JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Pre-Flood Management Practices in Western Maharashtra Region

Swati Parmeshwar Bansode
PG Student, Department of Civil Engineering
Dr. D. Y. Patil College of Engineering and Technology Pimpri Pune

Abstract- The present paper tries to investigate the potential flood mapping techniques. Conventionally use of traditional methods is adapted for flood plain mapping. But this paper focuses on the use of GIS and RS techniques. DEM is initially produced and then processing methods as per the data used is done. From the literature it is observed that 3D modelling using HEC-RAS is a dominant and most appropriate method for the analysis of the flood maps. This case study is applicable for Western Maharashtra Region (Kolhapur, Satara and Sangali). However it is noted that the use of these tools depends on the availability of data. Better resolutions of the satellite image can be used, but the limitation is that cost will increase. Also, using GIS and RS techniques will help in better updating of these maps. This paper describes the flood prone Pre-flood management areas of India along with the flood prevention and management techniques in western Maharashtra region. In this paper researcher focus on to study Rainfall Variability in Kolhapur,Satara and Sangli District and to study and analyze of pre- flood management at western Maharashtra region (Kolhapur, Satara and Sangli).Analyze Flood Management Measures Practiced in India and to Study and analyze detection methods are used for remote sensing the disasters. To Study and analyze Geographical information system (GIS) provides spatial data management and analysis to study flood management. Historically floods are known to cause damage to property and life leaving a long term traumatic impact on those who get affected by them. The intensity and magnitude of floods is supposed to be increasing world over in the recent decades because of climate change and global warming phenomenon. The Western Ghats are globally important, not only being rich in biodiversity, but primarily because of the role, they play in influencing climatic regime and annual precipitation in Indian subcontinent. The climate change has caused uncertainty and wide fluctuations in precipitation pattern from extreme droughts to heavy rains and periodic cloud bursts. Thus, floods, which were locally almost unknown, are becoming a potential disaster in the earlier relatively safe and climatically stable areas such as Western Ghats. Kolhapur district being largely i.e. over 65- 70% of the total area, being situated in the Western Ghats region, receives high annual rainfall in its western hilly part. It was therefore felt necessary to study the region for vulnerability and risk analysis of annual floods in Kolhapur district to know their main causes and their consequences. Therefore, this paper deals with the relevant topics such as rainfall variability in Kolhapur district, correlation and multiple regression analysis of rainfalls and water levels in flood prone Panchganga basin. It also includes readings on drinking water quality from Panchganga river basin, during pre and post flood period and people‟s perception on the issue through social Impact assessment (SIA) studies.

Keywords: Floods, GIS, RS, HEC-RAS, River, CWC (central water commission), FMS (flood management system), Indian Meteorological Department (IMD).

1. INTRODUCTION

1.1 Introduction

Incidences of natural hazard are increasing day by day in the world. Flood is a situation when there is flow of water in a river more than its capacity and the water overflows the levees and spreads in nearby areas. Since the emergence of civilization, flood is the most frequent natural hazard. The fact that rapid demographic and economic growth patterns have disturbed the balance between ecosystems has, in turn, increased the frequency or severity of some natural disasters, such as floods and droughts

1.2 Floods in Upper Krishna Basin

In the upper Krishna basin western tahsils are known as flood prone tahsils. Overall study region 13 tahsils out of 29 tahsils are flood affected and out of these tahsils some tahsils are affected by Krishna, Koyana, Warana and Panchganga River. As per record 16.05 per cent of the population lives in flood prone areas with the major rivers Koyna, Krishna, Venna etc. in which flood comes at least once in a year during the monsoon. Table no. 4.1 shows the flooded rivers and its impact on village-wise population of upper Krishna basin. The river Krishna Koyana, Warana and Panchaganga affected in study region, the statistical data shows that in 2005, more than

23.89 lakh populations of 228 villages become a victim. In the same year Sangli district shows that Krishna and Warana played major role in flood period. The water volume of these rivers is increased as compare to water volume of Satara district. Therefore, 81 villages and their population were mostly affected and Satara district it was found that 1.19 lakh population of 16 villages and 131 villages (15.55 lakh population) of Kolhapur district came under the influence of flood water.

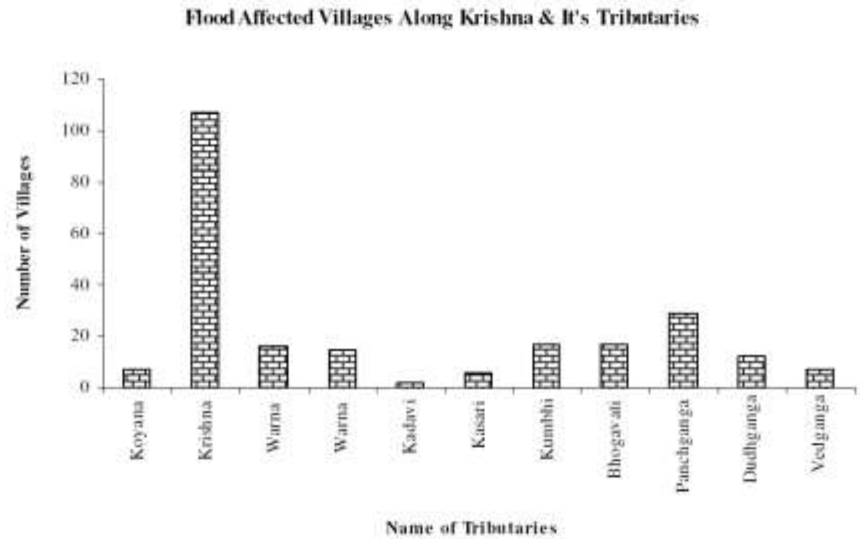


Fig 1.1 Name of Tributaries

Table 1.1: Flood Affected Villages in Upper Krishna Basin (2019)

Name of the River	District	No. of Villages	Affected Population
Koyana	Satara	07	14262
Krishna	Satara	09	103665
Krishna	Sangli	66	698728
Krishna	Kolhapur	25	150243
Warna	Kolhapur	16	97637
Warna	Sangli	15	72840
Kadavi	Kolhapur	02	6888
Kasari	Kolhapur	06	6504
Kumbhi	Kolhapur	17	24232
Bhogavati	Kolhapur	17	50453
Panchganga	Kolhapur	29	1073638
Dudhganga	Kolhapur	12	52496
Vedganga	Kolhapur	07	21125
Total		228	2388711

Release of excess water from the dams in the major rivers, heavy rainfall and the villages lying in or close the river course are the causes of flooding particularly in the Patan, Satara, and Karad tahsils. The Koynanagar dam on the Koyana river has contributed to reducing the vulnerability of many villages in Karad tahsil to flooding. In Kolhapur district there is a large number of river along villages (188) which are prone to floods. High floods generally occur due to heavy rainfall in catchment area of major dams and release of excess water. Past records show that comparatively high floods occurred in 1989 and 1994.

1.3 Causes of Floods in Upper Krishna Basin

Climatic condition of study region is monsoonal type. Though, more than 90 per cent rainfall received from south-west monsoon period (June to September) and other eight months are maximally dry. The flood disaster is a common phenomenon in rainy season due to the natural and manmade causes, which are responsible for flood condition. In upper Krishna basin, the major causes of floods are given below:

i) Morphology of Upstream Catchment Area

Configuration of upstream catchment area is complex in respect of topographical variance in terms of height and form of channels. Large catchment area of upper Krishna basin collects water. Vast area extended from Khambatki ghat (Satara district) in north to Chandgad (Kolhapur district) in south and west from Sahyadri range to east Yerla and Agrni basin. The large area of basin collects water from different channels at different rates. When any area of vast basin gets heavy rainfall it results in flood situation.

ii) Deforestation

Forest in general increases rainfall and evaporation while it absorbs moisture and lessens runoff (Naik, 2007). In upper catchment area of Krishna basin the forest cover has been decreasing at Mahableshwar, Jaoli, Patan, Shirala, Shahuwadi, Bavda, Radhanagari Bhudargad, Ajra and Chandgad tahsils. Large scale deforestation is effected by man for various purposes, decreases infiltration

capacity of the cut over land and consequently increases surface runoff which helps tremendously in increasing the magnitude of flood
(Singh 2003). According to table 4.2 and statistical data field observations of region area under forest are declining day by day.

