Integrated Remote sensing and GIS for Flood Hazard Mapping in Upper Krishna River Basin (India)

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Abstract

Remote sensing and GIS were applied for flood hazard mapping by means of weighting, a number of causative factors including annual rainfall, size of watershed, side slopes of watershed, gradient of river and stream, drainage density type of soil and land use, communication line and infrastructures. Population density was considered for rating the degree of hazard and risk. The objective of this study is to generate a flood hazard map for Upper Krishna river in India. The upper and middle watershed of Krishna River, which comes under heavy rainfall. River Koyana Warana and Panchganga are main tributaires of Krishna which recived enormouse amount of rainfall during the moonson every year causing a devasting flood in the vally and plain of Satara, Sangli and Kolhapur district in Maharastra and the adjoining district of upstream and downstream of the Alamatti dam in the Karnataka state.In July 2005 heavy rains occurred and flood situation happent in Satara ,Sangli , Kohapur district in Maharashtra and some part of Karnataka state This paper discusses the procedures that were applied for mapping flood hazard zones and its comparisons with ground truth.

Keywords* – *Flood hazard mapping, Remote sensing ,GIS

1. Introduction

Remote Sensing and GIS helps to find the reason of flood in the river basin. It will help us to know the hurdle due to which the water gets inside the habitat and affect the life of people. Remote sensing along with GIS will trap the reason of flood in the habitate. Sometimes the village which is near the river will not have flood but, the village whose level is up from sea level in comparison to other village will get flooded. In July-August 2005 flood situation occurred in Sangli, Satara,and Kholapur district. Sangli city and surrounded area got flooded fully and remained under prolonged submergence for seven to eight days. A large number of human lives and cattle were lost and the loss of property, standing crops, dwelling places and other assets, thousands of households stranded in relief Camps for several weeks.

This are something which can be solved out

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with the help of remote sensor and GIS. Remote sensing technologies include both imaging and non-imaging sensors. Remote sensing and other geospatial technologies provide all the phases of the response to flood disaster. Mapping flood hazard is not a new endeavor in the global . Flood hazard mapping by data LANDSAT and SRTM DEM is known as an economical and efficient method for mapping flood hazard and deal with the problem of inadequate data source in developing countries (Wang et al., 2002). Several factors need to be considered in accurate flood hazard mapping under conditions of data and other material scarcities that typify the situation in most countries. Flood hazard can be quantified by examining the occurrence of flood over a span of years, the size of the population vulnerable to floods and the available infrastructure.

2. Physiography of the Study Area

The investigated area is enclosed between latitudes 17°18′N and 16°15′N and longitudes 73°50′E
and 75°54′E, covering an area of 14539 sq. km falling in Survey of India (SOI) toposheet Nos: 47 /K,47 /L,47 / P on 1:250,000 scale (Figure 1). Geologically, the area consist largly of Archaean formation, part of which are covered by Deccan trap lava ,cuddaph and vindyan series and faulted blocks of Gondwanas . The area is well represented by structural hills, denudational hills, burried pediments, valley fills and alluvial plains forming soil covers of silty clay, red sandy and red loamy and alluvium.(Figure2) The area enjoys tropical climate of semi arid in nature and the temperature ranges from 19 to 28º C in December and 28 to 40º C in May. The average annual rainfall in the basin is 4000 to 7000 mm with maximum contribution from southwest monsoon

3. Material and methodology

The materials that were used for this study include:

- Land Sat, TM. false color composite (scale 1 : 250,000), of February 1999
- Topographic (Map scale 1 : 250,000)
- Soil Map scale 1 : 250,000
- Land use Map scale 1 : 250,000 (was compiled by interpretation of the above-mentioned Land
  Sat imagery and field survey)
- Computer hardware and software which include ARC/INFO, ARCVIEW, and ERDAS.

Various base maps like drainage network,infrastructures(road way,rail way,settelments etc.),water bodies,landuse land cover are prepared in GIS environment.

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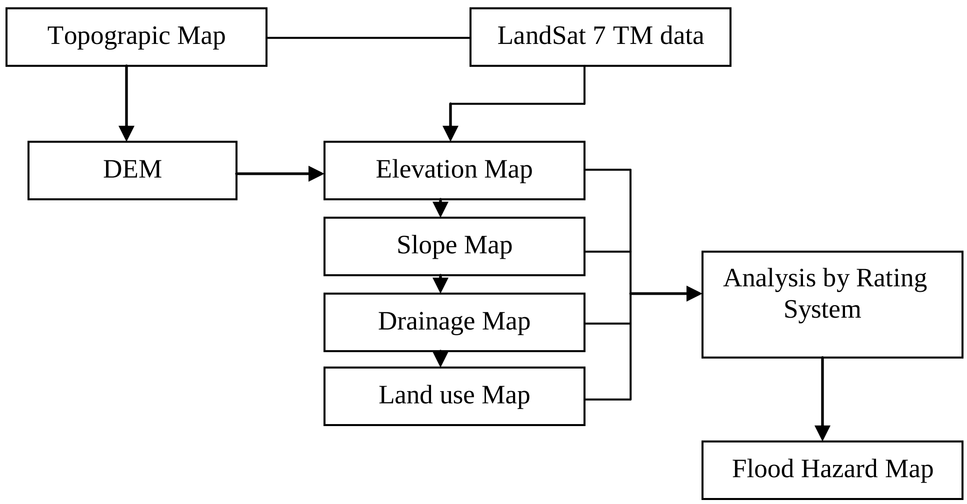
Flow chart for Methodology



