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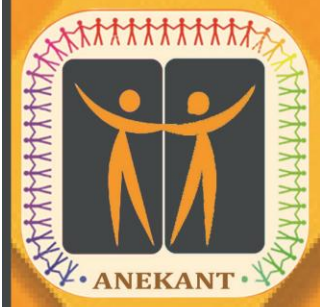

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STUDY OF WATERSHED USING GIS APPROACH: A CASE STUDY OF PUNE CITY

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Abstract:

The purpose of the present study is to introduce GIS approach in a watershed study. Based on daily rainfall data from 1950 to 2010 for fourteen stations of the Pune district, one day extreme rainfall series for each station were identified. Also, on the basis of rainfall data of all stations, we have identified a station and a day with highest rainfall value in the last 60 years. Then, observed rainfall values of remaining stations for that particular day. Finally, on the basis of rainfall values for that day of all stations, spatial pattern of one day extreme events have been created with the help of ArcGIS software. The seasonal and annual variability in the rainfall and temperature for Pune district is shown by the map. Attempt has been made to show temporal changes in 1, 2 and 3 days extreme rainfall for Pune district.The map of land use / land cover of the study area has been prepared using LISS III satellite image in a SWAT model.

Keywords: GIS, Seasonal Temperature, Seasonal Rainfall, Extreme Rainfall, LISS III, SWAT Model.

ITRODUCTION:

Rainfall at many places in India is governed by summer monsoon. The word 'Monsoon' is derived from the Arabic word ‘Mausim’, means 'season' or 'change in wind directions'. These winds bring moisture from the adjoining seas onto the land areas, making the continental weather humid (Gadgil et al., 2002). Two monsoon systems operate in India, namely, summer monsoon season accounting for 70-90% of annual over most part of India during June to September and post monsoon accounting for about 40% in south peninsular region of India during October to December (Gupta, 2002). The rainfall in India shows large spatial and temporal variability. It generally exceeds 1000 cm in the areas the east of 80oE (Cherrapunji / Mawsynram in northeast India receives rainfall of 1000 cm and more in a year), while in Thar desert, located in western part of India receives hardly 20cm of rainfall during a year. (Deshpande and Singh, 2010) However there is almost no area where rainfall is less than 100 mm annually, and even this is sufficient to meet local drinking water needs, provided it is harvested properly and where it falls. Heavy Intense rainfall at a place naturally generates a large runoff within short period of time, making it imperative to store this water if it is to be of use. As such storage of water in excess rainfall regions as well as deficit rainfall regions is of prime importance. Because of the sporadic spatial and temporal distribution of rainfall, the only way for water supply can be controlled to match demand is through storage.

Fundamentally, a reservoir serves to store water and the size of the reservoir is governed by the volume of the water that must be stored, which in turn is affected by the variability of the inflow available for the reservoir. These Reservoirs are of two main categories: (a) Impounding reservoirs into which a river flows naturally, and (b) Service or balancing reservoirs receiving supplies that are pumped or channeled into them artificially. (Wagner et al, 2012) In general, service or balancing reservoirs are required to balance supply with demand. Reservoirs of the second type are relatively small in volume because the storage required by them is to balance flows for a few hours or a few days at the most. Reservoirs that are sited upstream of major demands have maximum operational flexibility to shift water among competing uses, for example, taking advantage of rainfall in one area to conserve water for use at another location or time. Impounding or storage reservoirs are intended to accumulate a part of the flood flow of the river for use during the non-flood months. With this view, an attempt has been made here to assess the water availability and its temporal variations in the area where the reservoirs supplying water to Pune City are located. (Deshpande and Singh, 2010).

OBJECTIVES:

1. To bring out the spatial patterns of seasonal and annual rainfall/Temperature patterns and their temporal changes and over Pune District using the daily rainfall data of 19 stations from Pune District and data at 5 reservoirs.

2. To document the statistical inferences in the 1-day extreme rainfall series at various stations in the Mula-Mutha basins.

3. To discuss some applications of the Remote Sensing data in characterising the landuse pattern and also to run the Hydrological model.

