International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

FLOOD HAZARD VULNERABILITY MAPPING FOR DARBHANGA DISTRICT OF BIHAR USING SAR DATA: EFFORT TOWARDS EFFECTIVE DISASTER MANAGEMENT

Dr. Renu Bali[1] and Ms. Shivani Pathak[2]

[1]Associate Professor, Geography, Kamala Nehru College, University of Delhi

[2]Product Engineer, ESRI Inc. R&D Center, 2nd Floor KLJ Tower North, B-5 District Centre Netaji Subhash Place, Wazirpur, New Delhi, Delhi

DOI: 10.46609/IJSSER.2021.v06i12.013 URL: https://doi.org/10.46609/IJSSER.2021.v06i12.013

Received: 15 Dec. 2021 / Accepted: 27 Dec. 2021 / Published: 31 Dec. 2021

ABSTRACT

Bihar experiences floods every year due to heavy rainfall in monsoon season and melting of snow in upper reaches of Himalayas during the summers causing both infrastructural damage and loss of life. During the floods, the sky is overcast, due to which traditional techniques of flood mapping and monitoring like aerial surveys and optical sensor satellite imagery fail to provide a good quality data as they are unable to penetrate through clouds and mist. New and alternative technique for the mapping of floods is the use of Synthetic Aperture Radar (SAR) data, which is capable of penetrating through clouds since it uses microwaves to capture the data. For the present study, Darbhanga district of Bihar was taken as the study area. The district faces floods each year due to Kosi River which emerges from Nepal Himalayas and enters Bihar. Aim of the study was to create flood hazard vulnerability map using flood inundation extent maps for the years 2017 to 2020. These maps help in demarcating and identifying the areas which are highly prone to floods annually. Flood inundation extent maps for this study were generated for each year from 2017 to 2020 using Sentinel-1 data and ArcGIS software. These flood inundation extent maps were then superimposed, and a vulnerability map was created. This flood hazard vulnerability map is a valuable source of information while making disaster management plan for the DRR of the region. These maps can help to understand spatial extent of flooding, and can provide scientists and authorities with objective data sources for decision making. These maps can play an important role in pre-disaster and post-disaster strategy planning in an effort towards making the community aware, more resilient and well prepared to face the disaster. These maps will further improve our understanding of the worse affected areas which requires more attention towards meeting immediate needs and relief operations after the floods.

Keywords: Disaster Risk Reduction, Flood inundation mapping, GIS, Remote Sensing, Resilience, SAR

1. Introduction

Reducing disaster risks and vulnerability depend totally on knowledge of the region its physiography and topology as well as socio economic status of the community and scientific and evidence-based techniques. As industrialization and urbanization increase globally, it's creating conditions for more disaster-related challenges. There's a requirement to expand the utilization of innovation and technology for disaster risk reduction (DRR). The 2005 Hyogo Framework for Action outlined comprehensive guidelines for the key policy and technical areas of action for disaster risk reduction. Application of science and innovative technology can significantly reduce loss of lives and damage to property. Use of Remote Sensing data and disaster mitigation planning together can help in devising effective and accurate methods for prevention, preparedness and minimizing losses after the disaster.

Disaster prevention is a long-term planning, which begins with the collection of data. Satellite data can help at various stages of disaster management planning Use of satellite data, can help in monitoring of varied relevant factors, such as, changing land use pattern, changing river courses, encroachment of floodplain, loss of vegetation, soil erosion etc. which directly affect the impact of disaster. Disaster preparedness depends on timely warnings and accurate forecasts of impending disasters. Disaster relief operations are taken up after (and sometimes during) the emergency phase of occurrence of disaster. Identifying exact location of disaster occurrence and its accessibility with the help of remote sensing data can help in providing relief on time without any wastage of time to areas worst affected by disasters. A crucial aspect in terms of satellite monitoring involves the assessment of the damage incurred during the disaster. Satellite technology also can help in identifying escape routes and locations of temporary shelters.

The increasing pressure on the earth's resources caused by increasing population growth rate has resulted in increased vulnerability of humans and their infrastructure to natural hazards. Encroachments on land prone to disasters for residential and agricultural purposes has increased the risk and vulnerability of large numbers of population. There is requirement for focused action within and across sectors from local, national, regional, to global levels for better understanding of disaster risk. There is need to improve disaster risk governance and to invest in disaster risk

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

reduction for improving the resilience, enhancing disaster preparedness for effective response, and to Build Back Better in recovery, rehabilitation, and reconstruction. Remote sensing and GIS are among many scientific tools available to disaster management professionals for making effective and accurate project planning. Repetitive or multi-temporal coverage has helped in review of dynamic phenomena which changes over time. These include natural hazard events, changing land-use patterns, and hydrologic and geologic characteristics of the region.