Field work
Field study was conducted to collect various data like flood affected area, total number of villages in each district. Each flooding hazard zone was transferred to a topographic map of the same scale which had already been digitized and stored in the computer system. ASTER DEM digital data are used for generation of 3D view (Figure2) .All the data arranged systematically and compared with flood hazard mapping by remote sensing and GIS.

Analysis technique by Rating system
Probability rating of flooding in each hazard zone in every watershed was done by considering
certain causative factors. Their significance was indicated by weighting. The causative factors taken
into account for this study include:

- Size of watershed
- Annual rainfall sum
- Degree of both side slopes of the watershed
- Gradient of main river and stream of the watershed
- Drainage density of watershed
- Type of soil in watershed
- Land use type of watershed and,
- Communication lines and other infrastructure that influences drainage of the watershed.

Theoretically, there are still more causative factors, for example daily rainfall, the hydrograph of the main stream of the watershed, etc. The weight of each factor was given on the basis of its estimated significance in causing flooding.

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Table 1: The weight of each factor.

Annual rainfall	8
Size of watershed	7
Slope of watershed	6
Gradient of main river	5
Drainage density	4
Land use	3
Type of soil	2
Infrastructures facilities	1

Calculations of total weight factors

Rainfall

Besides, each factor was divided into a number of classes and each class, weighted according to the estimated significance for causing flooding. The maximum weight for each class of every factor is 8 the minimum is 1 and the total weight used for considering the rate of probability of flooding is:

Total weight of each factor = factor weight * weight of factor class

For example, the annual rainfall in watershed A. is 1,000 mm. The factor of annual rainfall was
divided into 4 class, and, each class was given weight as in table 2
The total weight of factor "annual rainfall" for this watershed A. is:
weight of annual rainfall * weight of rainfall class (1,000 mm) .= 8 * 6 = 48

Table 2: The classes distinguished for each factors

Class	**Rainfall (mm)**	**Size of watershed (km^2)**	**Slope (%)**	**Weight**
1	>7000	>350	45-60	8
2	7000-6000	250-350	30-45	6
3	6000-4000	150-250	15-30	4
4	< 4000	70-150	15	2

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Gradient of main stream

Gradient of the main stream of the watershed can be calculated by

River and stream gradient = (H2-H1) * 100 D

H1 = altitude of the highest point of the slope at the upper river or stream channel (in meters)

H2 = the altitude of the outlet of the river or stream (in meters)

D = Distance of H1 to H2 (in meters)

Table 3: Gradient of the main stream of watershed

Class	Slope (%)	Weight
1	>5	5
2	4-5	4
3	3-4	3
4	2-3	2
5	1-2	1

Drainage density

The drainage density of the watershed is calculated as follows:

$D_d = L / A$

D_d = drainage density of watershed

L = Total length of drainage channel in watershed (km.)

A = Total area of watershed (km^2)

Chankao (1982) stated that a watershed with adequate drainage should have a drainage density >5

and the poor ones have drainage density classes 1-5 and <1 respectively.

Table 4: Drainage density and Soil types

Class	Soil type	Drainage density	Weight
1	watershed with shallow soil, clayey poorly drained soil and soil with high percentage of silt and very fine sand particle covering more than 60 % of the area	<1	8
2	watershed with shallow soil, clayey poorly drained soil and soil with high percentage of silt and very fine sand covering 40-60 % of the area	1-3	6

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3	watershed with shallow soil, clayey poorly drained soil and soil with high percentage of silt and very fine sand covering 20-40 % of the area	3-5	4
4	watershed with shallow soil clayey, poorly drained soil and soil with high	>5	2

Land use of watershed

Considering the land use map compiled from land sat imagery of the area, the class and weight of each land use class is as follows.

