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Water Resources Development and Causes of Flood Blossoming in Upper Krishna River Basin

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ABSTRACT

Since the 1850s, progressive agricultural and water development in the Krishna basin in South India has led to rising over-commitment of water resources. This over-commitment and signs of basin closure are apparent during dry periods: surface water resources are almost entirely committed to human consumptive uses; increasing groundwater abstraction negatively affects the surface water balance by decreasing base flows; and the discharge to the ocean continues to decrease. Flood condition has become catastrophic during recent years mainly part of July and early August in Krishna River basin. It is also important to note that floods are serious spectacles by human and natural activities. About 27.72%of the geographical area of the upper Krishna River basin of southern Maharashtra is affected by floods of which about 2.12% of total population of Upper Krishna basin has agonized in 2006. Since, the floods of rivers are responses of both natural and anthropogenic factors, the relative effects and causes vary from place to place. To analyse the causes of flood situation in the region under study, the statistical data and concerned information have been collected through personal visits and records available at Tehsil headquarters of Sangli, Kolhapur and Satara districts. The present paper attempts to analyse causes of floods occurred in recent years in Krishna River basin of southern Maharashtra with the help of Geo-spatial approach.

Keywords: Catchment, Rainfall, Runoff, Groundwater, Infiltration, GIS, Flood

1. INTRODUCTION

Sangli & Kolhapur districts faced heavy flood situations in past also & floods of 2005 & 2006 were noteworthy. However, 2019 flood event was comparatively much more severe which lasted more than a week & losses experienced were also on higher scale [1]. The floods of rivers are the responses of both natural and anthropogenic factors. The causes of floods of alluvial rivers are highly complex and their relative importance changes from place to place. The present paper aims to find on the probable causes of flood situation in upper Krishna Basin of Maharashtra [2] [3]. Design flood is the discharge adopted for the design of a hydraulic structure and it is obviously very costly to design any hydraulic structure so as to make it safe against the maximum flood possible in the catchment. During the months of July & August 2019, Sangli & Kolhapur districts in Krishna sub basin experienced extreme floods for long durations. Heavy losses to life, property & crops etc. had been reported [4]. Different opinions at various levels were put forth concerning these flood events. Sangli & Kolhapur districts faced heavy flood situations in past also & floods of 2005 & 2006 were noteworthy. However, 2019 flood event was comparatively much more severe which lasted more than a week & losses experienced were also on higher scale. The floods of rivers are the responses of both natural and anthropogenic factors. The causes of floods of alluvial rivers are highly complex and their relative importance changes from place to place. The present paper aims to find on the probable causes of flood situation in upper Krishna Basin of Maharashtra [5,6].

2. MATERIALS AND METHODS

In order to accomplish the objectives of the study, various spatial and non-spatial (historic as well as contemporary) data were used. This section deals with the collection, processing, and analysis of the different datasets used in the present project. Required data and information have been collected from various sources. The vast statistical data and concerned information have been collected through personal visits to tehsil headquarters of Sangli, Kolhapur and Satara districts. Number of affected villages have been visited to have discussion with the affected people and Government officers. The secondary data have been taken from socio-economic reviews and district statistical abstracts, census handbook and district gazetteer of Satara, Sangli and Kolhapur districts. Various articles published on flood situation in daily newspapers, journals, magazines, S.O.I. toposheets and reference books were also referred. To find out causes of floods in upper Krishna Basin, the relative information regarding the rainfall, area under irrigation, bridges on Krishna and other rivers, statistical information about flood affected area, population and other aspects were collected through primary and secondary sources of data.

3. STUDY AREA

Krishna River is the second largest river in Peninsular India. It originates in the Mahadev range of the Western Ghats near Mahabaleshwar, at an altitude of 1337 m above msl (13°.7”/N to 19°20”/N and 73° 22‟/E to 81°10‟/E) and flows through Maharashtra, Karnataka, Andhra Pradesh and drops into the Bay of Bengal in Andhra Pradesh state. Krishna Basin is having a total area of 2.59 Lakh sq. km, which is nearly 8% of the total geographical area of the country. The total length of river is about 1400 km. The basin is roughly triangular in shape and is bounded by Balaghat range on the north, by the Eastern Ghats on the south and the east by the Western Ghats on the west [7].

