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Application of GIS in flood hazard management of Kosi River Basin

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Abstract
Over the last two decades Geographic Information System (GIS) has emerged on an effective tool for planning and management and has become an umbrella concept for all automated systems that integrate and handle geo- referenced information. GIS is a computer-based tool for the input. Storage, management, retrieval and out- put of information. Long (2000) defines is as "A Geographic Information (GIS) is a computer system for analyzing and mapping just about anything moving or stationary. A GIS integrates common database operations such as query and statistical analysis with the ability to see how data relates in space and time, "on Hall's Hall (1999)" stresses the point that "GIS are much more than simply computer mapping system and can do much more than merely out putting improved digital versions of static paper based map, GIS blend map production, image presentation and statistical analysis capabilities into a powerful analytical tool that can be applied to a variety of Problems."

Keywords: Decades, emerged, effective, umbrella, automated, integrated, retneral, analyzing, operations, query, stresses, merely, capabilities, component, appropriate, identifying, accurately, multi-criteria, hierarchical, tupyraphical, susceptibility, inherently

Introduction
Flood Hazards Mapping is a vital component of appropriate land use planning in flood-prone areas. It creates easily-read, rapidly-accessible charts and maps which facilitates the administrators and planners in identifying areas of risk and priorities their mitigation/response efforts. This article presents an efficient methodology to accurately delineate the flood hazard areas in the Kosi River Basin, North Bihar, India in a GIS environment. We have used one of the multi-criteria decision making techniques. Analytical Hierarchical Process (AHP) which provide a systematic approach to assessing and integrating the impact of various factors, involving several levels of dependent and independent, qualitative and quantitative information. We present a novel methodology for computing a composite index of flood hazard derived from topographical, land cover, geomorphic and population related data. All data are finally integrated in a GIS environment to prepare a final flood hazard map. The flood hazard index computed from AHP method considers not only the susceptibility of each area to be inundated but also takes into account the factors that are inherently related to flood emergency management.

The study area
Floods are probably the most recurring, widespread, disastrous and frequent natural hazards of the world. India is one of the worst flood-affected countries being second in the world after Bangladesh and accounts for nearly one fifth of the global death count due to floods. About 40 million hectares or nearly 1/8th India's geographical area is flood-prone. The plains of north Bihar are some of the most susceptible areas in india, prone to flooding. A review by Kale (1997) [12, 16] indicated that the plains of north Bihar have recorded the highest number of floods during the last 30 tears. The total area affected by floods has also increased during these years.
Drained by two major river systems the Kosi and Gandak, and several others smaller systems such as Burhi Gandak, Baghmati and Kamla-Balan, the plains of north Bihar have experienced extensive and frequent loss of life and property over the last several decades (Sinha and Jain, 1998) [16].

Kosi, sorrow of Bihar is well-known for rapid and frequent avulsions of its course and the extensive flood damages it causes almost every year. The Kosi is one of the major tributaries of the Ganga River and rises in the Nepal Himalayas. After traversing through the Nepal Himalayas, it Enters India near Bhimnagar after traversing the Nepal Himalayas. It flows across the plains of north Bihar and joins the Ganga River near Kursela, after traverlling for 320 km from Chatra Gorge. The river has been causing a lot destruction by its lateral movement and extensive flooding. As its waters carry heavy load of silt and have steep gradient, the river has a tendency to move sideways, Thus in about 200 years the river has moved laterally by about 150 km (Gole and chiltalate, 1966; Wells and Dorr, 1987) [11, 13]. To check the lateral movement and to control, embankments, were constructed, five to sixteen km apart. Although this has prevented the lateral shift of the river and confined it to within the embankments, the problem of flooding is still a challenge in this area. The problem of river flood is getting more and more acute due to human intervention in the flood plain at an ever increasing pace. It should be realized that minimizing the risk and damage by floods may be more rational way of flood management rather than formulating structural measures along the surging rivers such as the Kosi.

