using Satellite Data over North Bihar during the August 2017 Flood Event. Hydrology 2019, 6, 38.