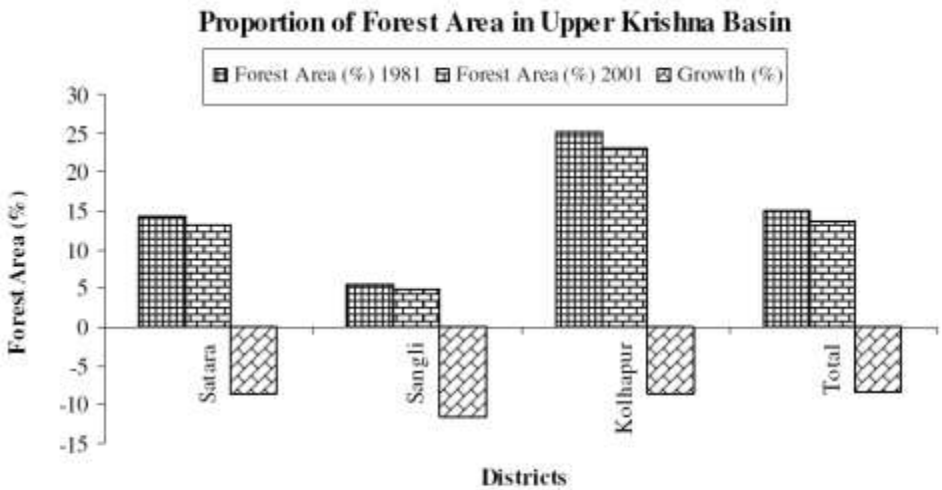


Fig. 1.2 Proportion of forest area in Upper Krishna Basin

The forest cover growth shows negative trend in study region and it revels in Sangli district (-11.56 %) which is highest in upper Krishna basin followed by Satara district which is - 08.63 per cent and in Kolhapur district has - 08.50 per cent. The upper Krishna basin it is 14.95 per cent forest land in 1981 and in 2001 it has 13.71 per cent which reflects forest land decreased by - 08.29 per cent.

iii) Heavy Rainfall in Upstream Catchment Area

Continuous heavy rainfall for long period is the root cause of river floods of study region. Immense volume of water through high intensity rainfall is the prerequisite condition for river floods. Heavy rainfall in upper catchment area is concerned with sudden increase in the water volume of downstream. Occasional heavy rainfall resulting from strong rainstorms can cause severe floods. Because of the fact that the rivers maintain very low flow and low discharge of water during most part of the year and hence sudden torrential rainfall causes sudden increase in the volume of water which cannot be disposed off by the rivers immediately and thus the river banks are over topped by the swelling water and instantaneous floods are caused (Singh, 2011). In 2005 and 2006 year, months of July and August recorded heavy rainfall in study region which become the root cause of floods.

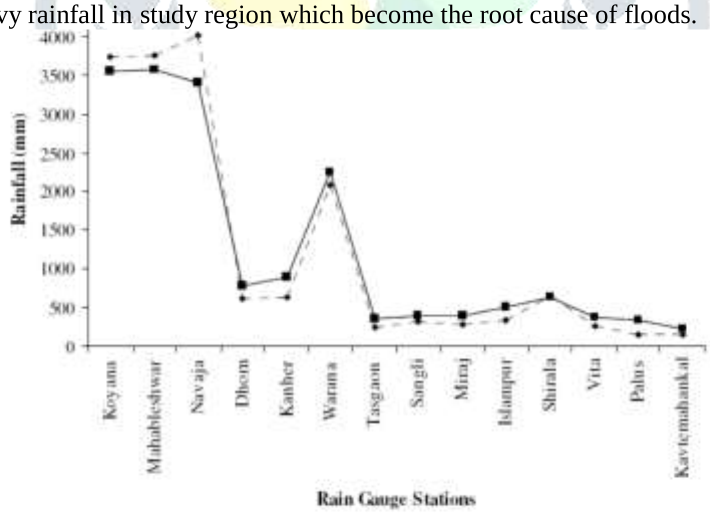


Fig. 1.3 Rainfall in Upper Krishna Basin

The table and fig.4.3 shows exceptional floods were observed in the lower part of the upper Krishna basin in Maharashtra due to heavy rainfall of July 22nd to August 13th, 2005 causative factor of floods. Actual rainfall amount in study region is more than the average rainfall. Actual rainfall is highest recorded on 26th July. Within 23 days upper Krishna basin received more than 262 mm rainfall which is double from average rainfall. Rainfall variation in this period is high from 26th to 28th July 2005 (215.3 to 233.6 %).

iv) Over Irrigation and Ground Water level

Ground water level is very much significant in the flood causes because ground water level affects on the percolation rate of surface water. In heavy rainfall period, ground water level is increased and then extra water is not absorbed by the soil. It affects on the increase in the runoff which generates flash floods. The ground water table near the river side tahsils Karad, Walwa, Miraj, Kagal, Karveer, Shirol and Hatkanangale is high due to irrigation so, it increases the total runoff.

v) Construction of Bridges on Rivers and Kolhapur Type Weirs

There is large number of constructed bridges across the rivers and their streams and Kolhapur type weirs on various rivers and its streams in upper Krishna basin. KT weirs are constructed on the river Krishna, Warna, Panchaganga for the purpose of water storage to irrigation. The KT weirs assist to deposition of sand and silt in the river basin of river Krishna (Khemlapur, 2006).

vi) Anthropogenic Encroachment Under Flood Zone

Three districts are included in upper Krishna basin flood region. The study region has urban centers namely Karad, Satara, Wai, Sangli-Miraj, Shirol and Kolhapur. All these centers are located on the bank of rivers. These centers are growing day by day and there is very less space left for their extension. To overcome on this situation, construction within flood lines and filling up of the drainages are the most important man made cause.

vii) Meandering Course of Rivers

Highly sinuous meandering courses of the rivers obstruct the normal discharge of water and thus the velocity is reduced which delays the passage of water resulting into stagnation of water. Consequently, the meandering valleys are immediately overflow and meander belts and loops are flooded (Singh, 2011). Rivers like Krishna, Warana, Panchganga, Dudhganga and Vedganga enter in plain region. These rivers form many meanders in their course. The meanders of Krishna are sharp at Shirgaon, Shirate, Retre Harnaksh, Banewadi, Bhilawadi and Haripur. Warna river formed meander near Kokrud, Punvat, Sagaon, Kale, Devarde, Tandulwadi, Shigaon and Samdoli.

viii) Retardation of Flow Due to Back Water Effects

Retardation of flow due to back water effects is also one of the important causes of flood disaster (Patil, 2009). Such prerequisite happens in the study region at various places e.g. near Bramnal where Yerala meets to Krishna and also similar condition is observed at the confluence of Warana and Krishna river near Haripur. Nrusinghwadi is the one location in study region where retardation of flow due to back water affects. In this process major river velocity and volume are high due to that water of tributaries push back. The flood intensity is frequently occurred in the upper Krishna basin particularly in Palus tahsil and Miraj tahsil of Sangli district and Shirol, Hatkanangale tahsils of Kolhapur district.

ix) Backwater Effect of Alamatti Dam

Karnataka state government has constructed Almatti dam on the river Krishna for irrigation purpose. Almatti dam is one of the major causes behind flood situation in Sangli district. Because the back water of Alamatti dam controls the volume of Krishna flow (Daily Sakal, 2007). Hon. R.R. Patil expressed their view about Alamatti dam that water level of Almatti dam is more than 509 meters and back push of water comes up to Sangli.

x) Excessive Water Discharge from Upstream Dams

There are numbers of upstream dams in the catchment area of upper Krishna basin. The upstream dams are namely Dhom, Kanher, Urmodi, Tarli, Koyana, Warana, Radhanagari and Kallamwadi are major water storage projects. These projects had excessive discharge due to heavy rainfall period. In July 27th, 2005 discharge from Koyana dam is highest recorded and it is more than 100000 cusecs. Along with Koyana dam, Dhom, Kanher and Urmodi dams discharge is high in this period and all discharges are collected near Karad Bridge and near Narsinhvadi were highest recorded.

xi) Land use Pattern in the Study Region

Western part of the study region is highly irrigated. So, the farmers destroy the natural vegetation for the intensive agricultural. Satara, Karad, Walwa, Miraj, Palus, Shirol, Karveer and Kagal tahsils forest area is decreasing day by day to increase the net sown irrigated area. So in absence of forest cover, soil erosion rate is highest and it helps to increase runoff. Soil erosion effects on the siltation in the river bed and water level is increasing in rainy season.