METHODOLOGY:

To study the rainfall and temperature climatology, for each station or each grid within the study area, seasonal rainfall time series for 4 seasons (total rainfall for each season) have been calculated first. Then the average based on all the years is calculated for each station/grid. Then using GIS interface it has been displayed on the map of study area. Smooth isolines have been drawn and shaded using appropriate colours are shown.

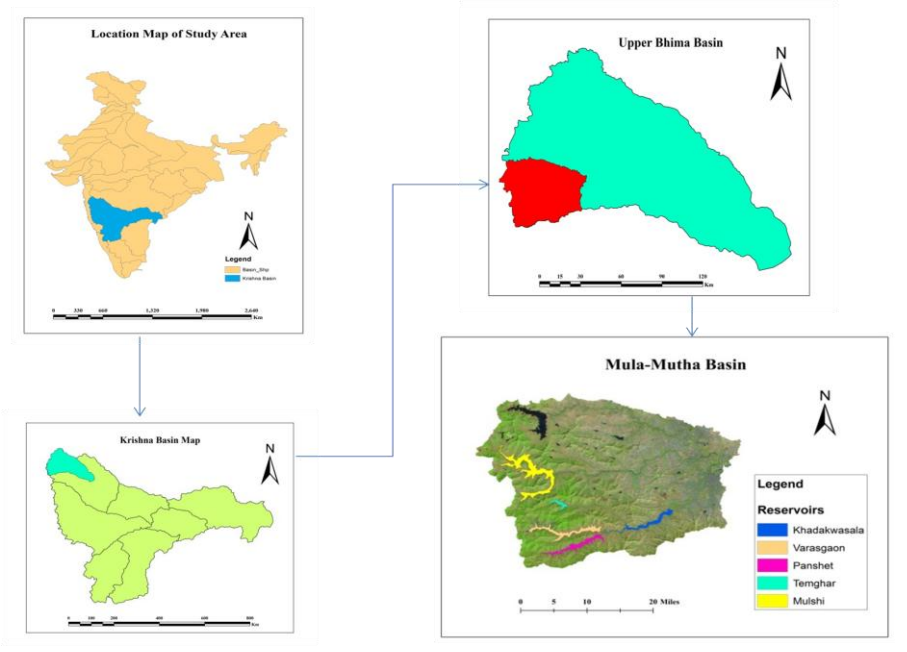
First step followed in Extreme rainfall analysis is that, to prepare 1 day extreme rainfall series for each station/grid for the available data (For each year 1 extreme value has been picked up for 365 days in a year). Based on all years one highest ever recorded value has been selected and map of such values for different duration has been displayed using GIS interface.

Spatial averages of Seasonal and extreme rainfall of all the stations inside the study area have been estimated for each year and then such time series has been subjected for examining the temporal changes.

STUDY AREA:

The Study area considered here is situated in the Krishna River Basin, India's fifth largest river basin covering an areas of 2,58,948 km^2 in Peninsular India. It covers nearly 8 % of total geographical area of the country. The basin is situated between East longitudes 73°21' to 81°09' and North latitudes 13°07' to 19°25' in the Deccan Plateau (Map.1). The Krishna River originates in the rugged topography of the Western Ghats or Sahyadri at an elevation of about 1337 m above msl, North of Mahabaleshwar and flow East-ward for about 1400 km to meet the Bay of Bengal (Deshpande and Singh, 2010). Pune city is situated in the Bhima Subbasin of the Krishna Basin. The Mutha and Mula rivers, tributaries of the Bhima flow through Pune City and are the lifeline for the citizens. These rivers originate from Deccan volcanic province, rises in a mass of hills on the edge of Sahyadri, near 3000 feet (986 m) above sea level at Mutha village. In the upstream region, two tributaries of the Mutha River, namely Ambi and Mose, originate near Dapsar and near Dhaman oval. Mula River merges with the Pawana River on the left bank and Mutha River on the right bank to form the Mula-Mutha River, which later meets the Bhima River. The citizen of Pune utilizes water from 4 reservoirs Khadakwasala, Panshet, Varasgaon, Temghar. Dams at Panshet, Varasgaon and Temghar supplement the storage capacity of Khadakwasla. Mulshi reservoir supplies the water for the parts of Pimpri-Chinchwad area.