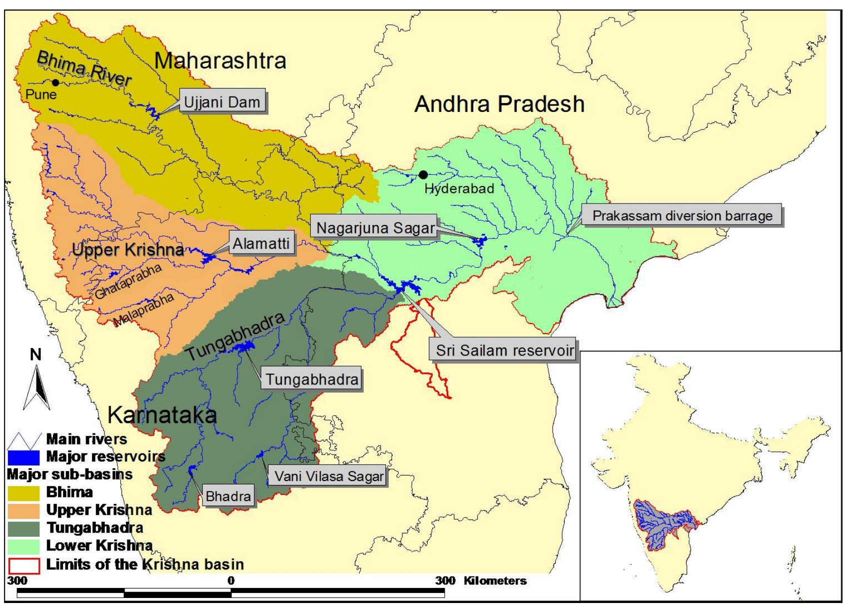


Figure 1: Location map of Krishna Basin

4. WATER RESOURCES DEVELOPMENT AND RURAL CHANGES IN THE KRISHNA BASIN

The Krishna river discharge to the ocean gradually decreased, providing the first indication of river basin closure (Figure 2). Before 1960, river discharge into the ocean averaged 57 Billion cubic meters a year (Bcm/yr). Since 1965, it steadily decreased at an average of 0.8 Bcm per year, falling to 10.8 Bcm in 2000, or less than 15% of its historical value and falling further, close to nil in 2004 (0.4 Bcm) [8-10].

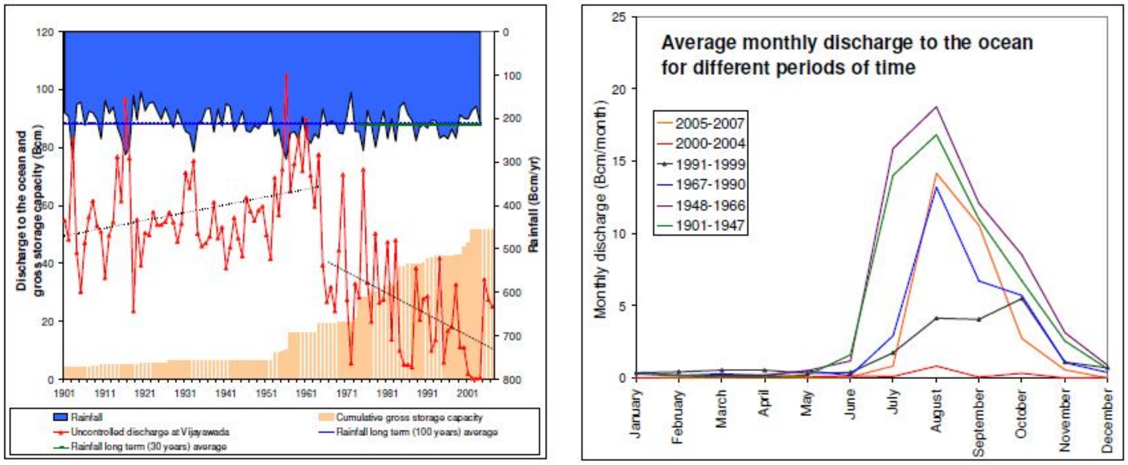


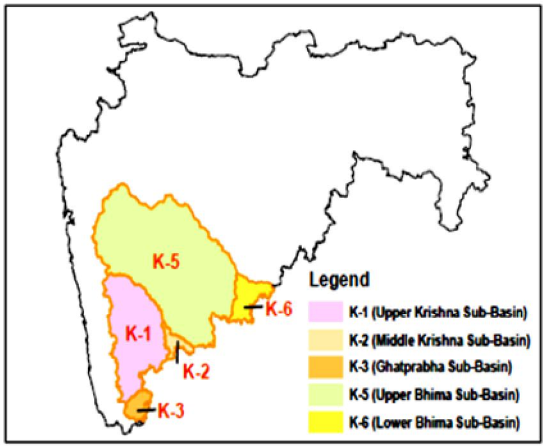
Figure 2. The closure of the Krishna basin: A declining discharge to the ocean

