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DEVELOPMENT OF GIS BASED DISASTER RISK INFORMATION SYSTEM FOR DECISION MAKING

Gangapriya P, Indulekha K P

M.Tech Student, Dept. of Civil Engineering, College of Engineering Trivandrum, Kerala, India

Assistant Professor, Dept. of Civil Engineering, College of Engineering Trivandrum, Kerala, India

ABSTRACT

Disasters can occur as a consequence of the impact of a natural or a human caused hazard. This study aims to analyze the multiple hazards of Thiruvananthapuram district. The disasters considered for the study are flood, forest fire, coastal erosion and drought. Separate methodology is developed for each of these disasters to analyze the severity of hazard. The results obtained from the study reveals that Thiruvananthapuram district is prone to flood, drought, coastal erosion and forest fire. The integration of individual disaster maps created the multi hazard map of the study area. It indicates some of the regions in study area prone to multiple hazards. By using these databases a risk information system for disaster management in Thiruvananthapuram district was developed. The web based disaster management systems can reduce the pressure of organizers to manage information and data directly after a disaster and in the midst of a time of crisis.

NOMENCLATURE

| | |
|------------------------|--|
| CVI | Coastal Vulnerability Index |
| FR | Numerical index of fire risk |
| λ_{NIR} | reflectance in the near infrared (NIR) |
| λ_{RED} | reflectance in the red bands |
| NDVI | Normalized Vegetation Index |
| SPI | Standard Precipitation Index |

1. INTRODUCTION

Each year, disasters arising from volcanoes, storms, floods, and earthquakes cause thousands of deaths and tremendous damage to property around the world, displacing thousands of people from their home and destroying their livelihoods [1]. Many of the losses of life and property could be controlled if better information were available on the exposed populations and assets, environmental factors in disaster risk,

and the behavior and patterns of particular hazards [1].

The field of disaster management has greatly benefited from recent advancements in computers and related technology. In particular, GIS, remote sensing, and the Internet have had a significant impact, and are currently being used in a variety of ways during all phases of disaster management. Integrating these technologies to create a spatial decision support system offers new possibilities for disaster management, particularly during the initial response phase of a disaster.

The State of Kerala is prone to a host of natural hazards such as coastal erosion, flood, drought, lightning, landslide and earthquake [5]. All most all districts of Kerala are multi-hazard prone. In Thiruvananthapuram district 12.23% of the total area is flood prone and 41.11% of the total coast is eroding.

The earlier studies of disasters in the study area mainly deal with single hazards and its management plans. This study brings out multiple hazards mapping of a particular area. The concept of a disaster information system is new for the study area.

1.1. Literature review

Cees J. van Westen (2008) studied about remote sensing and GIS for natural hazards assessment and disaster risk management. The use of earth observation (EO) products and geo information systems (GIS) has become an integrated, well developed and successful tool in disaster risk management. Hazard and risk assessments are carried out at different scales of analysis, ranging from a global scale to a community level.

Quan-guo LI, Ling KANG, Dong-qi TANG and Yun-long ZHU (2011) made a study on applications of spatial information technology in natural disasters. This paper analyzes the uses of spatial information technology in the field of investigation and identification, distribution and law, risk evaluation and zoning, loss assessment, forecasting and dynamic monitoring of the application in natural disasters.

1.2. Objective

The present study attempts to bring out the information about different disasters experiencing in Thiruvananthapuram district and develop a disaster information system which will be useful for disaster management practices.

1.1. Study area

Thiruvananthapuram, the southernmost district of Kerala State is situated between north latitudes 8°17' and 8°54' and east longitudes 76° 4' and 77° 17'. The district stretches 78 kms along the shores of the Arabian Sea on the west, Kollam district lies on the north, Thirunelveli and Kanyakumari districts of Tamil Nadu on the east and the south respectively. Location map of the study area is shown in figure 1.

The State's geographical location, weather pattern and high population density makes it prone to severe natural as well as human-induced disasters which can be countered only through organized mitigative actions [5].

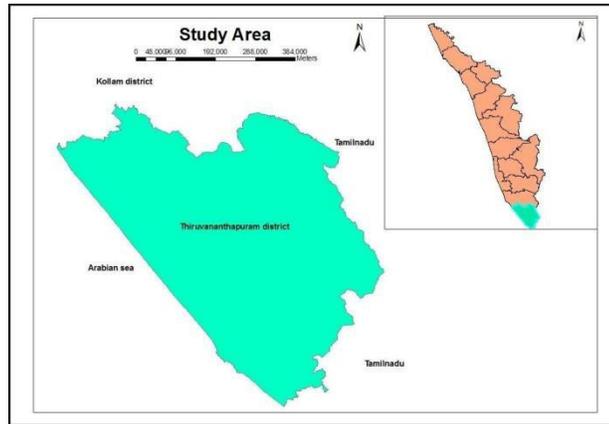


Fig 1: Location map of study area

2. METHODOLOGY

Multi hazards are identified from the literatures, past studies and enquiries to the experts. Methodology for the mapping of each single hazard is adopted from earlier researches and then developed a strategy to prepare multiple hazard maps. Each hazard mapped separately with the help of GIS techniques. Then a weighted overlay analysis had been carried out to obtain multi hazard map. By using this database a disaster information system were created.

