Generation of Thematic Layers for Flood Hazard Zonation Along the Banks of Koyna River Near Patan

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Abstract Floods are the most frequent and devastating natural hazards. Floods tend to cause large-scale loss of human life and extensive damage to property. Flood hazard mapping is a critical component of effective land use planning in flood-prone areas. This allows the development of charts and maps that help recognize areas of risk and offer priority to mitigation and response efforts. The objective of this study is to generate a flood hazard zonation map for part of Koyna River along Patan town, Dist. Satara, Maharashtra, India. High-resolution remote sensing images from Google Earth imagery and IRS–1D satellites are combined with hydraulic analysis of ASTER DEM to derive layers in ILWIS software developed by ITC, Netherlands. These layers were used to identify the flood-susceptible area of the study area. The flood hazard map developed can be further used for vulnerability and mitigation studies.

Keywords Geographic information system GIS · Aster DEM · Google Earth imagery · ILWIS · Flood hazard mapping

1 Introduction

Floods are one of the most destructive of natural disasters. In addition to the loss of precious human and animal life, floods lead to devastation of crops, dwellings and public services. Flooding can occur as a result of heavy precipitation, combined

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with inadequate channel capacity, or as a result of obstruction in the river bed. Extreme floods occur almost every year in one or more regions of India.

It has been experienced that the best way of flood management is a combination of various measures. First, preventive measures and, subsequently, necessary damage mitigation measures must be taken together through a combination of structural and non-structural measures.

The remote sensing satellites are capable of providing coverage of very large areas at regular interval and with quick turnaround time. We have extensive, synoptic and multi-temporal coverage of wide areas in real-time and at regular intervals. This has made them important for the continuous monitoring of flood-related atmospheric and surface parameters. Geographic information is contained in a geographical information system (GIS) database that can be queried and graphically represented for analysis. Through overlaying or intersecting various geographical layers, flood-prone areas can be identified and targeted for mitigation and implementation of flood-prone management practices [1].

Flood maps are used for many purposes. The primary flood maps are used to assess flood insurance costs, construction guidelines and flood preparedness for those at risk. Government authorities use them to establish zoning, land use and construction standards; flood warning, evacuation and emergency response planning; and to anticipate and respond to floods. Maps do not prevent floods from occurring, but they are an essential tool in avoiding or minimizing the damage to property and loss of life caused by floods, and for communicating flood risk.

In the creation of quality flood hazard data, high-quality topographic information is essential. From Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), commonly known as the Global Digital Elevation Model (GDEM), the degree tile of the GDEM was obtained. It was developed jointly by the Ministry of Economy, Trade, and Industry (METI) of Japan and the National Aeronautics and Space Administration (NASA) of the United States of America. This elevation dataset has multiple uses, and associated costs are avoided since this data are available freely on internet [2].

2 Study Area Location

Koyna River is a fifth-order perennial stream basin which is about 119 km in length. The basin is developed in the uppermost reaches of the drainage system of Krishna river, in Satara district of Maharashtra and is included within the survey of India topographic sheet number 47G/11 on the scale of 1 Inch: 1 Mile. The study area is lying between the latitudes 73° 53′ 1.23″ E, 73° 54′ 40.32″ E and the longitudes 17° 23′ 00.2″ N, 17° 21′ 49.5″ N. Koyna River receives its water from the catchment of Koyna Dam built at Deshmukhwadi, Tal.-Patan, Dist.-Satara and its tributaries Kera, Morna and Wang. Also from the Sahyadri ranges, on both sides of Koyna River drains an area of about 891 km^2. The area under study experiences