1.4 Effects of Floods in Upper Krishna Basin

Flooding is the most common environment hazard; due to the wide spread geographical distribution of river valleys and coastal areas and attraction of human settlements to these areas (Kewalramani, 2006). Almost all the river valleys are subjected to varying degrees of flood incidents, either creating minor damages or devastating havocs at times. Such calamities of floods pose a serious problem to the whole environment setup of the region bringing about some of the phenomena changes of the physical environment, inrushing in accelerated erosional, transportational and depositional work of the river with the consequent effects of the soil.

1.5 Positive Impacts

Flood is a natural disaster, and due to flood maximum adverse effects are seen on the human life. Each incidence has merits and demerits, in above discussion researcher has elaborated demerits of floods but floods are having some merits, which supports for the human development.

1.6 Problem Statement

In existing scenarios the heavy floods can be so disastrous that the infrastructure is washed away, the people and the animals drown, and the people can be stranded for long periods, the society and the economy of the country will suffer in many ways after the flood. The loss of lives, vegetation, and infrastructure means there will be fewer people on the labor force, less agriculture available for the locals and the exportation, and fewer businesses to contribute to the economy of the country. There will be mass dislocation of people, many people may be left homeless and jobless, So, The government will have to spend a little more, The country may seek the assistance from the foreign countries to supply the food and the materials to clean and replace the infrastructure.

1.7 Scope of the projects

The scope of this project is only upper Krishna basin western tahsils (Kolhapur, Satara and Sangli) are known as flood prone tahsils. Overall study region 13 tahsils out of 29 tahsils are flood affected and out of these tahsils some tahsils are affected by Krishna, Koyana, Warana and Panchganga River. As per record 16.05 per cent of the population lives in flood prone areas with the major rivers Koyna, Krishna, Venna etc. in which flood comes at least once in a year during the monsoon.

1.8 Objectives of the project

1. To study Rainfall Variability in Kolhapur,Satara and Sangli District.
2. To study and analyze of pre- flood management at western Maharashtra region (Kolhapur, Satara and Sangli).
3. To Study and analyze Flood Management Measures Practiced in India
4. To Study and analyze detection methods are used for remote sensing the disasters.
5. To Study and analyze Geographical information system (GIS) provides spatial data management and analysis to study flood management.

2. REVIEW OF LITERATURE

Historically floods are known to cause damage to property and life leaving a long term traumatic impact on those who get affected by them. The intensity and magnitude of floods is supposed to be increasing world over in the recent decades because of climate change and global warming phenomenon. The Western Ghats are globally important, not only being rich in biodiversity, but primarily because of the role, they play in influencing climatic regime and annual precipitation in Indian subcontinent.

2.1 Research Gap

2.1.1 Flood Preparedness Planning

Flood preparedness planning is about putting in place a set of appropriate arrangements in advance for an effective response to floods. Some of the commonly identified flood preparedness activities are; Public awareness raising on flood preparedness, response and mitigation measures; Stockpiling of emergency relief materials i.e., food, fodder for livestock, emergency medicines, materials for temporary shelter

2.1.2 Flood Preparedness Plan

A flood preparedness plan (FPP) which is an integral component of the multi-hazard disaster management plan, is an action oriented document detailing specific actions to be undertaken prior to floods, which set the ground for effective execution of emergency response and recovery activities during and after floods. Assessment of probable needs: Based on historical data from previous flood disasters, officials at the State and district levels compile a list of likely needs and available resources. Gaps between needs and resources are identified in advance and also ways to mobilize them.

Institutional Mechanism for implementation of FPP: The Flood Preparedness Plan outlines the institutional structure of the States, District or Community level Committees for Disaster Management, its roles and responsibilities before, during and after floods

2.1.3 Flood Management

Though it is not possible to completely avoid the flood disasters, but the sufferings can be minimized by creating proper awareness of the likely floods and its impact by developing a suitable warning system, flood preparedness and management of flood disasters through application of information technology tools.

2.1.4 Flood Simulation

Simulation is nothing but a simple mathematical description of the response of a system to a series of events during a selected time period. The basic steps involved in the simulation process are (i) identification of the system; (ii) conceptualization of the system; and (iii) implementation of the model. More complex conceptual models with greater reliability and accuracy have been developed with the widespread use of large, fast electronic computers.

2.1.5 Policies on Flood Management

After the unprecedented floods of 1954, the Govt. of India took several Initiatives and constituted a number of committees to study the problems of floods in the country. The important steps are (i) Policy statement 1954 (ii) High level committee on floods – 1957(iii)Policy statement of 1958,Ministerial committee on flood control — 1964 (iv) Ministers committee on floods and flood relief — 1972 (v) Working group on flood control for Five Year Plans, Rashtriya Barh Ayog (RBA) — 1980 (vi) National Water Policy (1987) (vii) National Commission for integrated Water Resource Development Plan 1996 (viii) National Water Policy (Revised in 2002) (ix) National Disaster Management Authority (NDMA 2005) and (x) National Disaster Management Guide Lines (2008).

2.2 Literature Survey

Kabir Uddin et.al, in their research article, analyzed Sindh province Pakistan. The study area is the South Eastern province of Pakistan. In their framework of investigations, they used moderate resolution imaging spectrometer (MODIS) imagery to generate flood inundation maps. A topographic map and Shuttle Radar Tropical Misson (SRTM) Digital Elevation Model (DEM) data from different sources were used to analyze flood hazard area and flood shelter areas. For image analysis E-cognition software was used to perform Object Based Image Analysis (OBIA). The objective to go for OBIA analysis, over pixel based analysis was to get accurate and better classification. The outcomes of their work were flood hazard maps, delineating Sindh Province in district level and to identify the potential area of shelter zone locations. The results revealed that OBIA techniques and GIS systems allow different rules for different classes that can be analyzed for further flood mapping.

Gomaa M Dawood et.al, in their research article, investigated spatial mapping techniques for Makah City Saudi Arabia. In first stage of the work, Flood estimating was done, DEM was generated and soil, Land Cover, geological maps were overlaid. With these initial parameters, morphometric parameters were calculated using GIS Software. Then Curve Number (CN) was generated. Using these set of procedures, computations were done using the depth of precipitation for 200 mm for a return period of 50 years. Log Pearson III stastical analysis was used with all available datasets. The research findings showed that, Makah city flash floods are due to following factors Basin stream length Peak discharge. Also, it is observed that higher CN values indicate higher runoff and flood hazards.

Bashir Ahmad et.al, in their study for Nullah Lai Basin, Rawalpindi Pakistan, used hydrological modeling using HEC- RAS and HEC-GeoRAS. Their objectives were to carry our river flood modeling within GIS environment to assess flood water depth and vulnerable mapping. Also, they focused don risk assessment and hazard mapping for different scenarios. 19 flood events occurred between 1944 to 2002 were analyzed, with extreme flood events in the year 1981, 1988, 1997 and 2001. Year 2001 experienced highest floods. In their methodology, DEM was prepared from elevation data and was modified using interpolation techniques. For flood modeling peak discharge of 100 year return period was considered. They concluded that the integrated modeling approach used in the study , works well in order to locate the area vulnerable to flood with a good estimation of inundation depths at a specific discharge value.

Adel Omran et .al in their research article used GIS techniques to produce a potential flood hazard map based on geomorphic parameter. In their study area Wadi Dahab Egypt, they used DEM for the morphometric analysis. Then delineation of basin boundaries by identifying the ridge lines (water divide) between sub basins. Snap pour point tool was used to ensure that selection of the points of high accumulated flow during delineation drainage basins using watershed tool.

Michalis Diakakis investigated a method for flood hazard mapping based on basin morphometry. A good quality DEM was developed, from it flow direction, flow accumulation, were used in Arc Hydro Model. Results were produced in form of maps categorizing the catchments in five classes according to their peak flows. The method proposed uses of simple morphometric variables like catchment area, basin slope, and point elevation that can be deduced from the topographic maps.