2.1. Flood

Rainfall, elevation, slope, drainage density, road density and landuse type data layers that were selected as input data for assessing flood hazard. Selection of these factors was based on the previous studies. Flood hazard map was created by using the weighting and ranking technique. Risk refers to the threat to life or property that may result from the action of a hazard upon some structure, system, or population. Flood risk map was created by using the same weighting and ranking technique used for mapping flood hazard areas. Hazard, population, and landuse types were selected as the most influential factors in evaluating flood risk. A flood risk map then was created by overlaying the flood hazard map with the population density and then the land use maps.

The total estimated risk, obtained by adding the weighted risk rankings of all factors, also was classified in five categories; very low, low, moderate, high, and very high risk.

2.2. Coastal Erosion

To address the multi-faceted task of predicting sea-level rise impact, the USGS has implemented a methodology to identify areas that may be most vulnerable to future sea-level rise (Hammar-Klose and Thieler, 2001). This technique uses different ranges of vulnerability (low to very high) to describe a coast's susceptibility to physical change as sea level rises. The vulnerability determined here focuses on six variables which strongly influence coastal evolution [3].

The coastal vulnerability index (CVI) allows the six variables to be related in a quantifiable manner that expresses the relative vulnerability of the coast to physical changes due to future sea-level rise. A relatively simple vulnerability ranking system allows the six variables to be incorporated into an equation that produces a coastal vulnerability index (CVI). Once each section of coastline is

assigned a vulnerability value for each specific data variable, the CVI is calculated as the square root of the product of the ranked variables divided by the total number of variables.

$$CVI = \frac{\sqrt{a \times b \times c \times d \times e \times f}}{6} \quad (1)$$

Where,

- a = geomorphology
- b = shoreline erosion/accretion rate
- c = coastal slope
- d = relative sea-level rise rate
- e = mean wave height
- f = mean tide range

2.3. Forest Fire

The most important factors leading to accidental fires in the Trivandrum reserve forest are the vegetation type and density, humidity of the area, proximity to settlements and distances from roads. Thematic maps were prepared separately based on their sensitivity to forest fire as very high, high, moderate or low. Then suitable weights were assigned.

The equation used in a GIS for the fire risk modelling and or mapping the fire risk areas is:

$$FR = 10F_{i=1-11} + 2H_{j=1-4} + 2R_{k=1-4} + 3S_{l=1-6} \quad (2)$$

Where,

- FR - Numerical index of fire risk,
- F- Vegetation variable (with 1–11 classes),
- H- Indicates proximity to human habitation (with 1–4classes),
- R- The road factor (with 1–4 classes) and
- S - Slope factor (with 1–6 classes).

The superscripts i , j, k, l indicate subclasses based on importance in determining the fire risk.

2.4. Drought

Calculation of drought is based on Standard Precipitation Index (SPI) and Normalized Vegetation Index (NDVI).

The SPI calculation is based on the long term precipitation record for a time period. This long term record is fitted to a probability distribution, which is transformed into a normal distribution where the mean SPI for the location and desired time period is zero[3].

Tucker in 1979 suggested NDVI as an index of vegetation health and density.

$$NDVI = (\lambda_{NIR} - \lambda_{RED}) / (\lambda_{NIR} + \lambda_{RED}) \quad (3)$$

Where,

- λ_{NIR} - reflectance in the near infrared band
- λ_{RED} - reflectance in the near red band

The NDVI is the most commonly used vegetation index. It varies in the range of -1 to + 1[5].

Flood hazards are mainly located nearer to the water bodies especially rivers and the areas are having lower elevation values. Due to the type of use, certain areas on the flat relief such as coastal plains are having moderate high values.

3.2. Coastal Erosion

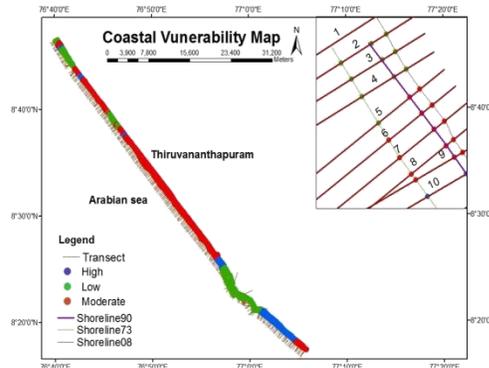


Fig 3: Coastal vulnerability map

The rate of shoreline change from the year 1973 to 2008 is calculated using DSAS tool. The coastal vulnerability of Thiruvananthapuram district is shown in figure3.