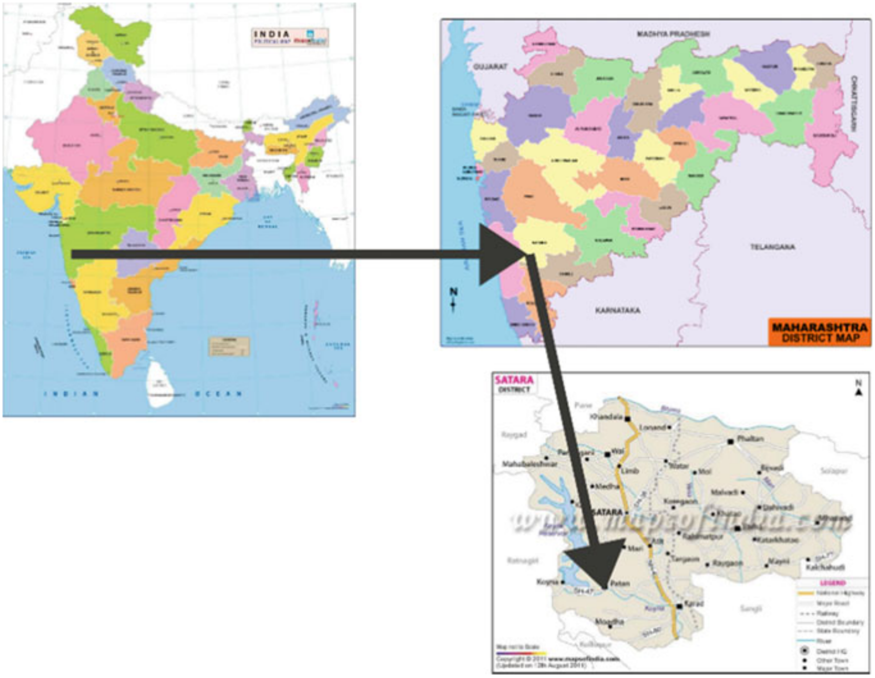

Fig. 1 Location of study area

semiarid to sub-humid climate. During the period from June to October it receives heavy rainfall, the annual rainfall being in excess of 2000 mm in Patan Tehsil. The summer is dry with maximum temperature reading from 38 to 40 °C [3] (Fig. 1).

3 Objectives

The objective of this study is to generate a flood hazard zonation map for part of Koyna River along Patan town, Dist. Satara, Maharashtra, India. The present study deals with the observation, analysis and interpretations of remote sensing data, ASTER DEM, IRS–1D panchromatic (PAN) data, Google Earth imagery and various GIS layer outputs derived from it. Flood hazard zonation map has been generated in GIS environment. High-resolution colour composite from Google Earth imagery data has also been imported and geo-referenced. The observations at the site made during the ground truth finding field visit were correlated with the GIS data layers. The interpretative outcome can be brainstormed and remedial measures based on them may further be designed.

4 Methodology

4.1 Standard FCC of Study Area

The high-resolution satellite data of the study area, near Patan, were collected from Google Earth satellite imagery. Google Earth imagery has good discrimination capacity for different land cover types or individual objects. This data were imported in ILWIS software via geo-gateway. The further generated raster maps were glued, and standard colour composite was made by assigning red, green and blue bands to final raster map. For further analysis, this high-resolution map was geo-referenced, and new coordinate system was generated.

4.2 Base Map

Land surface reference information describing streams, roads, buildings, settlements, agricultural land and administrative boundaries was digitized. These vector layers with high-resolution satellite data of a study area make a base map that shows the background context for mapping the flood hazard zone.

4.3 Interpolated Flood Level Map

Digital elevation model and IRS–1D PAN data procured from NRSC Hyderabad were used for the analysis. The mid-section of the stream was taken as datum and digitized with the value “zero” in value domain. Perpendiculars were drawn to the datum level. The text of available DEM was enabled to get reduced level at any point. By adding 5 m to the datum, 5 m level segment was created in value domain. Similarly, 10 and 15 m levels were extracted.

These vector layers were added on DEM of the study area, and contour interpolation operation was done at 0.1 m precision [4]. This led to the development of flood inundation map.

Geo-coded and geo-referenced high-resolution satellite data were overlaid on flood discharge model. The flood level value in metres for which a point on the ground shall be inundated can be displayed with a single click at the corresponding point on the imagery.