Ahmed M, et al, studied the utilization of remote sensing data such as Landsat Thematic Mapper (ETM) plus, Shuttle radar Topography Mission (SRTM), coupled with geological, Geomorphological, and field data in the GIS environment for the estimation of the flash floods risk along the Katherine Road Southern Sinai Egypt. In this study, different types of data like ETM and SRTM was used to identify the outline surface features of the study area. Arc Hydro toll of Arc GIS 9.2 was used for better understanding of the drainage and watershed system. Morphometric analysis was done in each sub watershed to analyze the potential degree of risk. Risk analysis was done and results computed were used to assist flood mitigation and land use planning.

Eric Forkuo, in his research article tried to address the need of efficient and cost effective methodology to prepare the floods maps. A composite flood hazard index map was developed incorporating variables near to the river flow. The level-1B of ASTER (Advanced Spaceborne Thermal Emission and Reflectance Radiometer) image data was used to produce a high-resolution land use map for the study area. This data is geometrically and radiometrically calibrated Classification of remotely sensed data is used to assign corresponding levels with respect to groups with homogeneous characteristics, with the aim of discriminating multiple objects from each other within the image. The study has described the integration of GIS and ASTER imagery in combination of DEMs in delineating flood hazard extent of each revenue district of the study area. An additive model was utilized to create a composite flood hazard index based on administrative units.

3. CONCEPTUAL BACKGROUND

3.1. Rainfall Variability in Kolhapur District

The rainfall of the twelve tahsils of Kolhapur district, in the years 2001 to 2013, was collected from relevant agencies and analyzed for the mean, S.D., coefficient of rainfall variability, rainy month‟s rainfall percentage, and month wise total rainfall variation and finally the choropleth map were evaluated. The study revealed significant variation trends in the frequency and the magnitude of extreme rain events all over Kolhapur district. This type of detailed localized study is useful for the practical implementation for disaster planners and managers. (Data generated is applicable to the tahsil level but not geographical area).

Table no 3.1 presents the mean annual rainfall value with standard deviation and coefficient of variability, during the years 2001 to 2013 for the twelve tahsils of Kolhapur district.

Table No. 3.1. Two Way ANOVA table for Determining Significant Difference between Rainfalls

Sum	DF	SS	MSS=SS/DF	F Factor
YSS	11	22788154	2071650.32	18.21
PSS	11	3.09E+08	28110928.27	247.14
ESS	121	13763287	113746.17	
TSS	143	3.46E+08	2417983.58	

Where, DF= degree of freedom, SS= sum of squares, MSS= Mean sum of squares, YSS= Year sum of square, PSS= Place sum of square, ESS= Error sum of square, TSS=Total sum of square. Two way ANOVA (Analysis of Variance) table (table no 3.2) calculated for checking average equality between rainfall of 12 different tahsils for 13 years, shows that the two calculated F values are greater than cut of point value (1.8686) i.e. cut of point < F. Hence from the two ways ANOVA test; there is significant difference in the average rainfall of 12 tahsils of Kolhapur district in last 13 different years. It was noticed that there were large variation in the rainfall of these tahsils in the period from rainfall in Gaganbawda (average 5812.4 mm) to Shirol (average 535.4 mm). Kolhapur district annual average rainfall also varied from 16850.4 (2003) to 33102.9 (2005). Hence it was realized that the occurrence and intensity of flash floods, dependent upon the rainfall in a particular tahsils, is varied in different tahsils of Kolhapur tahsil.

3.2. Floods in Kolhapur District

River Panchganga is formed by five tributaries in the mid-section of the district and is the major flood prone river along with others in the south of the district namely Dhudhganga, Hiranyakeshi, Vedganga, and Tamraparni. These flood plains are restricted only to lower reach in the east of the district till they meet river Krishna flood plain. There are several irrigation and multipurpose projects in the district which include 3 major dam projects, 12 medium project and 10 minor projects. It is seen that majority of these dams are situated in the maximum rainfall area i.e. western parts of the district. This will be helpful to reduce the impact of flood during maximum rainfall period and also it maintains river flows in the summer season and reduces the severity of water. However, in the event of unforeseen situation, as a result of climate change, the excess water from these tanks also needs to be considered as potential threat for flooding. It can be seen that the large percentage of flood affected villages in Kolhapur district are from Chandgad tahsil followed by Karveer and Shirol tahsils. Whereas excessive rainfall in the river basins is the main cause to flood prone villages in Kolhapur district except in Shirol and Hatkanangale tahsil, where main cause of floods is due to the back water pressure of Panchganga River caused by excesses swelling of Krishna river flood

During the same time.

4. RESEARCH METHODOLOGY

4.1 Flood Preparedness

Floods, which are a natural hazard, need not become a disaster, if we are prepared and are aware of how to deal with them. This would reduce the losses of life and minimize

Human suffering. This guide list simple thing one can do to stay safe and protect one from floods.

A. Before flooding occurs

1. The route to the nearest safe shelters is to be known.
2. The First Aid Kit is to be ready with extra medication for snake bite and diarrhea.
3. Strong ropes should be available for tying things.
4. A radio, torch and spare batteries are to be arranged.
5. Fresh water, dry food, candles, matchbox, kerosene etc are to be stocked.
6. Umbrellas and bamboo sticks are also necessary to protect from snakes).
7. Higher ground is to be selected for stay where people and animals can take shelter.

B. After hearing a flood warning

1. Flood warning and advice may be easily obtained through radio and television.
2. We must keep vigil of flood warning given by local authorities.
3. Dry food and drinking water and warm clothes are made to be ready.
4. Emergency kit must be checked.

C. At the time of evacuation

1. Pack clothing, essential medication, valuables, personal papers etc in water proof bags to be taken to the safe shelter.
2. Raise furniture, appliances on beds and tables.
3. Put sandbags in the toilet bowl and cover all drain holes to prevent sewage backflow.
4. Do not get into water of unknown depth and current.
5. Lock your house and take the recommended or known evacuation routes for your area of safe shelter.

D. During Floods

1. Boiled water or use of halogen tablet to purify water must be used.
2. Food should be covered.
3. Children are not allowed to remain on empty stomach.
4. Bleaching powder and lime are to be used to disinfect the surroundings.
5. Entry in flood waters may be avoided. If one need to enter then proper foot wear may be used.
6. Water over knee level may be avoided.

E. After a Flood

1. One has to be in touch with local radio.
2. Children may not be allowed to play in, or near, flood waters.
3. One has to be stay away from drains, culverts.
4. Electrical appliances should not be used.
5. Food of floodwaters must be avoided.
6. Tap water should be boiled before use.
7. Halogen tablets must me used before drinking water.
8. One has to be careful of snake bites, snakebites are common during floods.

4.2 Present Flood Detection and Management System

The detection methods are used for remote sensing the disasters. Geographical information system (GIS) provides spatial data management and analysis .we basically use LANDSAT TM data to estimate soil water content and the use of ERS SAR (synthetic aperture radar images) data to analyse flash floods.The satellites with active sensors are ERS 2, Radarsat 1, SRTM, Envisat (ASAR) and ALOS (Palsar). Recent satellite missions have provided high resolution topography imagery using interferometric synthetic aperture radar (SAR) techniques.

4.2.1 Reservoirs

Reservoirs can moderate the intensity and timing of the incoming flood. They store the water during periods of high discharges in the river and release it after the critical high flow condition is over, so as to be ready to receive the next wave. Their effectiveness in moderating floods would depend on the reservoir capacity available at that time for absorbing the flood runoff and their proximity to the likely damage centre. The Ghaggar detention basin in Rajasthan is a good example. Depressions available upstream of Srinagar City, on the left bank of river Jhelum, the Mokama Tal area in Bihar and Ottu, Bhindawas, Kotla lakes in Haryana and various beels/haors of Barak basin are some examples of a few natural basins.

4.2.2 Embankments

Embankments (including ring bounds and town protection works) confine the flood flows and prevent spilling, thereby reducing the damage. These are generally cheap, quick and most popular method of flood protection and have been constructed extensively in the past. These are papered to have given considerable protection at comparatively low costs, particularly in the lower reaches of large rivers. In many places, embankments may be the only feasible method of preventing inundation. Embankments are designed and constructed to afford a degree of protection against floods of a certain frequency and intensity or against the maximum recorded floods till the time of their planning only (in the absence of detailed hydrological data for longer periods) depending upon the location protected and their economic justification. Expenditure has been incurred in the past.