In this scenario, the regulating the flood hazard areas and enactment and enforcement of flood hazard zoning could prevent damage of life and property by flooding in short as well as long term. Flood management and control are necessary not only because floods are curse to society, but the optimal exploitation of the land and proper management and control of water resources are of vital importance for bringing prosperity to the predominantly agricultural-based economy. This cannot become technically feasible without effective flood hazard maps. Flood hazard mapping and flood inundation modeling are two of the vital component in flood mitigation measures and land use planning, and are prerequisites for flood insurance schemes. This article presents a multi-parametric analysis to compute a composite index of flood hazard and to produce a Flood Hazard map. The primary data used for this study were obtained from three sources. The first set of data including topographic maps, district level maps, and census date of 1991 for the regional divisions of Bihar were obtained from the survey of India, National Atlas & thematic Mapping organization (NATMO), and district Statistical office, Saharsa respectively. The second set of data including the digital elevation data (GTOP030), a global digital elevation model (DEM) from U.S geological Survey's EROS data Center in Sioux Falls South Dakota and the DEM derived from the toposheets of the study area. The third set of data is the digital remote sensing images for the study area (IRS-ID, LISSI III) obtained from the national Remote Sensing Agency, Hyderabad.

Objectives

The goal or the objective of this study is the mapping of flood hazard zones in the Lower Kosi river basin. The decision factors to relate attribute to suitability concerning a particular goal are the factors controlling flood hazards in the study area. The primary decision factors considered in this study are geomorphic features, elevation, vegetation, land cover, distance to active channels, and population density (Fig.1). Once the decision factors are identified and selected sub-factors and even sub-factors are identified to describe these criteria in a better way. For example, the geomorphologic factor was sub- divided into nine sub factors as shown in Figure 1.

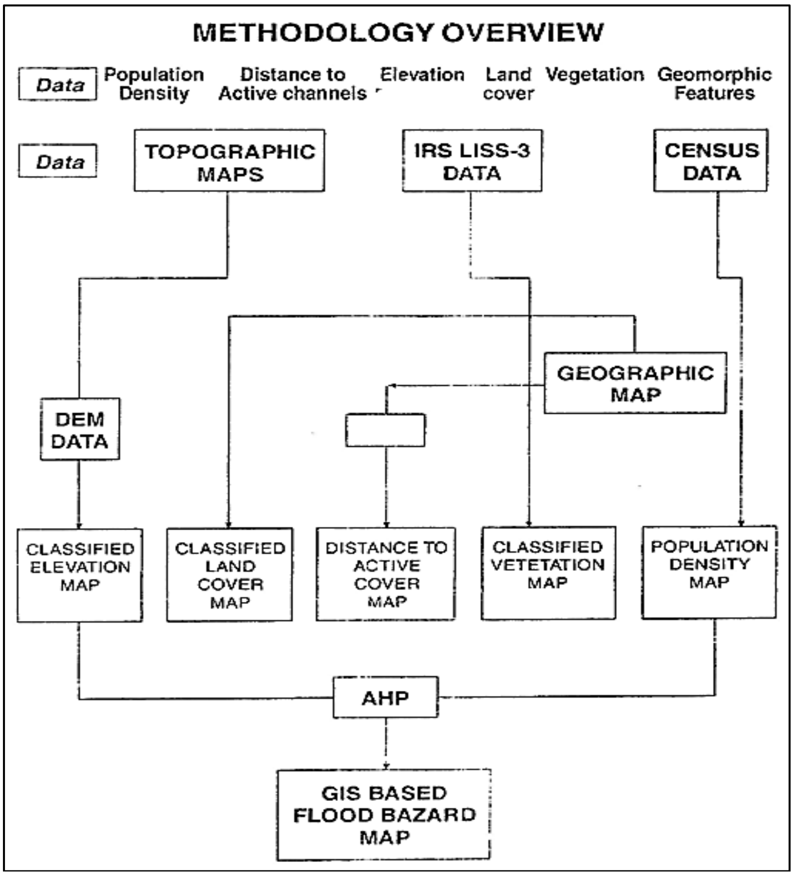

Fig 1: Methodology followed for flood hazard mapping

Similarly, the other decision factors like vegetation, land cover, elevation distance and population density were sub-divided into sub-factors.

Methodology

In this study. Arcbview GIS3. 2a was used in this study for working with grids and shape files. The sequence of operations is schematically shown in Figure 2.