Total area of the study region comprising the Mula-Mutha basin is 2036 km^2. However, the seasonal climatology has been discussed for Pune District with area 15642 km^2 (Map.1).

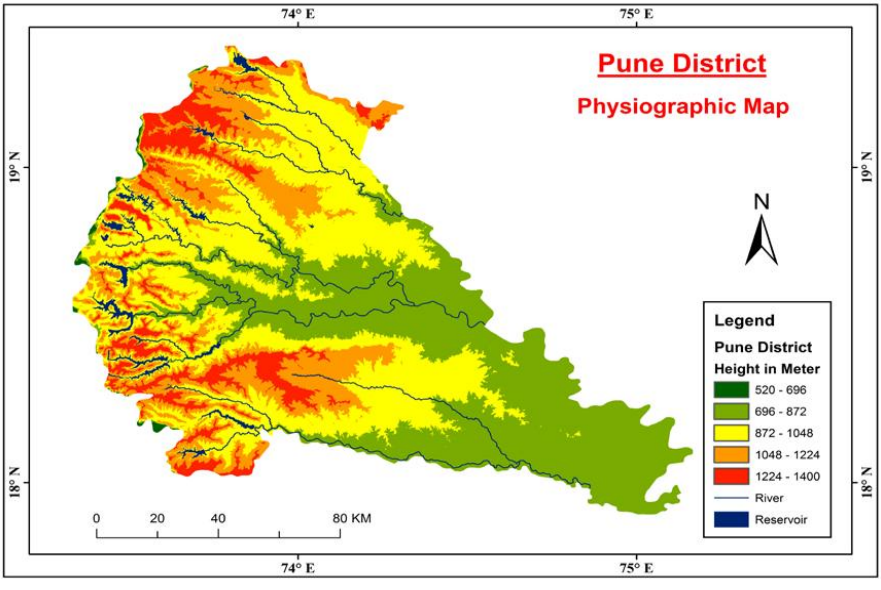


Map. 1.Location map of the study area.

Physiography:

Pune district covers 15,642 sq. km. area. Sahyadri mountain range lies from north to south in west part in study region and Crestline acts as a main water divided of peninsular rivers. There are three main mountainous ranges, namely, Harishchandra range, Jeevdhan range and Dhak-Ahupe range. In south, Saswad plateau lies in between Bhima basin in north and Neera basin in south and then it extends towards east (Map. 1). South of Harishchandra range, the Tasubai range lies in south, then Mandavi range and Tamhini

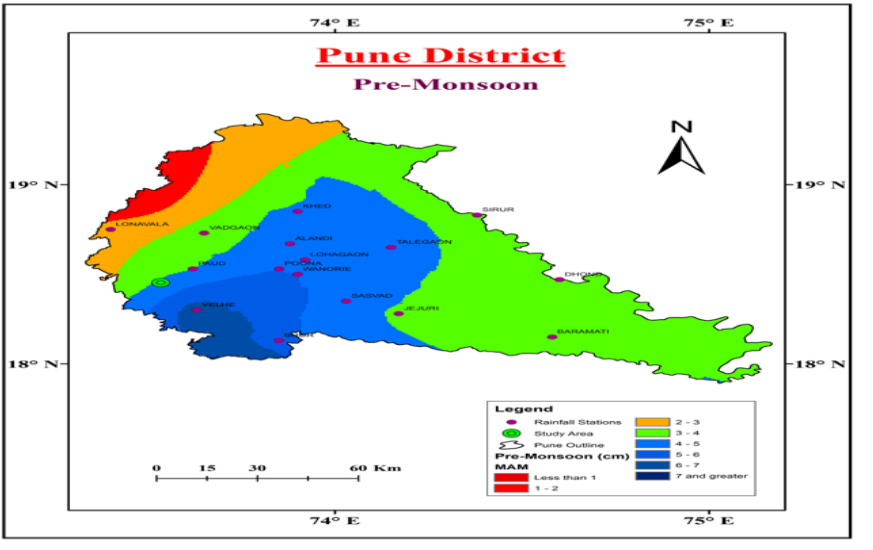
range followed by Saswad plateau indicates two regions of above 900 meters high. One lies in north i.e. Harishchandra and another is Jeevdhan range. The height in west part in study region is above 1200 meters and it lowers towards east 450 meters. The central and west parts have elevation from 600 to 1200 meters. The slope is towards southeast in study region (Map 2). The central and east parts show elevation between 450 to 600 meters lying from east to west. One zone lies between Tasubai range and Saswad plateau and east part and south part of Saswad plateau. The overall slope is 800 meters from northwest to southeast direction in study region.