First step for formulation of any flood management strategy is to identify the most vulnerable areas. It is sometimes difficult to record an extreme event of perennial floods occurring annually with the currently installed equipment at river gauging stations. Remote sensing can be a reliable technique with wide spatial coverage in a cost effective manner. The ground stations limitation to register data in a hydrological disaster can be augmented by remote sensing. The investigators can monitor the changes and also reconstruct the past flood events for analysis. Mapping and monitoring of flood can be done with aircraft and satellite acquired remotely sensed data. There are several sensors and data processing methods for flood events. For recording flood events different sensors with visible, thermal and microwave range of EM spectrum can be used.

GIS plays an important role in disaster management, disasters are multi-dimensional with inherent spatial component. The main merit of GIS for flood management is that it generates not only the visualization but can also help further in analysis and damage estimation due to the flood.

The remotely sensed data are often used very effectively not only for quickly assessing severity and impact of injury but also for planning efficient escape routes, charting quickest routes for ambulances to reach victims, locating places for shelter for victims, calculating population density in disaster-prone areas, identifying hardest-hit disaster areas to supply relief material and early warning of potential disasters. Pre-disaster assessments to facilitate planning for timely evacuation and recovery operations during a crisis, monitoring reconstruction or rehabilitation after a serious disaster; and developing, maintaining or updating accurate base maps can also be properly managed through remote sensing data.

This study focuses on application of remote sensing data which is of great help for disaster managers during the various phases of disasters, including policymaking and governance. A case study, conducted on the Kosi River watershed within the district of Darbhanga, Bihar (mainly monitoring the extent of human settlement) shows the utilization of satellite data to watch changing land use and its impact on river channel flows over the last 5 years. Attempt is also made to predict the potential loss in the study area where flooding is a common phenomenon

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

annually resulting in loss of lives and property due to improper management, monitoring, and governance and also we try to explain how to use the information in planning, prevention, and preparedness for flood risk management .

2. Literature Review

Flood comes under one of the most frequently occurring natural disasters in our country causing large scale devastation every year. According to United Nations Office for Outer Space Affairs "Flood is a general and temporary condition of partial or complete inundation of normally dry land areas from overflow of inland or tidal waters from the unusual and rapid accumulation or runoff of surface waters from any source."

Smith (1997) in his book reviews the application of remote sensing for detecting river inundation, stage and discharge. Apart from providing direct information about flooding, remote sensing data can also be integrated with flood models (via model calibration or validation, and data assimilation techniques) or provide floodplain topography data to augment the amount and type of information available for efficient flood management.(Smith, 1997)

Study by Lu et al (2004) focuses on application of Remote Sensing in damage assessment. Erosion of top soil due to a flash flood and sediment deposition in the course of stream reduces the fertility of soil and thus have a negative impact on agricultural economy. The process of change detection is found useful to monitor this kind of damage to agricultural land. The most widely used procedure is to monitor the change in brightness value (VB) at a particular wavelength or different bands to identify the erosion caused by a flood (Lu, et al., 2004).

Bapulu and Sinha (2005) in their study state that primary objective of Flood Hazard Mapping is to reduce the impact of flooding. According to them Flood Hazard Mapping is a vital component for appropriate land use planning in flood-prone areas. Flood prone area maps help in the identification of areas at risk of flooding and also helps prioritize mitigation and response efforts (Bapulu & Sinha, 2005).

Mohamed & Gasmelsied (2011) categories flood in terms of damages. The categories floods in three categories of damage firstly direct flood damages which are the outcomes of the actions of floodwater its flow and inundation duration on structures and property. Indirect damages results from the physical and economic activities disruptions caused by flooding Tangible damages are monetary losses directly related to flooding. They may occur as direct or indirect flood damages. Intangible damages arises from adverse social and environmental effects of flooding like loss of life, stress and anxiety, damage caused to someone's health, emigration etc. These are not easily

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

quantifiable and hence cannot be included in the monetary assessment of flood damages. And lastly primary damages which results directly from the flood event and secondary damage is responsible for the actual flood event (Mohamed & Gasmelsied, 2011)

3. Objectives of study

Main objectives of this study are:

- To create flood hazard vulnerability map of Darbhanga district of Bihar;
- To create village level vulnerability map of the district of Darbhanga.
- To specify the role of remote sensing and GIS in Disaster Management.