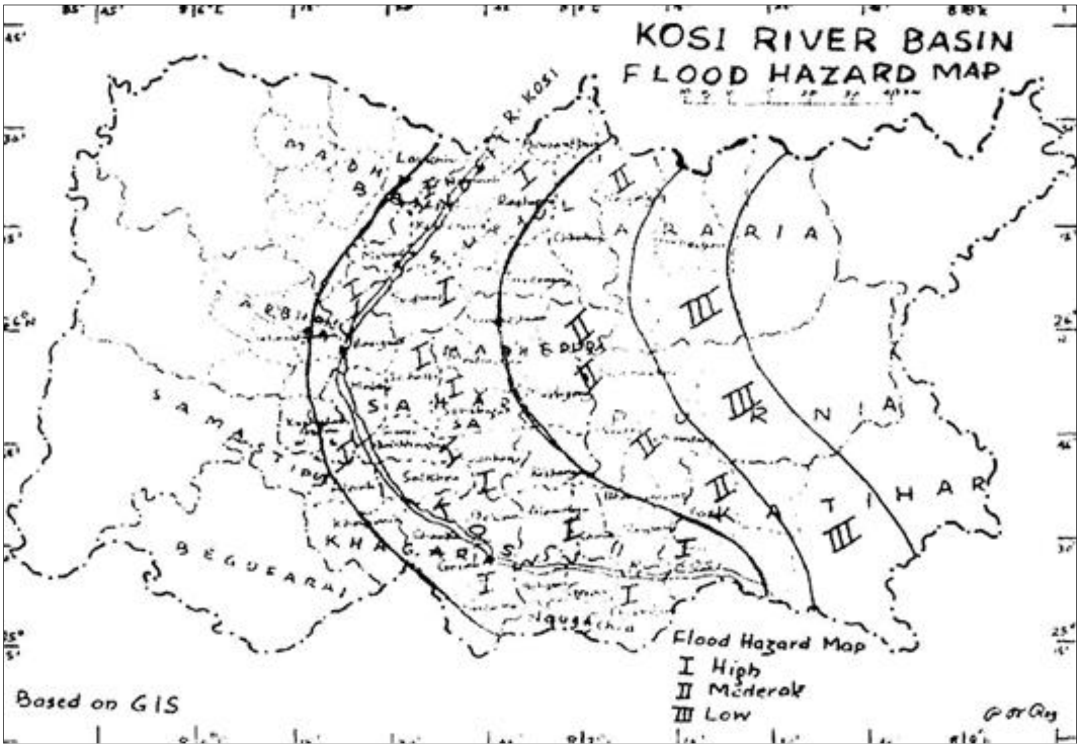

Fig 2: Kosi river basin flood hazard map

Firstly, the DEM of the study area was generated first using the spot height data collected with the help of topomaps in IL WIS 3.2 Image Processing software. Then it was converted into a point map and exported into Arc View GIS; where this vector elevation map is converted into raster grid format for overlay analysis. Next, the satellite in imagery was georeferenced and registered to the geographic space. On this georeferenced image, Image classification algorithms like GMLC, NDVI were applied to extract the land cover and vegetation information. Also on screen digitization was carried out to delineate the geomorphic features form the image. All these classified and processed images were then exported into Arc View GIS for conducting overlay analysis at the third stage. Demographic data like population density (delineated from Census data in Arc View GIS) was also included in the overlay analysis. Some extra GIS operations like buffering were applied on some of the above obtained data to derive some new significant data which in turn used in overlay analysis. Finally, all data were integrated in a GIS environment using AHP method discussed next. The study is carried ort suing ENVI 4.0, ERDAS IMAGINE 8.5, ILWIS 3.2, Arcview GIS- Spatial Analysis Extension with Model Builder, Arcview GIS-3D Analyst Extension.

Analytical Hierarchical Process (AHP) is a multi- criteria decision making technique, which provides a systematic approach to assessing and integrating the impacts of various factors, involving several levels of dependent, qualitative as well as quantitative information. It is a methodology to systematically evaluate often conflicting, qualitative criteria (Saaty 1980) [14]. Like other multi-attribute decision models, AHP also attempts to resolve conflicts and analyze judgments through a process of determining the relative importance of a set of activities or criteria by pair wise comparison of these criteria on a 9 point scale. In order to do this a complex problem is first divided into a number of simpler once in the form of a decision hierarchy (Erkut and Moran, 1991) [10]. AHP is often used for comparing the relative preferences of a small number of alternatives concerning an overall goal. AHP is become popular in decision making studies where conflicting objectives are involved. Recently Siddiqui *et al.,* (1996) introduced a new method known as Spatial - AHP to identify and rank areas that are suitable for a landfill, using knowledge based user preferences and data contained in GIS maps.