4.4 Flood Hazard Zonation Map (in Terms of Flood Levels in Metres)

Flood level map was analysed for settlement vulnerability. The area above the 1.9 m level where structures go under inundation is considered to be vulnerable and the rest as non-vulnerable. The area above 1.9 m is divided into three zones according to risk to structures. Finally, the slicing operation was done to generate the flood hazard zonation map layer.

This map can be easily used for the zonation of flood level. Here, in the present study, the flood inundation model has been sliced into three flood hazard zones. These layers along the interpretative aspect of the satellite data can be used for the assessment of the degree of hazard and vulnerability condition along both the banks of Koyna River [5].

5 Interpretation and Analysis of GIS Layers

5.1 Standard FCC of High-Resolution Map of Study Area

Here, we can see the stretch of study area—Patan Town. This map is a result of putting red, green, blue band images together in one colour composite. This map can give a better visual impression of the reality on the ground, than by displaying one band at a time. The spatial resolution of data is 0.125 m. It serves as a base map for different map generations. A colour composite was created to serve as a background image during sampling and subsequent image classification and for visual interpretation purposes, a printed colour composite may be useful as a field map, but you can also use a colour composite as a background image during on-screen digitizing [6] (Fig. 2).

5.2 IRS–1D PAN Data

IRS–1D panchromatic data were used to extract a sub-map around Koyna River at Patan. The 5.6 m single band data were stretched so as to highlight the water bodies, agriculture and forest, hilly area, plateau and drainage with 8-bit radiometric resolution. It has been observed that Koyna River, flowing east to west is confluences by Kera River from North near Patan and Morna River from South. A particular stretch ending near Kera confluence has been selected for mapping the flood mapping. The main stretch of Koyna, bound by high reliefs of Deccan trap hills, was digitized to develop mainstream vector. The moderately dark tone agriculture and the settlement patterns of Patan are seen on the image. The brighter tone of the hill slopes indicates barren land and lateritic plagues. The darker tones near the Koyna and Morna-Gureghar water bodies indicate dense forest of Western Ghats (Fig. 3).