The calculated CVI value along the study area of Thiruvananthapuram coastline ranges from 1.73 to 8.66. The mean CVI value is 5.10. The 25th, 50th and 75th percentile of CVI value are 4.73, 6.03 and 9.39 respectively. Those grids having CVI value ranging from 0 to 4.73 is taken as low vulnerable area, grids having CVI value from 4.73 to 6.03 is taken as medium vulnerable area, grids having CVI value from 6.03 to 9.39 is taken as high vulnerable area and grids having CVI value greater than 9.39 is taken as very high vulnerable area.

The coastal vulnerability is lower at Kovalam, Edava, Kayikkara and pulinkudi and Puvar, Vettur etc are high vulnerable regions. Meenamkulam to Karikkakam and Puvar region shows higher erosion. The rate of shoreline change shows increments in every year. In this region observed a mean erosion rate of -6.38 and mean accretion rate of 10.39mm. Out of 78kms coastal stretch, 14.3 km is highly vulnerable, 21km is having low vulnerability and 42.7 km is moderately vulnerable.

3.3. Forest Fire

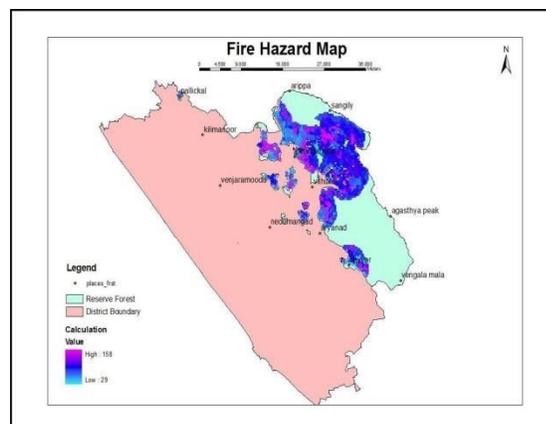


Fig 4: Forest fire hazard

The union process of flood hazard map, coastal erosion map, forest fire map and drought map created the multi hazard map of the particular study area. The study area has an area of 2192km². In that 200.20 km² comes under very high hazard category and 1689.73 km² area under the high hazard category. Most of the regions in Thiruvananthapuram district are affected by any one of the hazard or more than one hazard.

3.6. User Interface

A web application interface called Disaster Risk Information System was created. This provides information related to hazards, its severity, population, landuse and the administrative region. In the module for displaying the information of disasters, there is an option for the user to select the hazard. Then the details corresponding to that disaster, its severity, the administration region, landuse category and population density are displayed. It provides the facility to choose more than one hazard at a time.

4. CONCLUSION

A disaster is comprised of three components; hazard, risk, and vulnerability. The hazard is the probability of the occurrence of a potentially damaging phenomenon within a given period of time and space. In this study the study area prone to four kinds of disasters. They are flood, coastal erosion, drought and forest fire.

Thiruvananthapuram district a total area of 2172 km² is affected by flood. Flood hazards are mainly located nearer to the water bodies especially rivers and the areas are having lower elevation values. Due to the type of use, certain areas on the flat relief such as coastal plains are having moderate high values.

The rate of shoreline change shows increments in every year. In this region observed a mean erosion rate of -6.38 and mean accretion rate of 10.39mm. out of 78kms coastal stretch, 14.3 km is highly vulnerable, 21km is having low vulnerability and 42.7 km is moderately vulnerable.

The low and mid land regions of Thiruvananthapuram district have higher range of drought. The forest region shows lower drought hazard values.

In Thiruvananthapuram district a total area of 260.98km² area of forest region is affected by forest fire. Most of the regions in Thiruvananthapuram district are affected by any one of the hazard or more than one hazard. A disaster risk information system is developed for Thiruvananthapuram district using Geoserver. It displays the hazard category, severity of hazard, panchayath, population and landuse. Internet based GIS could play a key role in the collection and dissemination of relevant information in a fast, relatively inexpensive and straightforward manner during various stages of a disaster life cycle. Computer based disaster management systems reduce some of the pressure of having to organize information and data directly after a disaster and in the midst of a time of crisis. They provide decision makers with the information that they require to develop and maintain their understanding of the spatial characteristics of a natural disaster, and its impacts over a range of time.

5. ACKNOWLEDGMENT

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