4.2.3 Channelization of Rivers

Some of the states are proposing channelization of rivers, at least in certain reaches, in the context of tackling the extensive meandering problems of the rivers, activating navigational channels and training these rivers into their original courses. While venturing to channelize rivers, thought must be given in allowing the river certain freedom to flow and right of way to pass its flood waters and silt load within its natural waterway. The dynamic nature of the rivers should be appreciated and preventive measures planned accordingly instead of pinning down the river by channelizing.

4.2.4 Channel Improvement

The method of improving the channel by improving the hydraulic conditions of the river channels by desalting, dredging, lining etc., to enable the river to carry its discharges at lower levels or within its banks has been often advocated but adopted on a very limited extent because of its high cost and other problems. Dredging operations of the Brahmaputra, which were undertaken in the early seventies on an experimental basis, were discontinued because of their prohibitive cost and limited benefits Dredging in selected locations may perhaps be considered as a component of a package of measures for channel improvement to check the river bank erosion subject to techno economic justification. It may be economically justifiable as a method for channel improvement where navigation is involved. Dredging is sometimes advocated for clearing river mouth or narrow constrictions.

4.2.5 Drainage Improvement

Drainage congestion is one of the recurrent phenomenons in India. It is often difficult to distinguish between flood and drainage congestion situations. This problem is rather acute in Andhra Pradesh, Bihar, Haryana, Punjab, Orissa, Uttar Pradesh, Assam and West Bengal, J&K, Gujarat and Tamilnadu. Therefore, improvement of drainage by construction of new channels or improvement in the discharge capacity of the existing drainage system is recommended as an integral part of the flood management program in the country.

4.2.6 Diversion of Flood Waters

Diversion of flood waters takes a part of the flood discharge to another basin or to the same basin downstream of the problem area or to a depression where it could be stored for subsequent release. This measure can be used to manage unusual floods around cities as in the case of flood spill channel near Srinagar and also in the lower reaches of a river near the sea as in the case of Krishna Godavari drainage scheme.

4.2.7 Watershed Management

The watershed management measures include developing and conserving the vegetative and soil covers and also to undertake structural works like check-dams, detention basins, and diversion channels, etc. In the watershed management of upper catchment, land treatment through afforestation and grass land development practices should be supplemented by structural works for retarding the water velocity and arresting silt.

4.2.8 Administrative / Non-structural Measures

The administrative methods endeavor to mitigate the flood damages by:

(a) Facilitating timely evacuation of the people and shifting of their movable property to safer grounds by having advance warning of incoming flood i.e. flood forecasting, flood warning in case of threatened inundation

(b) Discouraging creation of valuable assets/settlement of the people in the areas subject to frequent flooding i.e. enforcing flood plain zoning regulation providing absolute protection to all flood prone areas against all magnitude of floods is neither practically possible nor economically viable. Such an attempt would involve stupendously high cost for construction and for maintenance. Hence a pragmatic approach in flood management is to provide a reasonable degree of protection against flood damages at economic cost through a combination of structural and non-structural measures.

4.2.9 Flood Plain Zoning

Central to flood plain management is the concept behind FPZ (flood plain zoning). Demarcating zones or areas which are likely to be affected by floods of different magnitude or frequencies and probability levels, and specify the types of permissible development

4.3 RS and GIS in Flood Management Techniques

GIS has been defined in different ways, perhaps the most commonly used definition is that provided by Burrough (1986) generally known as the tool box definition. He defined a GIS as a powerful set of tools that enables collection, storage, retrieval, analysis and presentation of geographically referenced information. Remote sensing on the other hand is generally defined as the science of acquiring information about the earth's surface without actually being in physical contact with it.

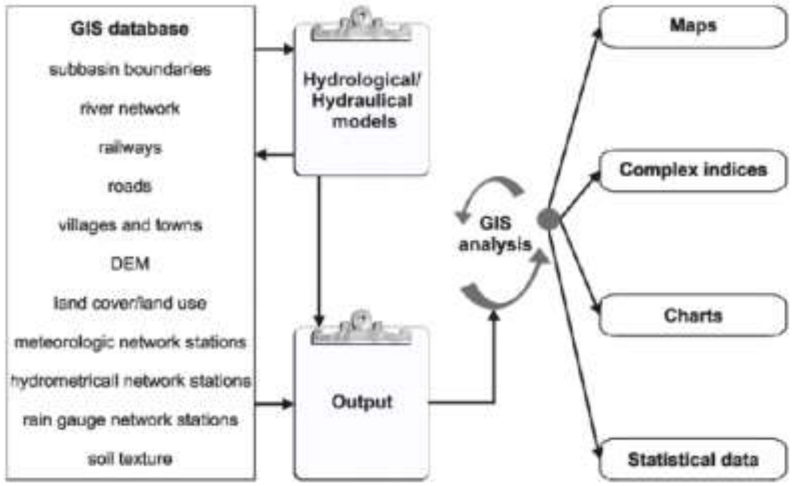


Fig. 4. 1: Integration of hydrologic model outputs and GIS info-layers for preparing flood-risk maps (Source: Stancalie et al., 2019)

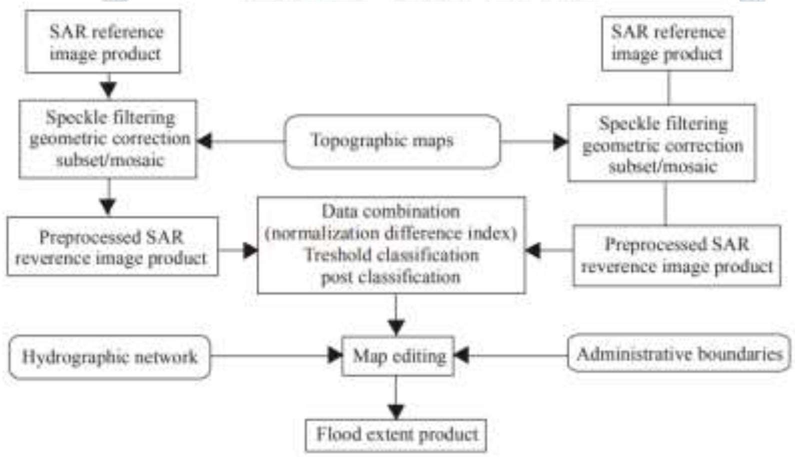


Fig. 4.2: Flowchart showing the generation of flood-extent maps from Satellite Radar (SAR) images (Stancalie et al., 2009)

Hydrological models to simulate/ predict flood. The general idea is that RS and GIS provide spatial and temporal data input required by the distributed hydrological models in order to simulate runoffs and thus floods. RS data in some studies have also been utilized to calibrate and improve on the performance of distributed hydrological models.