Table 5: Land use types

Class	Land use	Weight
1	Natural forest, perennial crops and fruit tree cover less than 10 % of total watershed area	8
2	Natural forest, perennial crops and fruit tree cover 10-20 % of total watershed area	7
3	Natural forest, perennial crops and fruit tree cover 20-40 % of total watershed area	6
4	Natural forest, perennial crops and fruit tree cover 40-60 % of total watershed area	4
5	Natural forest, perennial crops and fruit tree cover more than 60 % of total water area	2

Communication line and other infrastructure

Highways, roads, railways, tracks and other infrastructure that obstruct the flow of the river and stream promote flooding. The classes and weight of each class of this factor are as follows:

Table 6: Infrastructure

Class	Infrastructure	Weight
1	Watershed area that has infrastructure obstructing the flow direction of stream and river within the flood hazard zone at more than 10 locations	8

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2	Watershed area that has infrastructure obstructing the flow direction of stream and river within the flood hazard zone at 6-10 locations	6
3	Watershed area that has infrastructure obstructing the flow direction of stream and river within the flood hazard zone at 3-5 locations	4
4	Watershed area that has infrastructure obstructing the flow direction of stream and river within the flood hazard zone at less than <3 locations	2

Flood hazard mapping

In the procedure, the net probability of occurrence of flooding in each flood hazard zone is estimated from the total sum of the weight of each causative factor considered. To obtain this total sum weight, all of causative factor maps were overlaid.

The total weight for estimating the probability of flooding in a particular flood hazard zone = the sum of every causative factor.

In this step, a map of every causative factor compiled and the weight identified. The data sources used include topographic map, land sat imagery, soil map, landuse map, and climatic data. All of these processes, the compilation of causative factor maps, the overlaying of all maps and the calculation of total weight were obtained by applying, ARC/INFO and ARCVIEW. Based on the weight of every factor and its class, the maximum total weight of each factor is the result of the multiplication of such factor weight with the weight of its dividing first class. Thus, maximum total weight of the factors rainfall, size of watershed, side slope, slope gradient, drainage density, land use, soil type, and infrastructure are 64, 56, 48, 40, 32, 24, 16, and 8 respectively. The sum of these total maximum weights is 288.For the total minimum weight of each factor, the same, it is the result of the multiplication of the factor weight with the weight of its lowest class. These are 16, 14, 12, 10, 8, 9, 4, and 2 respectively and the summed minimum total weight is 75. Considering this, the total weight of the flood hazard zone with the highest probability to be flooded 288 and the lowest probability is 75.Considering the statistic standard deviation values of the total weight data obtained for the study area, the weight of each class was given as:

High	183-288
moderate	107-182
low	75-106

However, after fieldwork for checking the validity and reliability of the map these figures were adjusted. When compiling the final flood hazard map the following figures were considered for identifying the degree of the probability of occurrence of flooding in the identifying flood hazard zone. (Figure 5)

High probability	191-288
Moderate probability	147-190
low probability	75-146

Based on the final weighing classes for rating the probability of the occurrence of flooding in the identifying flood hazard

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zone, the final thematic maps with significant landmarks were compiled. After that, again, fieldwork for checking the validity and reliability of the map was carried out.

4. Result and Discussion

The study shows that at Sangli town area comes under high risk due to low gradient and slope of the watershed. Geographical nature is like trough in shape, this led a poor drainage and water gets accumulated for longer time unless there were no passages for main river water to move forward. Around 228 villages having population 15,72,091 were got affected in Sangli, Satara and Kholapur district. It is found 10 to 20 % variation in ground truth and calculated affected area in moderate and high flood zones in this study area. This might be due to the reliability of the used data or the number of causative factors considered. It might also be connected with the scale of the map. Land Sat 7 imagery helps for ground truth. The flood hazard and risk map obtained from this study have been use as basic data for designing flood prevention and mitigation measures.

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http://glcf.umiacs.umd.edu/data/ and or http://glovis.usgs.gov/
(LANDSAT sources)

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(SRTM source).

http://visualizationsoftware.com/3dem.html
(3DEM software)