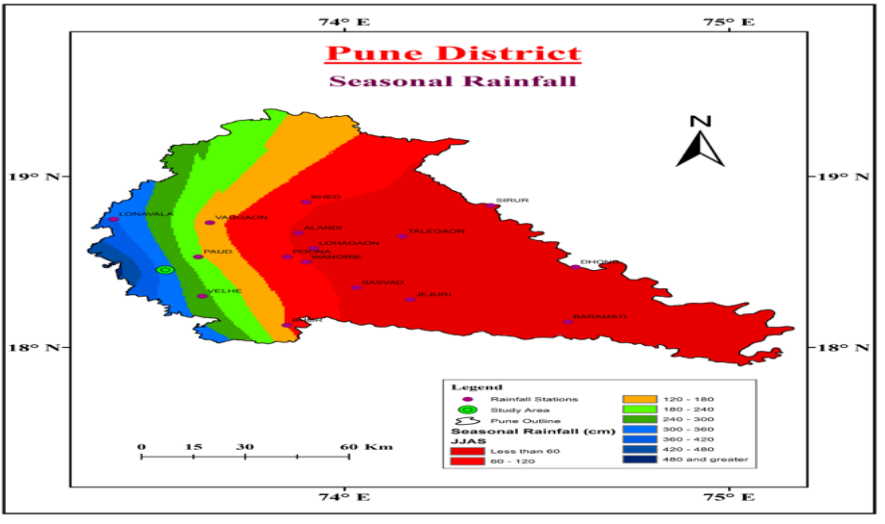


Map. 2 Physiographic map of the study area.

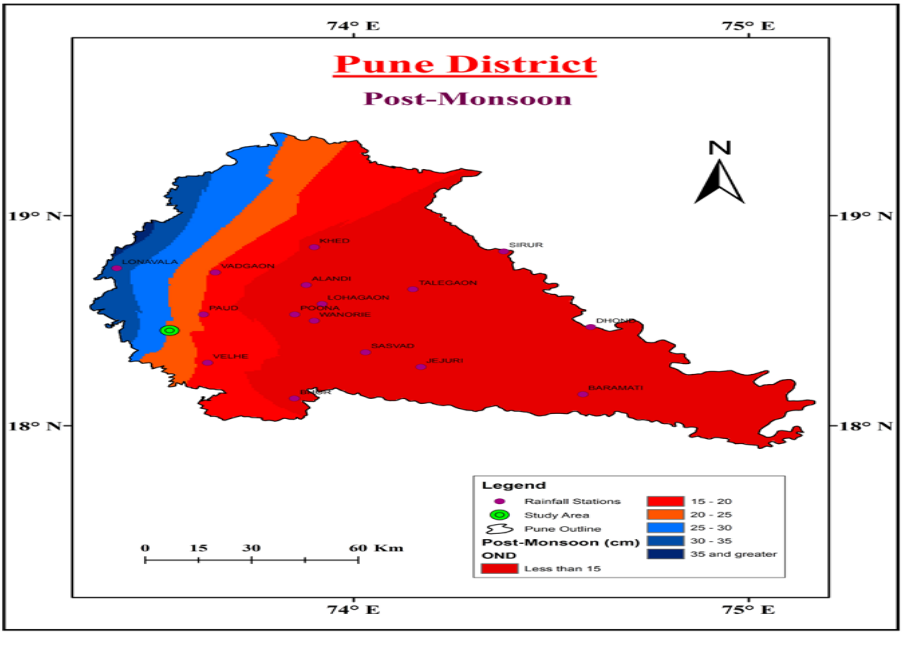
Seasonal Rainfall / Temperature Climatology and Temporal Variability:

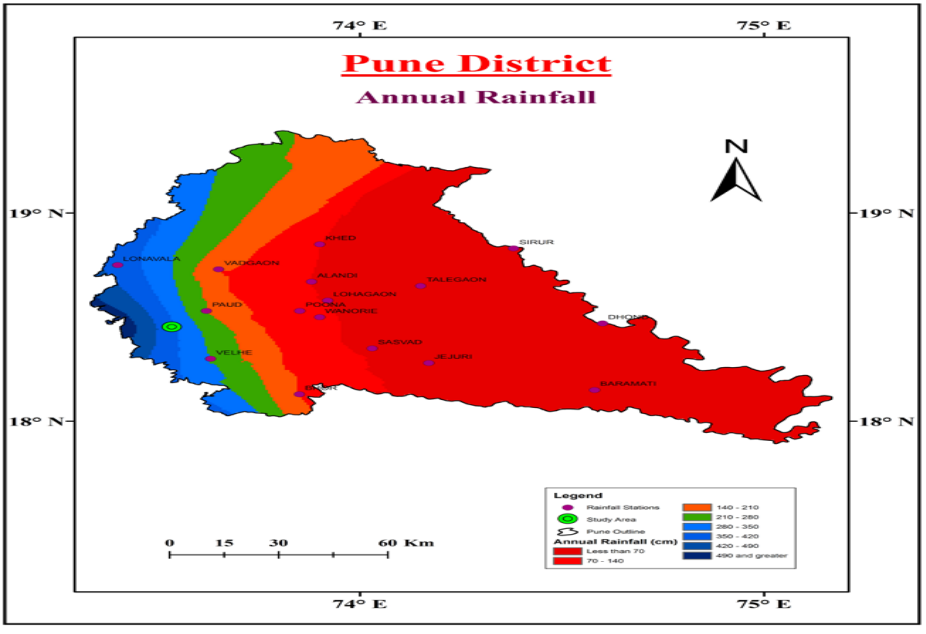
Normally India receives its annual rainfall of the order of 118cm out of which nearly 75-80 % is received in the summer monsoon or South-West monsoon season. The rainfall shows a large spatial and temporal variability over India. The study area lies in the Bhima sub-basin of the Krishna River in the peninsular India which is the second largest river in the peninsular India. Maximum part of the study area is semi arid and located in rain shadow region of the Western Ghats. However, western part of the study area lies in the ranges of the Western Ghats. So rainfall received here is much larger than that of Pune City area. Following figures depicts the spatial patterns of the seasonal rainfall over the study area.





Map. 3. Pre-monsoon and seasonal rainfall distribution of Pune District.





Map. 4. Post-monsoon and Annual rainfall distribution of Pune District.

Pre-monsoon Figure indicates rainfall activity is limited to the area in southwestern sector of the district in Velhe region. Study area or reservoirs lies in this heavy rainfall zone and receives rainfall of 6cm during this season (Map.3).