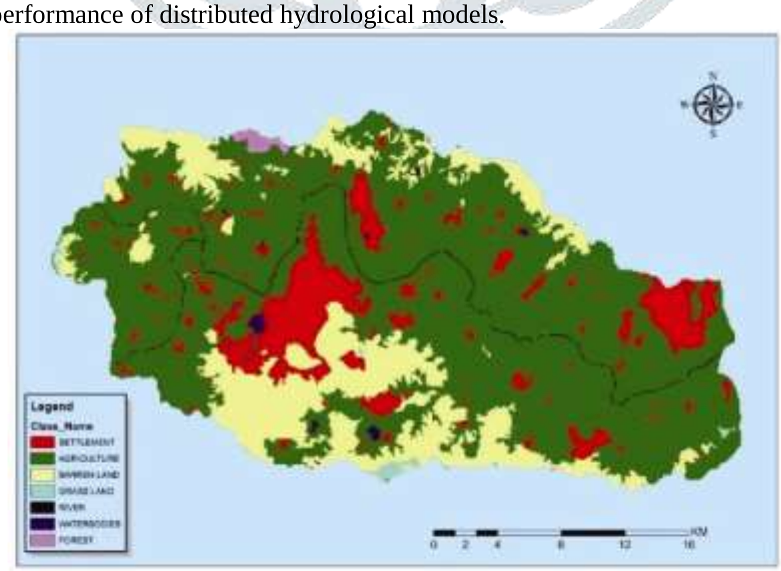
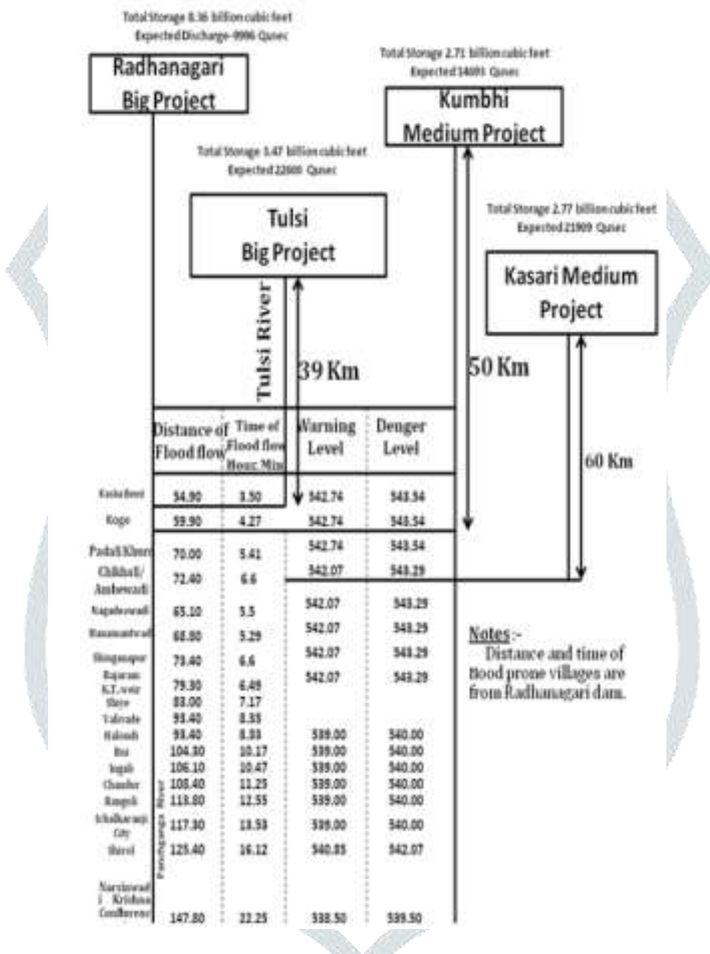


Fig 4.3 Flood Risk Assessment of Panchganga River (Kolhapur District, Maharashtra) Using GIS-Based Multicriteria Decision Technique

5. RESULT AND DISCUSSION

5.1 Case Study of River Panchganga Floods in Western Maharashtra Region

The Panchganga basin lies between 16019‟04” to 16055‟19” North latitudes and 73044‟08” to 74042‟18” East longitude in the northern part of the district is formed by the confluence of five rivers with their catchments namely Dhamani (188.42 km²), Kumbhi (227.09 km²), Tulasi (160.57 km²), Bhogawati (401.44 km²) and Kasari (354.86 km²). Thus called it is called „Panchganga‟ i.e. five rivers and it as a catchment of 767.25 km after it is formed till it meet river Krishna. Panchganga river system (PRS) thus is the main river system in the district with a total length of 338 km length and a total catchment area of 2099.63 km² sq km (MPCB and Collector office, Kolhapur (2009). Panchganga River receives average rainfall of 2501.9 mm according to the year 2005 (Pawar and Raskar, 2011). It gives organogram of the Panchganga river basin In Panchganga river system (PRS) basin has 5 major dams in its upper catchment, namely Radhanagari (8.36 TMC) with 10400 cusec total discharge capacity, Tulsi (3.47 TMC) with 640 cusec total discharge capacity, Kasari (2.77 TMC) with 22266 cusec total discharge capacity, and Kumbhi (2.71 TMC with 15046 cusec total discharge capacity (Sangli Irrigation Board, 2010). however, It has been seen that the flood intensity in Panchganga river is largely depended upon the discharge from Radhanagari dam due to its large capacity and position in PRS system, where more rainfall in the district is papered every year.



(Kolhapur Irrigation Department, 2019)

Fig. 5.1 . Panchganga sub basin organogram

Kolhapur Irrigation Department, (2009) has estimated the flood flow time (hours: minutes) required to reach the particular site after release of water from Radhanagari dam (figure no. 3.7). The time required to reach at particular place is varies from Kasba Beed (3:50) to Nrusinhwadi (22:25) hence there is less time for upper steam of the Panchganga river system as compare lower stream flood reaches in 6:49 hours at Rajaram K.T. weir in Kolhapur city. Warning levels and danger levels of the flood varies from place to place depending upon surface gradient. Warning level varies from 542.74 MSL (Kasba Beed) to 538.50 MSL (Nrusinhwadi) and danger level varies from 543.54 MSL (Kasba Beed) to 539.50 MSL (Nrusinhwadi).

5.2 Flood Zones of Panchganga River in Karveer, Hatkanangale and Shirol Tahsil

The Krishna river basin has experienced altered rainfall pattern during the last few years, which was evident due to the occurrence of drought situation followed up by the incidences of flooding in recent years. During the last decade occurrence of high rainfall and consequent flooding of vast areas in the Krishna river and its major tributaries like Panchganga Basin has been repeatedly experienced. Though the phenomenon of flooding of the riverbanks is not unfamiliar in the basin, the spread and duration required to deal with floods during the recent past are unprecedented. The obvious fallout is huge losses to agriculture and property in the region.

Fig. No. 5.2 . Flood Line of Panchganga River in Karveer Tahsil, Kolhapur District

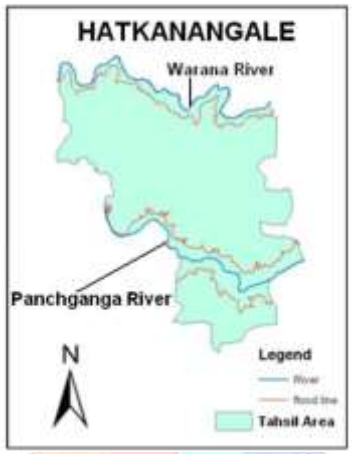


Fig. No. 5.3 . Flood Line of Panchganga River and Warna River in Hatkanangale Tahsil, Kolhapur District

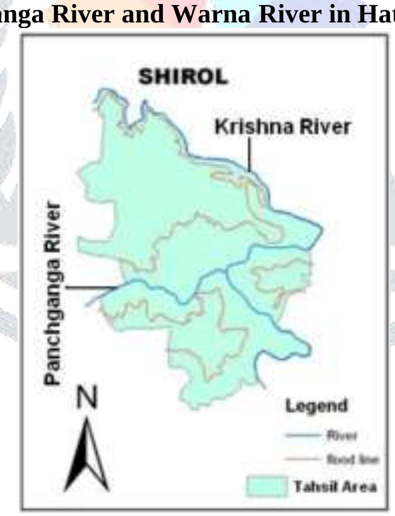


Fig. No. 5.4 . Flood Line in Panchganga River and Krishna River in Shirol Tahsil, Kolhapur District

Figure no. 3.8, 3.9 and 3.10 are images prepared from flood lines in Karveer, Hatkanangale and Shirol tahsil (Kolhapur Irrigation Department, 2005) using Arc GIS software 9.3 version. The images shows flood lines of Shirol tehsil having area of 507.83 km2, Hatkanangale tahsil having area of 609.57 km2 and Karveer tahsils having area of 671.13 km2. These figures show submergence area due to floodwater in the three tahsils. The total submergence area in Karveer, Hatkanangale and Shirol tahsil by Panchganga floods were 56.90 sq km, 64.59 sq km and 257.13 sq km respectively which was 8.48%, 10.60% and 50.53% of total area of that tahsil respectively. Also the area submerged by Warna river flood water in Hatkanangale tahsil is 41.14 sq km, i.e 6.75% of total tahsil area.