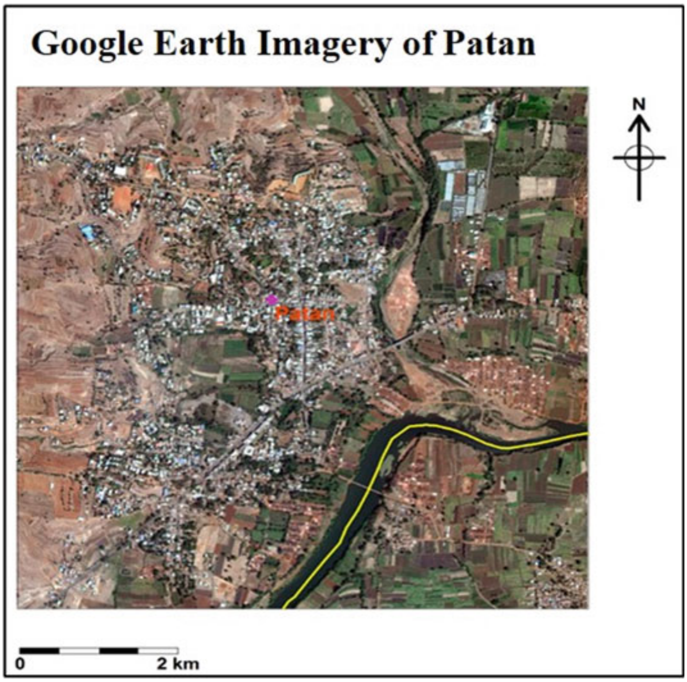

Fig. 2 Google Earth imagery of Patan

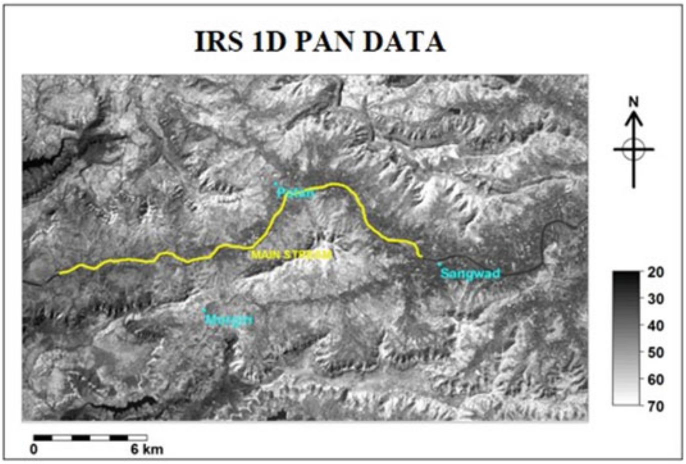

Fig. 3 IRS–1D PAN data

5.3 Digital Elevation Model

The ASTER DEM (Product of METI and NASA) was used for terrain analysis. This DEM has been prepared after the analysis of 30 m resolution stereo data. This DEM is a regular grid of elevation. Each node of the grid shows an altitude value. The resolution of the grid corresponds to the distance between neighbour nodes.

The spatial resolution of DEM used is 30 m with the vertical accuracy of 1 m. It can be observed from the DEM that Koyna River flows almost in a straight slope in the selected stretch. Both the banks are marked by gradually increasing altitudes towards the plateau at the elevation of about 1200 m for the study. This DEM was found to be very useful for extracting the flood levels to different Reduced Levels. Here, the DEM is superimposed in white by the mainstream segment (Fig. 4).

5.4 Digitized Flood Level Segment Map

Here, we assumed the mainstream as a datum level. The reduced levels of 5, 10, and 15 m were extracted and digitized with respect to the datum level. This map gives the scenario of the flood in terms of flood levels (Fig. 5) [7].

5.5 Interpolated Flood Levels Map

The flood level segments were interpolated to derive the flood level map. It has been observed that very large area is inundated near Patan for the lower flood level. Upon analysing this particular sheet, the Patan sub-map was selected and extracted for further research on flood hazard zonation, vulnerability assessment and

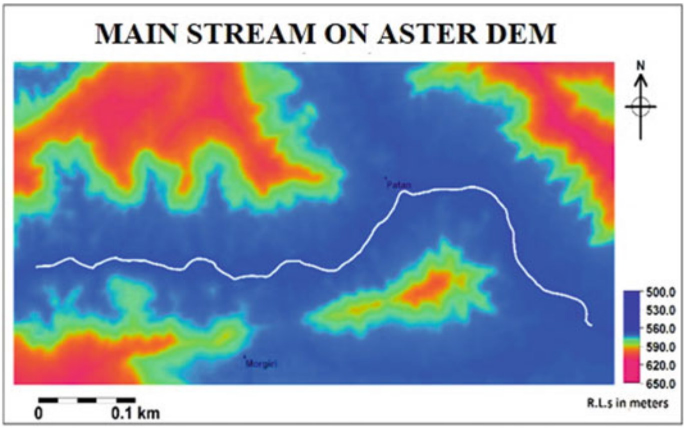

Fig. 4 ASTER DEM (Product of METI and NASA)