The RIWs are the normalized Eigen vectors corresponding to the maximum Eigen values of the pair - wise comparison matrices constructed at each level of the decision hierarchy. The RIW assigned to each hierarchy element was determined by normalizing the Eigen vector of the decision matrix. Eigen vectors were then estimated by multiplying all the elements in a row and taking the nth root of the product, where n is the number of row elements (Saaty, 1980) [14]. Normalization of the Eigen vectors was accomplished by dividing each Eigen vector elements to the decision factor.

For the hierarchy represented in the Figure 2, the relative important weightage of level 2 decision factors like population density, distance, elevation, vegetation, land cover, geomorphic features were determined by comparing the decision factors pairwise. This was followed by pairwise comparison within each level 3 decision factor. An attempt has been made to resolve conflicts and analyze judgment by a process of determining the relative importance of decision factors related to this study by pairwise comparison of these factors on a nine point scale.

Findings

A comparison of the flood hazard map with MODIS flood inundation image reflects the following findings facts:

a. The western part of the study area: The western part of the study area is a high and very high flood hazard zone. The population density is also high (8011100>1100 persons per km2 as per 2001 census) in the region. This area is frequently inundated.

b. Distance to active channels: Distance to active channels (which are the main sources of flood discharge) is playing an importance role in the control of flood hazard in the study area.

c. Geomorphic features: Geomorphic futures like active channels inactive channels, channels bars, water logged areas, oxbow-lakes, moist sand are undergoing rapid modifications due to channels avulsion, meandering cut offs in the study area. Such dynamic behaviour also contributes to frequent and extensive flooding in the area.

d. The entire region: The entire region is a plain having slope from north-west to south-east. The elevation in the study window gradually reduces from 49m in the north to 32 m in the south and as a result a number of marshes and swamps have developed in this region. Moreover, a number of tributaries join the Kosi in this region. As a result, this area has very high flood hazard index.

e. The inundation limit: The inundation limit or extent of MODIS inundation map of 2004 and previous years closely match with the hazard areas in the map validating (or confirming) the logic used in the analysis and the model developed; reflecting flood effects for operational years.

f. Flood hazard areas: Flood Hazard areas have been mapped as per the combined effect of different parameters and not just on the basis of a few years of inundation data. Thus, the potential of flood hazard of various areas is based on the integrated analysis and not merely on a hydrological phenomenon.

g. There are some: There are some areas which have not been inundated during the last 1-2 years but they still fall under high and very hazard areas e.g. part of Kiratpur, Gouraboram, Biraul, Mahisi Kusheshwarsthan west, Alauli development blocks. The suggests that the possibility of coming of flood in the future is high in these regions and therefore adequate measures should be taken to protect these areas.

h. The development blocks: The development blocks viz. Singheswar, Madhepura, Sour-Bazar, Eastern parts of Saharsa, Simri Bakthiarpur, Supaul fall under low hazard area and have also been inundated during the last 10 years. This indicates much lower probability of coming flood in future. This is perhaps a manifestation of gradual migration of the Kosi towards west during the last 200 years.

Conclusion

The research presented in this article formulates an efficient methodology to accurately delineate the flood hazard areas in the lower Kosi River basin, North Bihar India. This study represents some exploratory steps towards developing a new methodology for inexpensive, easily- read, rapidly accessible charts and maps of flood hazard based on morphological, topographical, demographical related data. The study has also focused on the identification of factors controlling flood hazard in the study area. It accomplishes this goal by combining Spatial AHP technique with GIS-based overlay analysis.

Such an efforts should be a part of non - structural measures of flood management to reduce short term and long term damages and to bring awareness among the scientific community of the potential need of this research. The basic merit of this methodology lies in its simplicity and low cost. This is one of the initial projects the lessons learned from this pilot effort can be applied to a larger area encompassing the entire Kosi River Basin and other river basins of the country.

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