5.3 Floods in Kolhapur City

Kolhapur Municipal Corporation (KMC) has demarked flood lines covering an area of 6682 hector in Kolhapur city. Out of which a significant area (1391.50 ha) is covered by the flood line i.e. Red line (Flood Danger Line of year 2005) which is 20.82% of the total city area. (Figure no. 3.11). According to the 2nd Developmental Plan of Kolhapur city, area covered by the Blue line (No development zone line) is 1518.26 hector which is 22.72% of total city area indicates where all developmental activities are prohibited. The area between Blue Line and Red line is known as „Red zone‟ where prior permission of KMC is required for any construction. Where the residential area covered by the blue line is 8.64 hector and the area covered between blue line and red line is

9.31 hector. The Plate IV (a-f) shows floods in the Kolhapur city. For prevention and mitigation of impact of floods, KMC in (2011), arranged 17 evacuation places for different flood prone areas in the city (Annexure- VI)

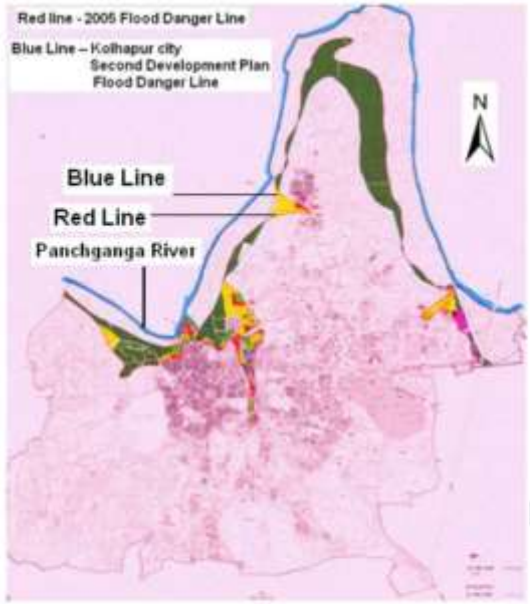


Fig. No. 5.5 . Flood Lines of Kolhapur City

5.4 Correlation of Rainfall and River Water Levels in Panchganga River

It was realized that the effect of rainfall in Panchganga basin has direct correlation with Panchganga river water levels at Rajaram K.T. weir (Kolhapur city). Which is dependent upon the capacity and periodic discharge from number of dams on the tributaries and K. T. weirs in the basin, located at upstream of Rajaram K.T. weir. Panchganga basin in its upper catchment has 5 major dams, namely Radhanagari (8.36 TMC with 10400 cusec total discharge capacity), Tulsi (3.47 TMC with 640 cusec total discharge capacity), Kasari (2.77 TMC with 22266 cusec total discharge capacity), Kode L.P.T. (0.21 TMC with 8262 cusec total discharge capacity) and Kumbhi (2.71 TMC with 15046 cusec total discharge capacity) (Sangli Irrigation Board, 2010). Originally, the full reservoir level of the dam was restricted to 519 meters MSL by the supreme court of India directive. The Krishna river conflict between Andhra Pradesh, Karnataka, and Maharashtra states was resolved by Brijesh Kumar Tribunal and the dam was authorized to be raised to the height of 524 meters MSL with increase in the gross storage capacity up to nearly 200 TMC. As of August 2013, the project has an estimated capacity of 90.91 TMC. The table no 3.4 presents mean and standard deviation of daily rainfall data of the five tahsils namely [Karveer (T1), Panhala (T2), Shahuwadi (T3),
Radhanagari (T4), and Gaganbawda (T5) from 1st July 2010 to 15th October, 2010] and water level at Rajaram K.T. weir as on at 8 A.M.

Table No. 5.1. Mean, Standard Deviation of Daily Rainfall of Five Tahsils and Water Level at Rajaram K.T. Weir in Panchganga River Basin

	Karveer	Panhala	Shahuwadi	Radhanagari	Gagan bawda	Rajaram KT weir MSL
Mean mm	6.12	9.48	13.41	22.87	45.35	535.82
SD	±11.35	±16.17	±22.60	±32.71	±48.78	±2.54

From the above table no 3.4 it is seen that during 1st July 2010 to 15^{th} October 2010 the average daily rainfall of Gaganbawda tahsils (45.35 mm) was more than other five tahsils in Panchganga basin followed by Radhanagari tehsil (22.87 mm). Shahuwadi tahsil also received average daily rainfall 13.41 mm. As compare to above three tahsils other two tahsils Panhala (9.48 mm) and Karveer (6.12 mm) received less average daily rainfall. Gaganbawda tahsil had large variation in daily rainfall as its standard deviation was 48.78. Radhanagari and Shahuwadi had medium variation in daily rainfall as standard deviation was 32.71 and 22.60. Less variation in daily rainfall was recorded at Panhala and Karveer tahsils as their standard deviations were 16.17 and 11.35 respectively.

Correlation Coefficient of rainfall in five tahsils

Correlation refers to any of a broad class of statistical relationships involving dependence and „Correlation Coefficient' is a measure that determines the degree to which two variable's movements are associated.

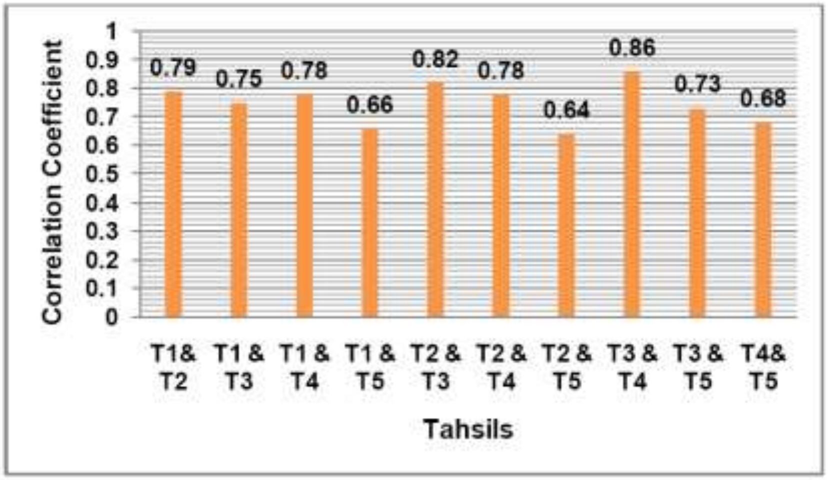


Fig. No. 5.6 . Correlation Coefficient between Daily Rainfalls of Five the Tahsils in Panchganga Basin

Correlation coefficients between daily rainfalls of the five tahsil i.e. Karveer (T1), Panhala (T2), Shahuwadi (T3), Radhanagari (T4), and Gaganbawda (T5), from 1st July to 15th October, are given in the figure no.3.12. It is observed that the rainfalls in the year 2010 (July to mid October) in the district is correlated, as all the values of correlation coefficients are more than 0.5. So there will be rain or increase or decrease in the amount of rainfall at five tahsils at a time. Among the above rainfall values Shahuwadi (T3) and Radhanagari (T4); Panhala (T2) and Shahuwadi (T3); Karveer (T1) and Shahuwadi (T3), Karveer (T1) and Radhanagari (T4); Panhala (T2) and Radhanagari (T4); Karveer (T1) and Shahuwadi (T3); Shahuwadi (T3) and Gaganbawda (T5) had higher correlation. High correlation means the probability of increase of rainfall at these respective tahsils is more as compare to the other tahsils.

As compare to Radhanagari (T4) and Gaganbawda (T5); Karveer (T1) and Gaganbawda (T5); Panhala (T2) and Gaganbawda (T5,) which had less correlation. That means, as compare to the other tahsils Gaganbawda tehsil rainfall correlation with other tahsil rainfall is less in Panchganga basin means the chances of increase or decrease of rainfall of Gaganbawda tahsil and other tahsils in PRS is less as compare to the other tahsils.

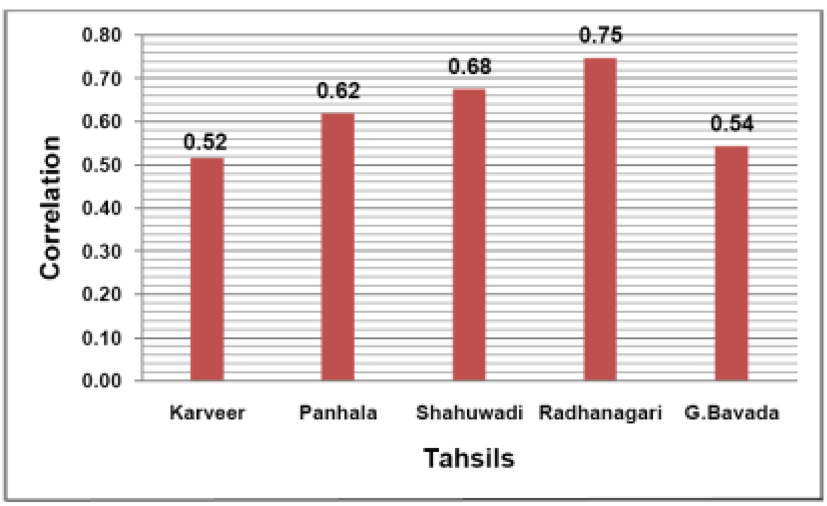


Fig. 5.7 . Correlation between Daily Rainfall of Five Tahsils

Daily Water Levels at Rajaram K T Weir in 2010 Correlation of daily rainfall of the five tahsils in the Panchganga Basin and water level at Rajaram K.T. weir during 1st July to 15th October 2010 is shown in the figure no 3.13. It is revealed that in Panchganga basin, the effect of rainfall of Radhanagari tahsil on the flood level at Rajaram K.T. weir is more than any other tahsils, because of more rainfall and major dam (Radhanagari) is situated in the tahsil which is main source of PRS.