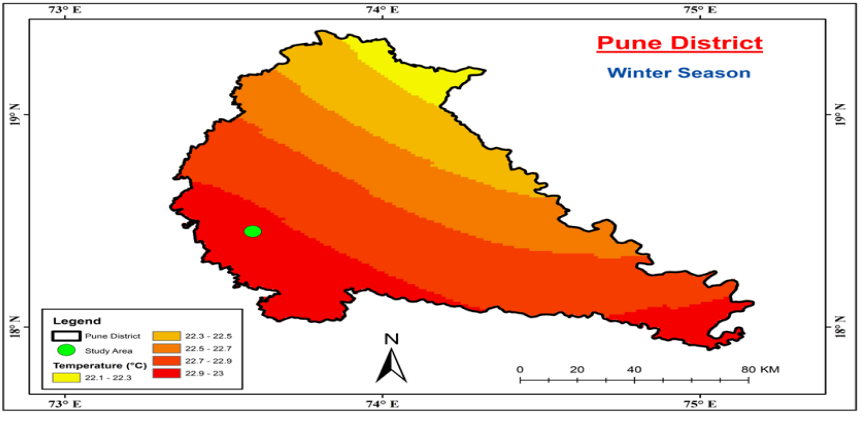
Summer monsoon Figure it is seen that summer monsoon rainfall ranges from less than 30cm to 400cm in a season. Nearly 50% of the Pune district area lying in the eastern part comes under the semi arid zone and receives rainfall of 30cm during June-September. While western part of the district where reservoirs are located (Paud area as seen from the figure) receives rainfall of the order of 250cm in summer monsoon season. Hilly areas around

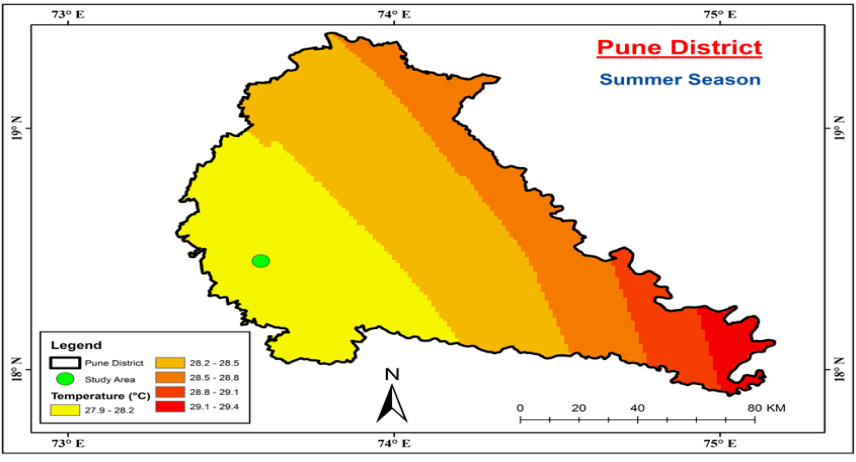
station Lonavala receive maximum rainfall of 400cm during this season. This is due to the orographic effect of the Western Ghats (Map.3).

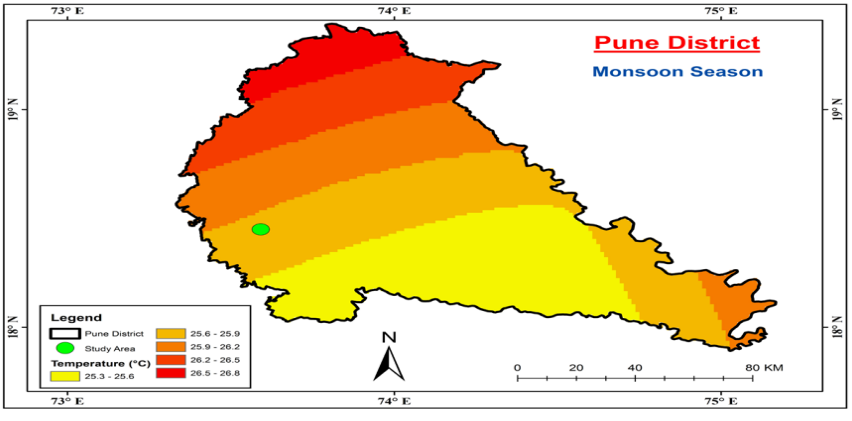
Post-MonsoonFigure gives the spatial pattern of Post-Monsoon season rainfall. Figure indicates that a substantial amount of rainfall is received during the post-monsoon season. This is corresponding to withdrawal phase of the southwest monsoon and beginning of Northeast monsoon in the peninsular India. Western part of the district receives rainfall around 30cm, (Khopoli) while eastern part receives around 10cm of rainfall during this season (Map.4).