The right panel shows that only monsoon flows (July-October) reached the ocean and that the peak outflow was delayed by about two months: this had dramatic impacts on the coastal ecosystems of the basin [10]. The high discharges observed in 2005-2007 (29 Bcm/yr on average) illustrate that the Krishna River basin is under transition: droughts intensify the interconnectedness of water users and leads to shortage of water downstream. As this might be a harbinger of the future, defining management intervention for sustainable water use at the basin level is increasingly needed. This requires identifying the spatial and historical dynamics of water use and understanding the drivers of the closure of the Krishna basin.

5. STATUS OF WATER RESOURCES SECTOR IN MAHARASHTRA DUE TO CLIMATE CHANGE

Krishna River is the second largest river in Peninsular India. It originates in the Mahadev range of the Western Ghats near Mahabaleshwar, at an altitude of 1337 m above msland flows through Maharashtra, Karnataka, Andhra Pradesh and drops into the Bay of Bengal in Andhra Pradesh state. Krishna Basin is having a total area of 2.59 Lakh sq. km, which is nearly 8% of the total geographical area of the country. The total length of river is about 1400 km. The basin is roughly triangular in shape and is bounded by Balaghat range on the north, by the Eastern Ghats on the south and the east by the Western Ghats on the west. Map of Krishna Basin of India is shown in Annexure “maps” (Map No.1) Krishna Godavari Commission had divided entire Krishna basin into 12 sub divisions & they are designated as K1 to K12 spread in all states i.e. Maharashtra, Karnataka & Andhra Pradesh (now divided into Andhra & Telangana). 5 basins K1, K2, K3, K5 & K6 are spread in Maharashtra state [11-13].

Out of 6 river basin systems, only 55% of the dependable yield is available in the four river basins (Godavari, Krishna, Tapi and Narmada) east of the Western ghats. The rest drains out in the westward flowing river basins into the Arabian Sea. Over dependency on ground water in a state where its recharge capacity is low, escalates vulnerability of systems dependent on the same such as irrigated agriculture, industries and drinking water. Maharashtra is prone to drought and floods. Out of the total geographical area of Maharashtra, 40% of the area is drought prone and 7% is flood prone. Rainfall trends indicate that Maharashtra could face an increase in rainfall variability, including droughts and dry spells, as well as increased likelihood of flooding in the future [9,12]. This has direct bearing on ground water as heavy intensity rainfall gets lost as runoff while low intensity rainfall which contributes to recharge decreases in frequency. Climate change vulnerability assessments are necessary for designing targeted adaptation actions. The vulnerability analysis was carried out for different sectors at various levels of governance, on the basis of Macro level Vulnerability Indices, estimated using the Indices of Exposure, Sensitivity and adoptive capacities to climate changes. This was done by the Department of Environment, Government of Maharashtra while preparing the Maharashtra State Action Plan on Climate Change in 2014. The Action Plan has also presented climate projections for future at 25km x 25 km resolution using the Hadley Centre regional climate model [14,15].



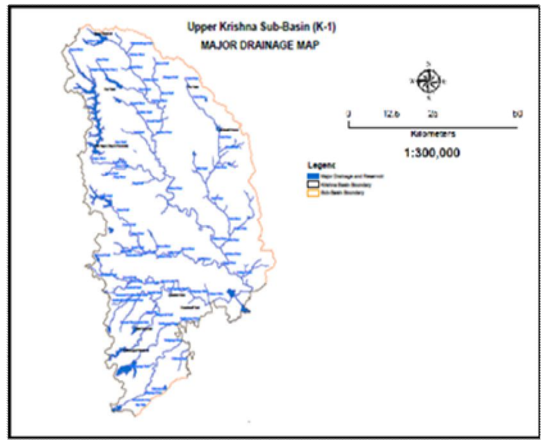


Figure 3: Index map of Krishna Basin Maharashtra **Figure 4:** Major Drainage map of Krishna Basin in Maharashtra