Conclusion

From the consideration of all the above points we conclude that this paper describes the flood prone Pre-flood management areas of India along with the flood prevention and management techniques in western Maharashtra region. In this paper researcher focus on to study Rainfall Variability in Kolhapur,Satara and Sangli District and to study and analyze of pre- flood management at western Maharashtra region (Kolhapur, Satara and Sangli).Analyze Flood Management Measures Practiced in India and to Study and analyze detection methods are used for remote sensing the disasters. To Study and analyze Geographical information system (GIS) provides spatial data management and analysis to study flood management. Historically floods are known to cause damage to property and life leaving a long term traumatic impact on those who get affected by them. The intensity and magnitude of floods is supposed to be increasing world over in the recent decades because of climate change and global warming phenomenon. The Western Ghats are globally important, not only being rich in biodiversity, but primarily because of the role, they play in influencing climatic regime and annual precipitation in Indian subcontinent. The climate change has caused uncertainty and wide fluctuations in precipitation pattern from extreme droughts to heavy rains and periodic cloud bursts. Thus, floods, which were locally almost unknown, are becoming a potential disaster in the earlier relatively safe and climatically stable areas such as Western Ghats. Kolhapur district being largely i.e. over 65- 70% of the total area, being situated in the Western Ghats region, receives high annual rainfall in its western hilly part. It was therefore felt necessary to study the region for vulnerability and risk analysis of annual floods in Kolhapur district to know their main causes and their consequences. The intensity and magnitude of floods is supposed to be increasing world over in the recent decades because of climate change and global warming phenomenon. The Western Ghats are globally important, not only being rich in biodiversity, but primarily because of the role, they play in influencing climatic regime and annual precipitation in Indian subcontinent. The climate change has caused uncertainty and wide fluctuations in precipitation pattern from extreme droughts to heavy rains and periodic cloud bursts. Thus, floods, which were locally almost unknown, are becoming a potential disaster in the earlier relatively safe and climatically stable areas such as Western Ghats. Kolhapur district being largely i.e. over 65- 70% of the total area, being situated in the Western Ghats region, receives high annual rainfall in its western hilly part. It was therefore felt necessary to study the region for vulnerability and risk analysis of annual floods in Kolhapur district to know their main causes and their consequences.

REFERENCES

[1] Adel Omran., Dietrich Schroder., Ahmed El Rayes., and Mohammad Geriesh. 2011, Flood hazard assessment in Wadi Dahab, Egypt based on Basin Morphometry using GIS Techniques. GI Forum ISBN 978-87907-509-6.

[2] Aditi Bhadra.,Sutapa Choudhary., and Daita Kar. 2011 Flood hazard Mapping in Dikrong Basin if Arunachal Pradesh India. World Academy of Science, Engineering and Technology 5:12-22.

[3] Ahmed M Youssef. Biswajeet Pradha., Adballah Mohammed Hassan. 2011. Flash Flood estimation along St. Katharine road, Southern Sina, Egypt using GIS based morphometry and satellite imagery. Environment Earth Sciences 62:611-623.

[4] Bashir Ahmad., Muhammmad Shumail Kaleem ., Mohsin Jamil Butt., Zakir Hussain Dahri. 2010. Proceedings of Academic of Sciences. 47(4): 215-226

[5] Bajabaa S., M Masoud., N.Al-Amri. 2013 Flash Flood hazard mapping based on quantative hydrology. Geomorphology and GIS techniques (Case study of Wadi Al Lith , Saudi Arabia). Arabian Journal of Geosciences DOI 10.1007/s12571-013-0941-2.

[6] Eric Kwabena Forjuo., 2011, Flood hazard mapping using ASTER image data with GIS. International Journal of Geomatics and Geosciences 4(1): 932-950.

[7] Fowze J S M., Gunashekara I P A., Liyange PP., Haziraka M. K., Samarakoon L., 2008 Flood Hazard Mapping In Lower Reach Of Kelani River, Sri Lanka. Procedings of 29th Asian Conference on Remote Sensing 3:1 731-736.

[8] Gomma M Dawood. , Meraj N Mirza., Khalid A Al-Ghamdi , 2011 GIS based Spatial mapping of Flash Flood Hazard in Makkah City, Saudi Arabia. Journal of Geographic Information System. 3: 217-223

[9] Kabir Uddin. , Deo Raj Gurung., and Basanta Shrestha, 2013 , Application of Remote Sensing and GIS for Flood hazard Management : A case study from Sindh Province, Pakistan. American Journal of Geographic Information System 2(1):1-5.

[10] Michalis Diakakis., 2011, A method for flood mapping based on Basin Morphometry: application in two catchments in Greece. Natural Hazards 56:803-814.

[11] Muhammad Isma., I O Sanyool,. 2013. Application of Remotes Sensing (RS) and Geographic Information System (GIS) in flood vulnerability mapping: case study of River Kaduna. International Journal of Geomatics and Geosciences 3:3 618-627.

[12]Sina Alaghmand., Rozi bin Abdullah., Ismail Abustan., and Behdokht Vosooggh. 2010. GIS-based river Flood hazard mapping in Urban Are (A case in Kayu Ara River Basin, Malaysia) International Journal of Engineering and Technology. 2(6) 488-500.

[13**]** Pandey, Anupam., (2009), Mapping of 2006 flood extent in Birupa Basin, Orissa, India, using visual and digital Classification techniques on RADARSAT image: A comparative analysis. Indian Institute of Remote Sensing, National Remote Sensing Center (NRSC) and Department of Space.Dehradun, India.

[14] Sanyal, Joy., and LU, X.X., (2004), Application of remote sensing in flood management with special reference to monsoon Asia: A review. Natural Hazards, 33, 283 – 301.

[15] V. Sharma, T. Priya, “Development strategies for flood prone areas, case study: Patna, India”, J. Disaster Prevention and Management, vol.10, no.2 pp.101–109, 2001.

[16] W. Kenyon, G. Hill, P. Shannon, “Scoping the role of agriculture in sustainable flood management”, J. Land Use Policy, vol.25, pp. 351-360, 2008

[17] V. N. Mikhailov, V. N. Morozov, N. I. Cheroy, M. V. Mikhailova, “Extreme flood on the Danube River in 2006”, J. Russian Meteorology and Hydrology, vol. 33, pp. 48-54, 2008.

[18] Savenije, H.H.G., 1995. Man and Water, Friends or Foes. UNESCO/IHE Institute for Water Education Press, Delft, The Netherlands.

[19] Metternicht, G., Hurni, L. and Gogu, R.,(2005), Remote sensing of landslides: an analysis of the potential Contribution to geospatial systems for hazard assessment in mountainous environment. Remote Sensing of Environment.98, 284 – 303.

[20] E. A. McBean, M. Fortin, J. Gorrie, “A critical analysis of residential flood damage estimation curves”, Canadian J. Civil Engineering vol.13, pp. 86-94,1986.

[21] E. A. McBean, J. Gorrie, M. Fortin, R. Moulton, “Flood depth-damage curves by interview survey”, J. Water Resources Planning and Management, vol.114, no.5, pp. 613-634,1988a.

[22] B. Ramlal, S. M. J. Baban, “Developing a GIS based integrated approach to flood management in Trinidad, West Indies”, J. Environmental Management, vol. 66, no.1, pp.1-8, 2002.

[23] Nawaz. M and Mooyoung, H. 2006 “Hill Torrents Management for increasing Agricultural Activity in Pakistan. Department of Civil and Environmental Engineering, Seoul National University Korea