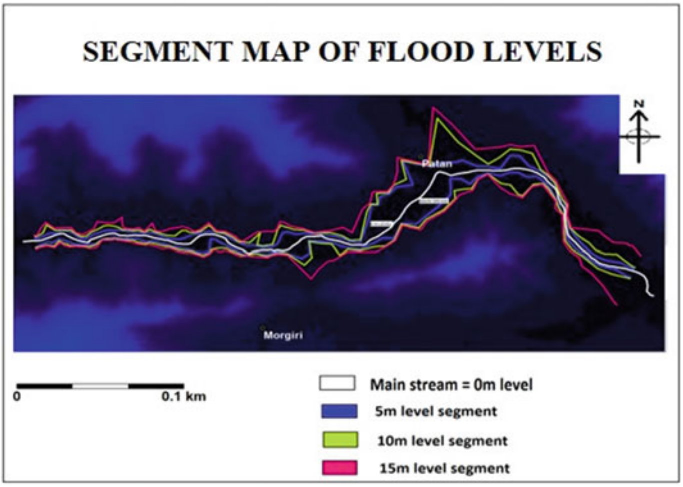

Fig. 5 Segment map of digitized flood levels

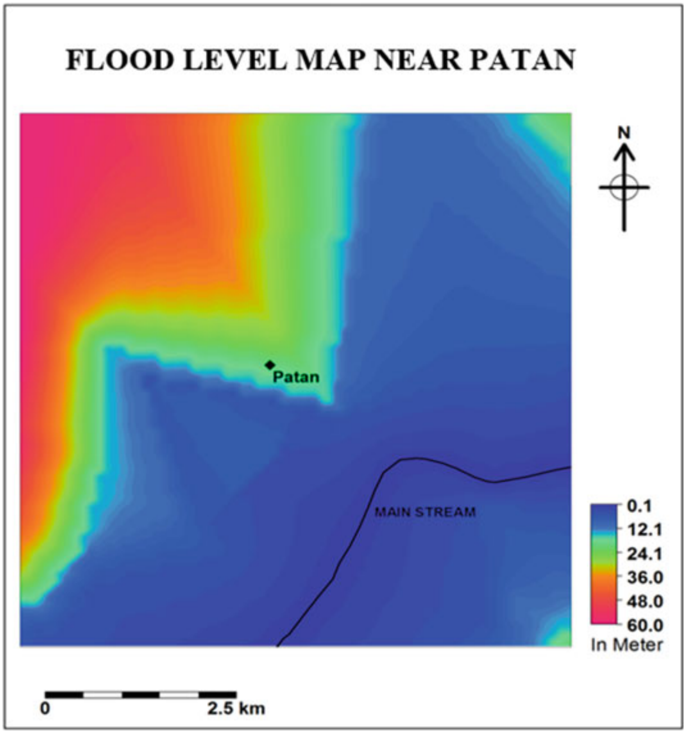

Fig. 6 Interpolated flood level map near Patan

preventative civil engineering measures. The sub-map was studied along with the high-resolution colour composite of Google Earth imagery data (Fig. 6).

5.6 Flood Hazard Zonation Map (in Terms of Flood Levels)

This map is the final result of the integration of different layers generated in ILWIS software. It includes 5 zones for flood hazard zonation mapping. High-resolution map of study area, Patan, is added for vulnerability analysis. First two zones are