Some of the projected changes in climate over Maharashtra are:

- Increase in mean temperature from 1.2 to 1.6 degree centigrade in 2030s.
- Rainfall is also projected to increase during the same period, with more rainfall projected as we progress from 2030 to 2050 to 2070 but it will be highly variable spatially.
- Annual rainfall shows highest increasing trend for Satara, Mumbai, Kolhapur and Sindhudurg and highest decreasing trend for Bhandara and Latur in 2030s.
- Extreme rainfall events with longer dry spells are projected to increase in all districts of Maharashtra.
- Numbers of dry days are likely to increase by minimum 3 to maximum 9 days in the state by 2030s.
- The sea level is expected to increase by 24 cm to 66 cm along the coastline in sync with the projections for global sea level rise, accompanied by an increase in wave heights, wind speeds, greater storminess and storm surges.

6. *RAINFALL PATTERNS OF UPPER KRISHNA RIVER BASIN*:

Rainfall data indicates that Konkan and adjoining Madhya Maharashtra experienced very heavy rainfall. In the beginning of the flood period i.e., from 27th Jul to 3rd Aug, the heavy rainfall events were localized in the northern part of the Konkan and adjoining North Madhya Maharashtra. Many stations in Pune and Nasik districts, recorded rainfall more than 150 mm/day during the period 3rd to 5th Aug [15]. Towards the latter part of the week, rainfall belt shifted towards south Madhya Maharashtra. Mahabaleshwar recorded highest rainfall of 380 mm on 5th Aug. 2019. It is also observed that Kolhapur district continuously experienced heavy rainfall throughout the period with highest rainfall amounts on 6th Aug. 2019. Gaganbawda recorded its highest rainfall of 340 mm rainfall on 6th Aug. It is also seen that though heavy rainfall occurred in the western part of the districts in Madhya Maharashtra, their eastern parts were devoid of rainfall. It is further seen that during the heavy rain spell of Aug. 2019, many stations in Kolhapur district and western part of Satara district have crossed their previous record of 7 days rainfall. This indicates that compared to previous years, rainfall over the region was widespread and remained very intense for a long period during 27th July to 13th August 2019. Sangli, Kolhapur and Satara district received very heavy rainfall of 1918 mm in comparison to 333 mm normal rainfall during 27th July to 13th August. This was about 6 times the normal and at the same time, in the free catchment, downstream of the dams, it was about 18 times the normal. Such high range of continued rainfall in short duration resulted in extreme heavy flooding mainly in Sangli, Kolhapur town and few talukas situated near Krishna and Panchganga rivers [17,18].

It is observed that, the Flood affected districts of Satara, Sangli and Kolhapur continuously received excess to large excess rainfall during the first fortnight of August. It was seen that the observed actual rainfall in various catchments to the upstream of dams varies from 5 to 19 times the normal. Average actual rainfall was about 6 times the normal rainfall in all these catchments bringing abnormal flood to downstream areas. The actual rainfall during the first 56 days of the monsoon (starting from 1st June 2019) was measured at 6 rain gauge stations, situated in the free catchments of these three districts. It is observed that the total rainfall during the peak period of 18 days (27th July to 13thAugust) measured at the same stations, was about 1.6 times the total rainfall during the previous 56 days (1st June to 26th July). Also, the actual rainfall during the event in free catchments was varied from 13 to 29 times the normal rainfall. The overall observed rainfall over the normal was about 18 times. Such abnormal high occurrence of rainfall even in free catchments also aggravated floods in Sangli & Kolhapur districts [19].

7. *HISTORICAL EVENTS OF UPPER KRISHNA RIVER BASIN*:

Arabian Sea contributed 5 out of these 8 cyclones against the normal of 1 per year, which equals the previous record of 1902 for the highest frequency of cyclones over the Arabian Sea. Out of 5 cyclones developed over Arabian Sea 2 were very severe, one was extremely severed and one was super cyclonic storm. Active spell of South West monsoon started from 27thJuly, 2019 and before it is fully dissipated; low pressure area was formed on the Bay of Bengal, which intensified into deep depression on 7th August. During the first spell catchment was fully saturated. Hence, during second spell almost all the rainfall converted into runoff causing severe inundation. During South-West Monsoon season over the country, rainfall over Maharashtra shows significant spatial and temporal variability. The state experiences extremes of rainfall ranging from 6000 mm over the Ghats to less than 600 mm in the interiors. Western coast of Maharashtra, the Konkan belt is often prone to heavy to very rainfall during active monsoon conditions due to favorable orography. The Western Ghats act as obstruction to the eastward-moving Monsoon cloud forcing it to rise ultimately leading to the heavy downpour on the windward side, while the leeward side forms the rain shadow area receiving less rainfall. Climatological records of the Satara, Sangli and Kolhapur districts indicate that, there is a large variation in space of rainfall [19,20].