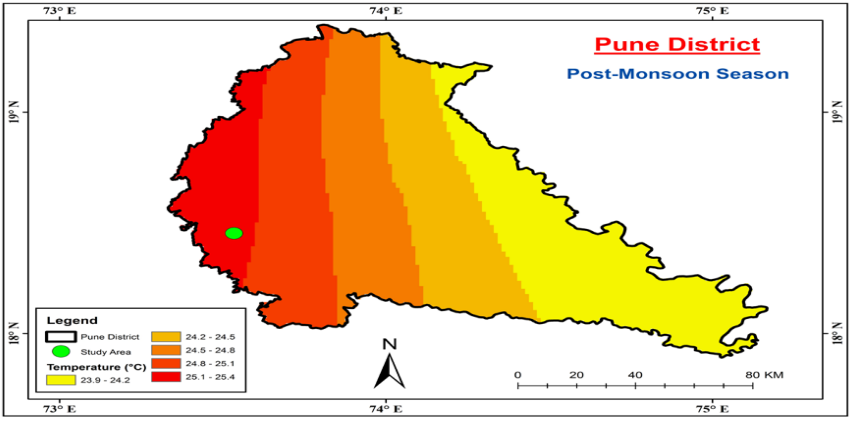
Annual RainfallFigure shows the annual rainfall pattern of rainfall. The pattern resembles to that of summer monsoon season as this season contributes nearly 75 % of rainfall to the annual rainfall total (Map.4).

Map. 5. Spatial variations in the seasonal mean temperatures




Pune District
Summer Season
73° E
74° E
75° E
19° N
18° N
Legend
Pune District
Study Area
Temperature (°C)
27.9 - 28.2
28.2 - 28.5
28.5 - 28.8
28.8 - 29.1
29.1 - 29.4
N
0 20 40 80 KM


Pune District
Monsoon Season
73° E
74° E
75° E
19° N
18° N
Legend
Pune District
Study Area
Temperature (°C)
25.3 - 25.6
25.6 - 25.9
25.9 - 26.2
26.2 - 26.5
26.5 - 26.8
N
0 20 40 80 KM


Pune District
Post-Monsoon Season
73° E
74° E
75° E
19° N
18° N
Legend
Pune District
Study Area
Temperature (°C)
23.9 - 24.2
24.2 - 24.5
24.5 - 24.8
24.8 - 25.1
25.1 - 25.4
N
0 20 40 80 KM

Winter mean temperatures, Figure Temperature variation during winter is hardly 1˚**C** and increases from north to south. Northern part is much cooler than that of southern part. This is due to the cold winds prevailing from the Himalayan region to southward.

Summer mean temperatures, Figure indicates that temperature gradient is seen in east west direction. Eastern part is hotter than that of the western part. This is due to the effect of Western Ghats. Temperature ranges from 27.9˚C in southwestern part to more than 29.4˚C over eastern part of the district

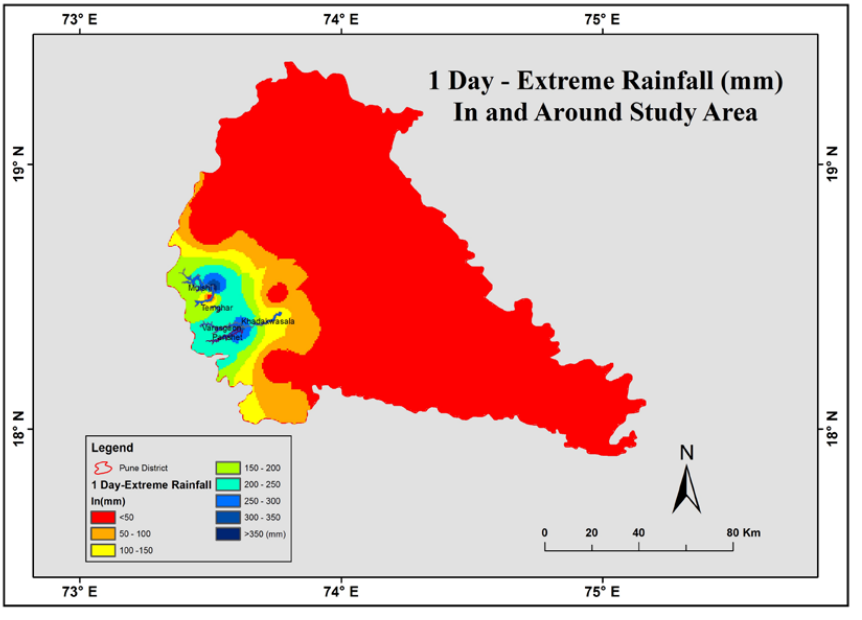
Monsoon mean temperaturesFigure depicts the spatial pattern of seasonal mean temperatures during monsoon season. It ranges from 25 to 27(˚C). Low temperatures are observed in the south-central parts and they increases in northern and eastern side of the district.Post- monsoon mean temperaturesFigure indicates that temperature gradient is in the east-west direction. Minimum temperatures are seen in the eastern parts and it increases steadily towards west. Temperatures of 25˚C are seen in the reservoir located area (Map. 5).