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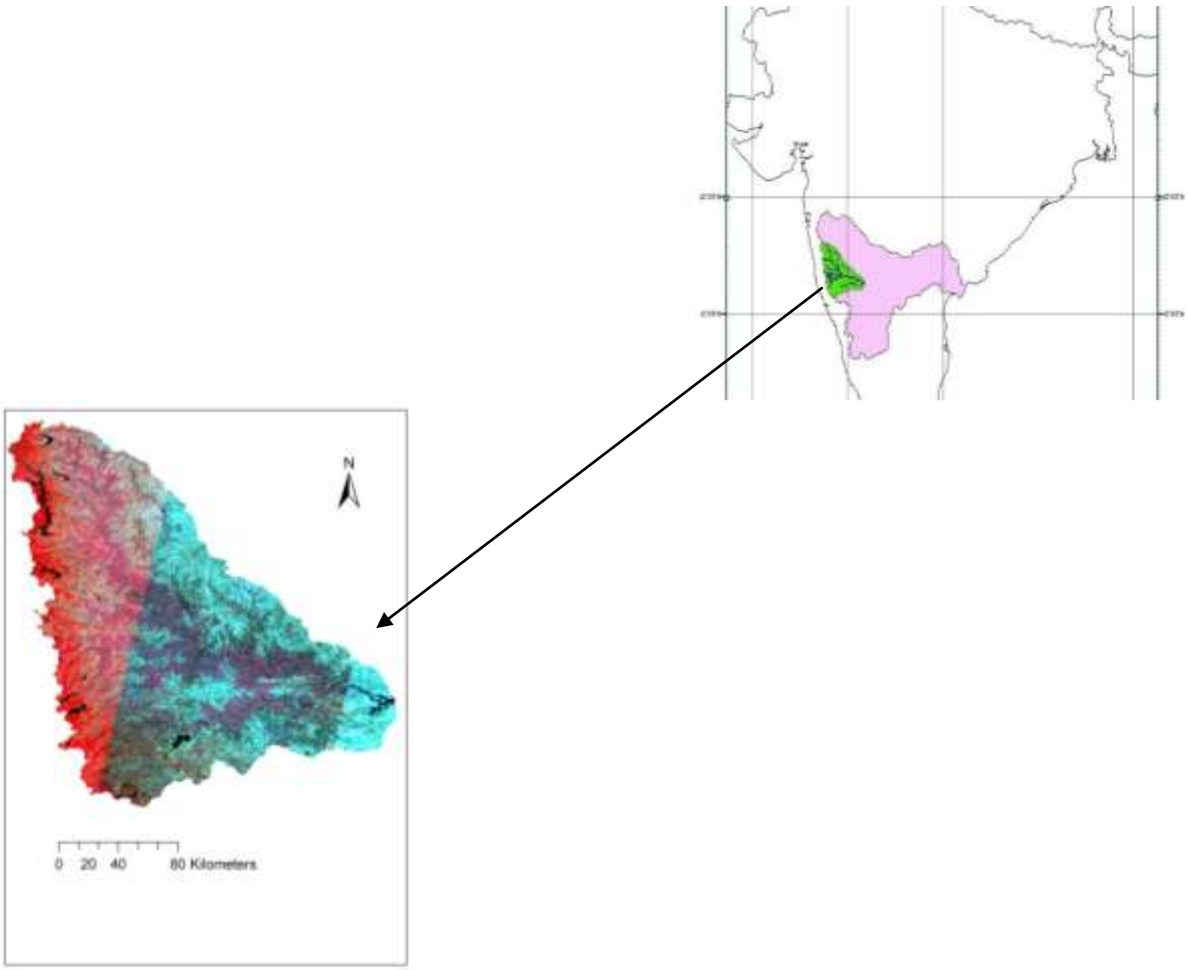

Figure No 1: Study Area (Land sat 7 image)

Figure No.2: 3D DEM

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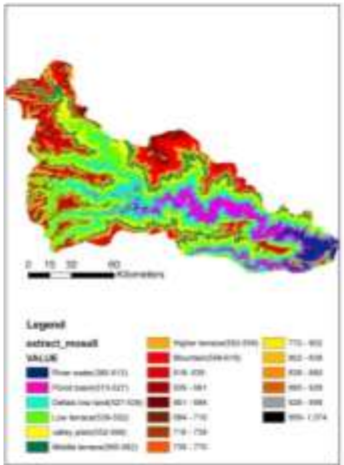

Figure No 3: Slope classification

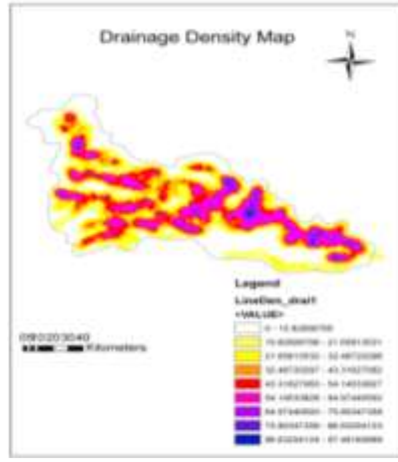

Figure 4: Drainage density map

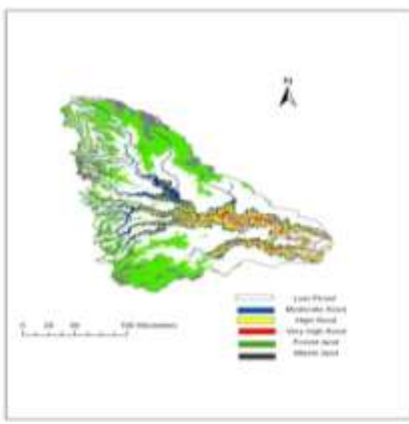

Figure No 5:Flood hazard map