4. Study Area

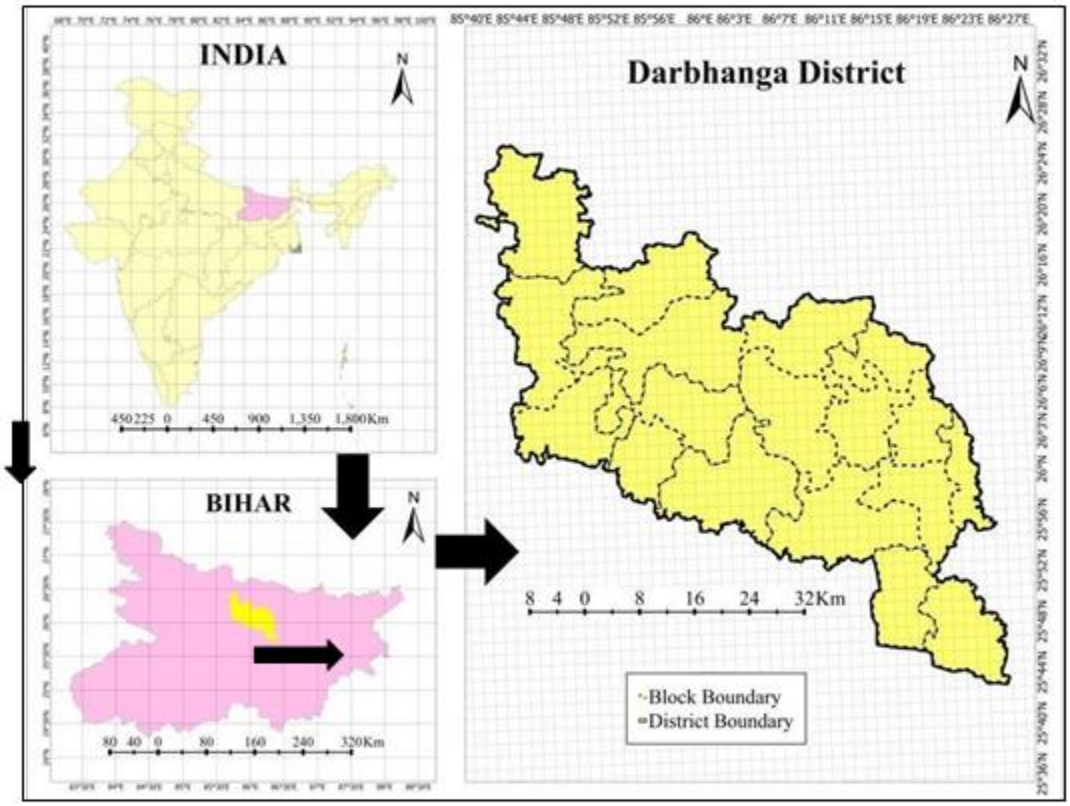
Bihar experiences multiple disasters every year and is one of the multiple hazard prone state of India. Disasters affecting the state include floods, droughts, earthquakes, heat/cold waves, boat capsizing and many other man induced disasters. Flood is the most prevalent phenomenon in Bihar.

District Darbhanga of the state of Bihar was selected as our study area. Flood almost occur every year in Darbhanga due to two rivers Kosi and Ganga.

Darbhanga district is one of the thirty-seven districts of Bihar. Its geographical extent is from 85° 45' - 86° 25' East and 25° 53' - 26° 27' North. Total geographical area of the Darbhanga is 2,279 km^2(Sahu, 2013). Darbhanga district forms a flat plain with low relief towards the south of Tarai/Bhabhar which is high relief belt of Nepal Himalayas.

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"



Location Map of the Study Area

5. Material and Methodology

5.1. Data Used

Sentinel-1 SAR data was used for the creation of flood inundation maps, as SAR is capable to penetrate clouds and gives accurate and high resolution (10m) results. JRC Global Surface Water dataset provides spatial-temporal distribution of surface water, this dataset was used to remove permanent water bodies. Village shape file of Bihar was taken from Revolutionary GIS website which was used for village level flood vulnerability mapping.