8. *HYDROLOGICAL ANALYSIS:*

To specifically clarify based on hydrological studies, whether due to any other reservoirs (back water effect) from Karnataka, create flood situation in Maharashtra.One dimensional unsteady flow analysis, of the River Krishna from Karad to Almatti, along with its three tributaries in the State of Maharashtra viz. Yerala, Warna and Panchganga, has been done using Version 5.0 of the HEC-RAS software. Analysis has been done for the period of 25th July, 2019, 8.0 am too 17th August, 2019, 8.0 am. Steady state analysis for PMF condition was also done.The important conclusions of this hydrodynamic analysis are:a) Although this mathematical model study, has certain limitations, the study indicates that Almatti and Hippargi reservoirs in Karnataka and its flood operations, during the Flood Event of 2019, has not adversely affected the flood situation in the State of Maharashtra. b) The discharge carrying capacity of the river Krishna was inadequate to accommodate the releases of Koyna dam, the contribution of tributaries and the runoff of the free catchment. c) The river Krishna flows, a near plain land, between Sangli and the State border. It is a general phenomenon that the river takes meandering course, while traversing on a plain land. Thus, River Krishna has so many curves and meanders. The velocity of the river is comparatively less while traversing curves and meanders, causing thereby more inundation on inner as well as outer sides of the curves and meanders as compared to straight reaches of the river. The Sangli city is on one of the curves of River Krishna and Kolhapur city is on the curve of river Panchganga. d) Flow stagnation in River Krishna from Sangli city to the State border, due to confluence effect. There exists series of confluences, Yerala-Krishna, Warna Krishna, Panchganga-Krishna and Dudhganga-Krishna within a reach of about 50 to 55 km length. At confluence points due to formation of stagnation zone velocity is reduced. e) Generation of backwater effect in the tributaries and nallas meeting the River Krishna. Due to comparatively higher discharge in the River Krishna, the backwater effect is generated in the tributaries. The flooding in tributaries viz. Yerala, Warna, Panchganga and other nallas like Bhilwadi, Nagthane was primarily due to backwater effect of the river Krishna. The situation was further aggravated, as these tributaries could not drain out their own discharge, till the flood in the river Krishna was receded. Water was spread on the side banks of the tributaries due to pounding effect. The river Krishna was flooded for a long duration from 5th August up to 13th of August. Consequently, the backwater spread in the tributaries and on floodplains could not return back to the river course. Thus, the floodplains were under water for a prolonged time. f) The lateral slope of the flood plains is very gentle. The flood plains are almost flat. This has resulted into spreading of flood on larger area on both the banks of the river

9. *CONCLUSION:*

Over-commitment of water resources and signs of basin closure are apparent during dry periods in the Krishna Basin. However, despite rising inter-sectoral, inter-regional and interstate tension and reduced investment in rural development, the three states that share the Krishna waters continue to expand their agriculture and irrigation sectors.Basin experienced an abnormally very high rainfall between 25th July to 13th August, resulting in severe flood in Sangli, Kolhapur, Satara districts. Average actual rainfall was about 6 times the normal rainfall in all dam catchments bringing abnormal flood to downstream areas. The overall observed rainfall over the normal was about 18times. Such abnormal high occurrence of rainfall even in free catchments also aggravated floods in Sangli & Kolhapur districts. The river Krishna was flooded for a long duration from 5th August up to 13th of August. Consequently, the backwater spread in the tributaries and on floodplains could not return back to the river course. Thus, the floodplains were under water for a prolonged time. Although this study based on mathematical model, has certain limitations, the study indicates that Almatti and Hippargi reservoirs in Karnataka and its flood operations, during the Flood Event of 2019, has not adversely affected the flood situation in the State of Maharashtra. Generation of backwater effect in the tributaries and nallas meeting the River Krishna. Due to comparatively higher discharge in the River Krishna, the backwater effect is generated in the tributaries.

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