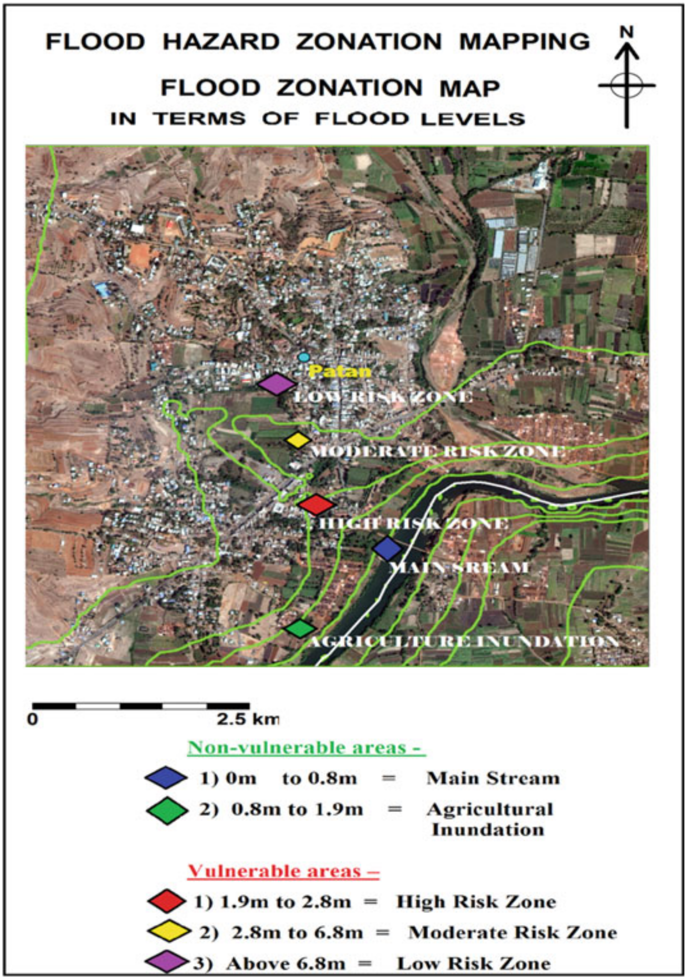

Fig. 7 Flood hazard zonation map in terms of flood level

Table 1 Area under flood hazard zones

Flood levels (m)	Settlement vulnerability	Zones	Area (km^2)
0–0.8	No	Main stream flow	2.55
0.8–1.9	No	Agricultural inundation	3.34
1.9–2.8	Yes	High risk zone	3.02
2.8–6.8	Yes	Moderate risk zone	12.14
Above 6.8	Yes	Low risk zone	33.3

non-vulnerable. Here, we can see 0–0.8 m region from the mainstream comes under areas of the stream zone. It indicates agricultural land that undergoes flooding. Remaining 3 zones are vulnerable as the flooding in those areas would impact the settlement. Flood water extends for various elevations in those three areas (Fig. 7 and Table 1).

6 Conclusions

ASTER DEM, IRS–1D PAN data and moreover the well processed high-resolution Google Earth imagery available for the common man with its impactful user interface have improvised the domain of data users. Remote sensing and GIS techniques have emerged as a powerful tool for addressing diverse facets of flood control in flood hazard prevention, notification, preparedness and relief control. They have a greater role to play as an improvement over the existing methodologies. In this study, attempts are made to illustrate the use of RS and GIS techniques in the flood hazard assessment. Using these techniques, the flood zone mapping of the Koyna River Basin has been carried out.

The primary purpose of making flood maps is to make them accessible to the public, which would help raise awareness. In this study, efforts were made for floodplain zoning for the settlements in Koyna river basin near Patan through the remote sensing data interpretation, and GIS database was generated after vector digitization and raster analysis.

With the help of remote sensing data, the study area has been divided into three flood risk zones, i.e. low, middle and high level. Based on the above study, it is found that about 3.02 km^2 area comes under high-risk zone, whereas 12.14 and 33.3 km^2 area comes under moderate and low-risk zone, respectively.

It is observed that ASTER DEM is an effective tool for many applications and can be used in planning for flood disaster management and mitigation. This work is an attempt to corelate the output from ASTER DEM with the flood hazard-related data generated from IRS–1D PAN data and high-resolution Google Earth imagery data.

References

1. Kumar A (2005) Application of GIS in flood hazard management: an alternative plan for the floods of North Indian Plain. Map India, New Delhi
2. Yamaguchi Y, Kahle A, Tsu H, Kawakami T, Pniel M (1998) The advanced spaceborne thermal emission and reflection radiometer (ASTER). IEEE Trans Geosci Remote Sens 36 (4):1062–1071. https://doi.org/10.1109/36.700991
3. Water Resources Department (2018) Integrated state water plan for Maharashtra. Government of Maharashtra
4. Khanna RK, Agrawal CK, Kumar P (2006) Remote sensing and GIS applications in flood management. In: Indian disaster management congress, National Institute of Disaster Management, New Delhi, India
5. Shinde VM, Deshpande PK, Kumthekar MB (2013) Application of ASTER DEM in watershed management as flood zonation mapping in Koyna River of the Western Ghats. Int J Sci Eng Res 4(5)
6. Cees van Westen, Jamshid Farifteh (2001) ILWIS 3.0 academic user's guide
7. Sathe B, Khire M, Sankhua R (2011) Integrated remote sensing and GIS for flood hazard mapping in Upper Krishna River Basin (India). Int J Sci Technol