5.2 Methodology

Sentinel-1 data was downloaded for four dates August 23rd, 2017; August 30th, 2018; August 20, 2019; July 26th, 2020 each representing its year scenario. These dates were selected by referring to research papers, news bulletins and ISRO's BHUVAN flood monitoring and dates with highest flood inundation area were selected for the analysis. Pre- processing of Sentinel-1

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

data was done on ArcGIS Pro.

Firstly, Sentinel-1 imageries were clipped for Darbhanga district extent. To get the radar backscatter values, radiometric correction was carried out, speckle filtering was applied to remove the salt & pepper effect from imageries. Geometric correction was applied to remove the height related noise which was introduced due to side looking SAR sensors. The permanent water bodies were removed using JRC GlobalSurface Water dataset. A threshold value was selected for each imagery using its histogram. Using the threshold value binary images were created which represents water (Value=1) and non-water (Value=0) pixels. The binary rasters were converted to polygons and these polygons were used for the creation of flood inundation maps.

All the four flood inundation maps were added together to create a flood hazard vulnerability map for the district based on frequency of flood occurrence. The flood vulnerability map has 5 classes: 0 – didn't faced flood for the past 4 years; 1 – flood occurred in one year out of 4 years; 2 – faced flood in 2 years out of 4 years; 3 – flood occurred in 3 years out 4 years and 4 – flood occurred every year from 2017-2020.

Village level vulnerability map was created using district flood vulnerability map and Bihar village shape file. The village feature layer was overlayed on district vulnerability map and the class to village polygons was assigned with value of class which has maximum number of pixels in that village polygon.

6. Results & Discussion

6.1 Flood Inundation

Sentinel-1A data was used to create flood inundation map for Darbhanga district of Bihar. SAR sensor can provide data during cloudy weather as it is active sensor and uses microwave to capture the data. Threshold method was used to differentiate between water and non-water pixels.

The flood inundation maps were created for four days each representing that year flood scenario. The flood extent maps for the following dates: August 23rd, 2017; August 30th, 2018; August 20, 2019; July 26th, 2020 are shown in Fig 5.1 to Fig 5.4.

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

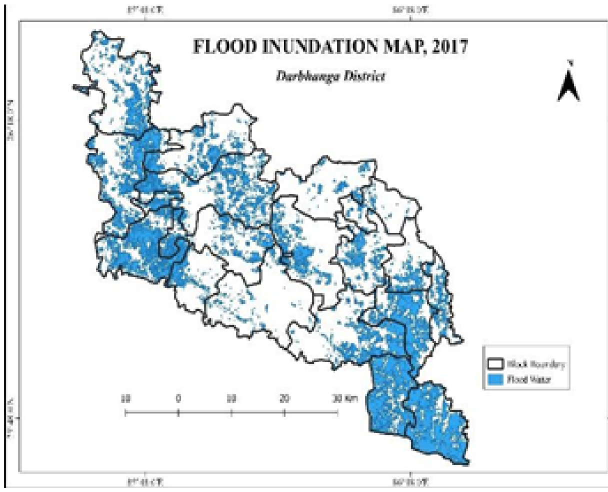


Fig 5.1.On August 23rd, 2017 approximately 650 sq. km(27%) of district's area was inundated in flood water.

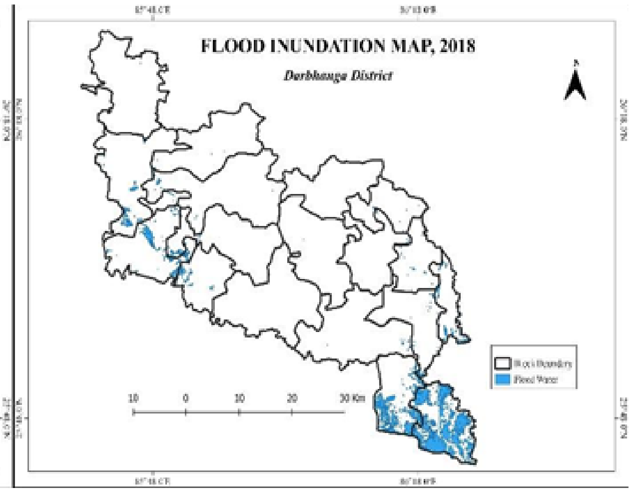


Fig 5.2.On August 20th, 2018, approximately 110 sq. km(5%) of district's area was inundated in flood water.

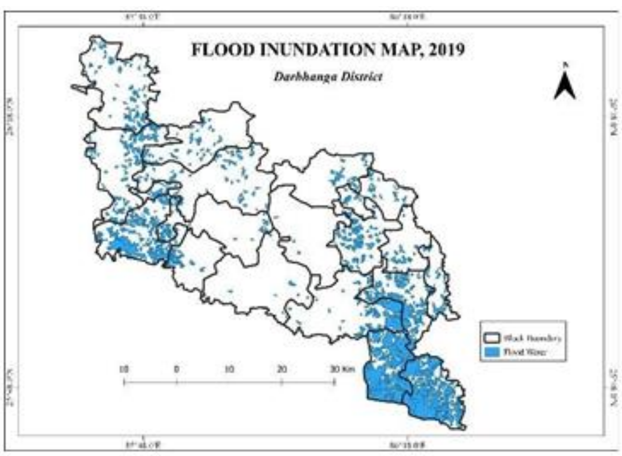


Fig 5.3.On August 30th, 2019, approximately 387 sq. km(16%) of district's area was inundated in flood water.

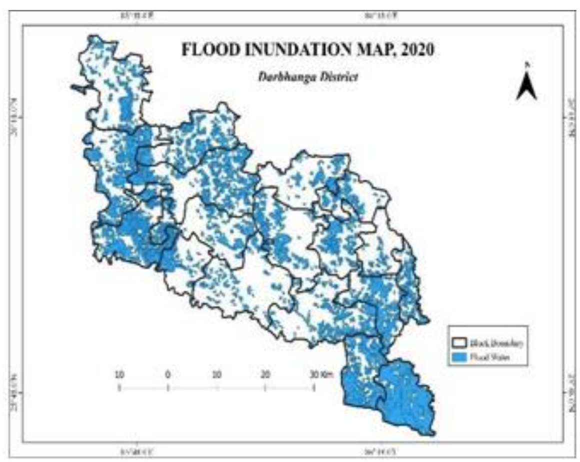


Fig 5.4.On July 26th, 2017 approximately 882 sq. km (33%)of district's area was inundated in fl

Flood Vulnerability Map

Flood vulnerability map for the district is created using flood inundation maps of 2017-2020. The flood vulnerability was estimated based on frequency of flood occurrence. Fig 5.5. shows flood vulnerability map for Darbhanga district.

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

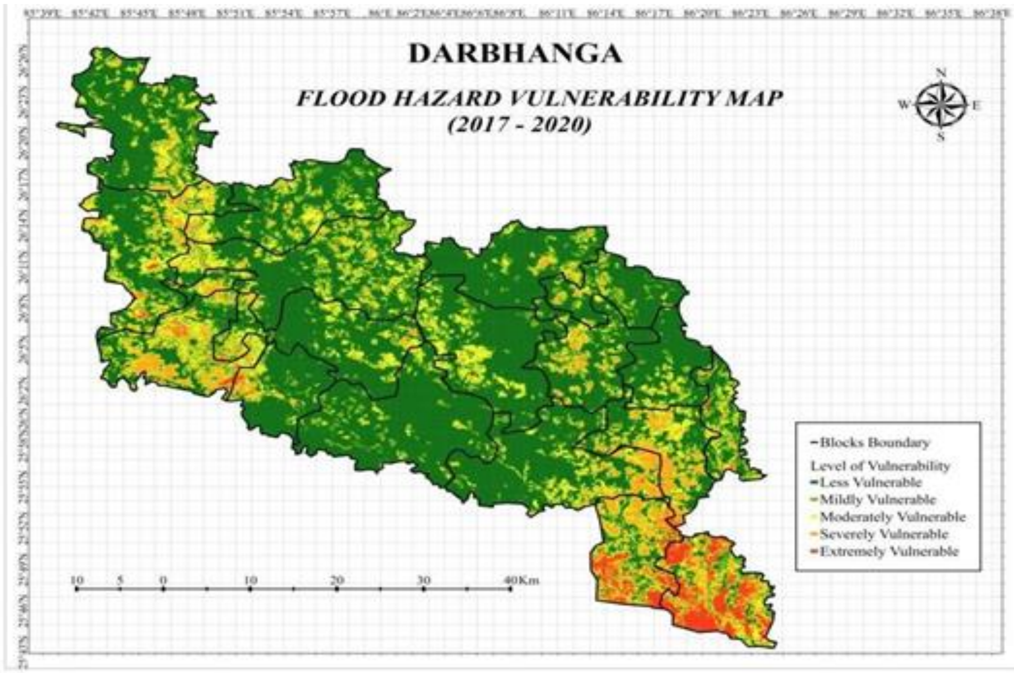


Fig 5.5. Flood Vulnerability Map

The results show that more than 80% of the total area of district has faced flood at least once in the past 4 years. The south-eastern blocks Kusheswar Asthan and Kusheswar Asthan Purbi are extremely prone blocks for flood and faces flood every year due to flooding in Kosi River and heavy rainfall. Red color represents extremely vulnerable areas and as we go to green color the vulnerability decreases. Table 5.1 shows area per vulnerability class.

Table 5.1. Area per vulnerability class

Class	Area (sq. km.)	Area (%)
Less Vulnerable	353.28	14
Mildly Vulnerable (flood occurred one time)	1568.15	62.14
Moderately Vulnerable (flood occurred two times)	333.2	13.2
Severely Vulnerable (flood occurred three times)	197.64	7.83
Extremely Vulnerable (flood occurred every year)	71.33	2.83
Total Area	2523.6	

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

6.2 Village Level Flood Vulnerability Mapping

District flood vulnerability map has been used to estimate village level vulnerability map which is shown in Fig.5.6.

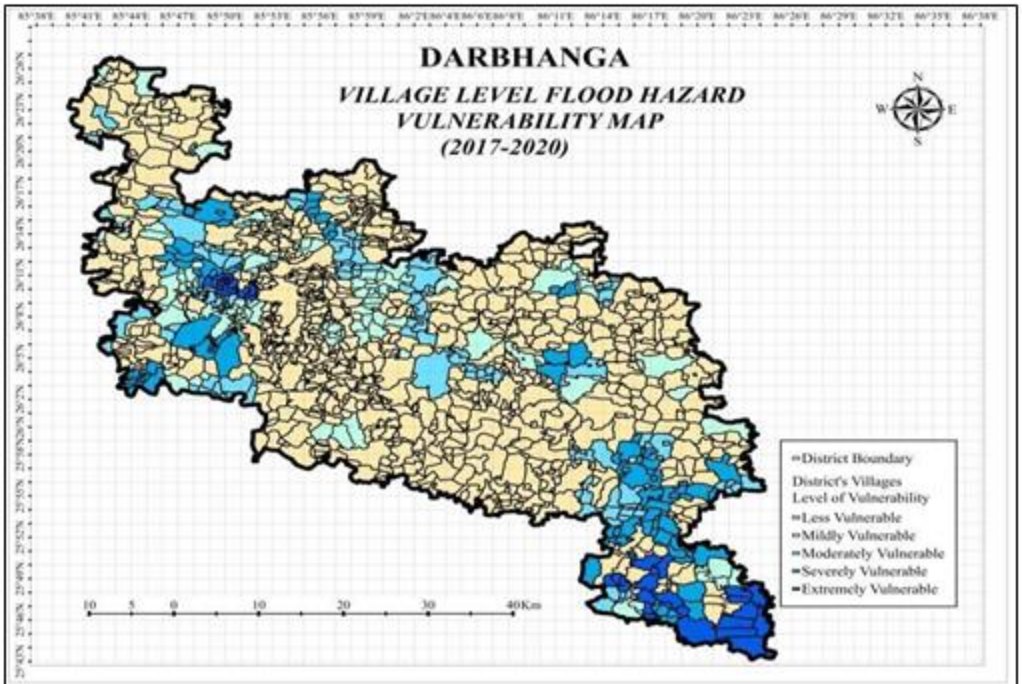


Fig 5.6. Village Level Flood Hazard Vulnerability Map

Table 5.2 Level of vulnerability (Village scale)

Level of Vulnerability	No. of Villages
Less Vulnerable	874
Mildly Vulnerable	156
Moderatly Vulnerable	147
Severely Vulnerable	106
Extremely Vulnerable	46

The results show that most of the villages have faced flood at least one time in past four years. 46 villages have faced flood every year and most of these villages are situated in the south-eastern part of the district in Kosi river catchment area, 106 villages have faced flood 3 times in the last 4 years and 147 villages got flooded 2 times during 2017-2020 period.

7. Conclusion

Natural disasters cause damage to life and property everywhere on the planet in various forms. Remote Sensing can help the disaster mitigation process through various processes like accurate predictions, detection of disaster prone areas, location of relief shelters and safe alternate routes etc. Post-disaster satellite data acquisition helps in disaster recovery; damage claim process and fast compensation settlement. Reducing disaster risks and incidents depends on scientific knowledge and evidence-based techniques like remote sensing. Use of science and innovative technology can significantly reduce lives and property losses. As industrialization and urbanization increases globally it is creating conditions for more disaster-related challenges that necessitate the process to expand the utilization of scientific methodology and technology for disaster risk reduction(DRR). There are many areas of DRR like systematic risk assessments, land use legislation based on accurate mapping with help of remote sensing data, building plans and implementation, disaster monitoring and warning systems and public awareness where the use and application of satellite remote sensing techniques have made it possible to get uniform data covering the entire nation during a relatively short time, and has also made it possible for these observations to be continually updated for the future.

This case study is an example of how remote sensing and GIS technology can help in monitoring and understanding the event of floods its pattern, extent and recurrence in a region. Use of remote sensing data can also help the authorities in forming the flood control policies not only with reference to land use planning but also can help in efficient planning for evacuation, providing relief and also suggest alternate agricultural practices like selection of water resistant seeds in regions facing perennial floods . The beneficiaries of latest technology are all stakeholders from people to government. It is crucial to understand which of the areas are at high risk and which of them are at relatively lower risk. Making use of the space technology helps in timely prediction and reduction in disaster damages, accurate and timely damage estimation and improved decision making.

References

1. Bapulu, G. V. & Sinha, R., 2005. GIS in Flood Hazard Mapping: A Case Study of Kosi RiverBasin, s.l.: GIS Development. http://www.gisdevelopment.net/application/natural_hazards/floods/floods001pf.htm

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

2. Census of India.India, 2011. District Census Handbook of Darbhanga, Bihar.
3. Ghosh, S. et al., 2017. The Potential Applications of Satellite Altimetry with SARAL/AltiKa for Indian Inland Waters. The National Academy of Sciences, 87(4), pp. 661-677.
4. Kanda, M. & Aggarwal, S. K., 2008. National Disaster Management Guidelines: Management of Flood, New Delhi: National Disaster Management Authority.
5. Lueng, L. & Cazenave, A., 2001. Satellite Altimetry and Earth Sciences: A Handbook ofTechniques and Applications. 1 ed. New York: Academic Press.
6. Lanza, L. and Conti, M. (1994). "Remote Sensing and GIS: Potential Application for Flood HazardForecasting." EGIS.
7. Lu, Sanyal, J. & X, X., 2004. Application of Remote Sensing in Flood Management with Special Reference to Monsoon Asia: A Review. Natural Hazards, Volume 33, pp. 283-301.
8. Mohamed, T. & Gasmelsied, 2011. Handbook of Research on Hydroinformatics: Technologies, Theoriesand Applications. New York: Information Science Reference.
9. OAS (1990). Disaster, Planning and Development: Managing Natural Hazards to Reduce Loss. Dept.Regional Development and Environment. Organization of American States. Washington, USA, 80.
10. P.A. Brivio, R. M. a. R. T., 2002. Integration of remote sensing data and GIS for accurate mapping offlooded areas. International Journal of Remote Sensing, 23(3), pp. 429-441.
11. Sahu, S., 2013. Ground Water Information Booklet,: Central Ground Water Board.
12. Shukla, R. R., 2013. Ground Water Information Booklet, s.l.: Central Ground Water Board.
13. Smith, L. C., 1997. Hydrological Processes, Volume 11, pp. 1427 - 1439.
14. UNDRO (1991). Mitigating Natural Disasters. Phenomena, Effects and Options. United Nations DisasterRelief Co-coordinator, United Nations, New York, 164.
15. World Disaster Report 2019.

ISSN: 2455-8834

Volume:06, Issue:12 "December 2021"

16. https://eird.org/americas/we/mandate.html
17. https://www.preventionweb.net/publication/chart-sendai-framework-disaster-risk-reduction-2015-2030
18. https://www.undrr.org/implementing-sendai-framework/what-sendai-framework
19. https://www.undrr.org/publication/hyogo-framework-action-2005-2015-building-resilience-nations-and- communities-disasters