Extreme Rainfall in Pune District: (1- day duration)

Daily rainfall data of 25 stations in and around the study area for the period of 1901-2005 have been analyzed. For each station extreme rainfall series have been constructed by picking up highest rainfall value from 365 days. Fig. 4.1 display the extreme rainfall values for 1-day duration that are highest ever recorded by that

location during the period of Study. The study area receives the extreme rainfall in monsoon period. Highest rainfall values increases from east to West side. It is seen that Western part of study area receives high amounts of rainfall compared to eastern part of the study area owing to the orographic effect of the Western Ghats.

Indicates that eastern part of Pune district or rain shadow region never received rainfall more than 5cm/day, while it is very common in the area where reservoirs are situated. Maximum rainfall of 35cm has been received on 26th July 2006 when Santacruz station in Mumbai received 94.9 cm rainfall.



Map. 6. One day extreme rainfall in and around Pune City.

Synoptic systems associated with extreme rainfall of 26th July 2005 is given here; Monsoon trough south of its normal position. Low pressure area located over Orissa coast. Cyclonic circulations extending up to mid tropospheric levels over Gujarat, Madhya Pradesh (Map.6).

Temporal Changes in 1-3 day extreme rainfall in Pune District:

Daily rainfall series for Pune district have been constructed first by spatial averaging the daily rainfall at grids lying inside the basin. Then yearly extreme rainfall is picked up to construct 1-3 day extreme rainfall series. Fig. 1 Shows the time series plots of these 1-3day extreme rainfall series.

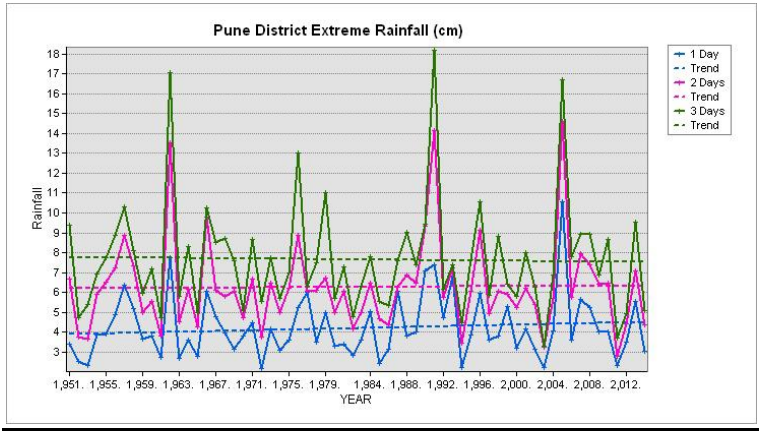


Fig. 1.Time series plot of extreme rainfall events of Pune District.

In years 1961, 1991 and 2005, Pune district received maximum amount of rainfall in 1-3 day duration. Though 1day extreme rainfall amounts are increasing over the period of last 60 years, the rise is not

statistically significant. No substantial change has been noticed in case of 2-3 day duration extreme rainfall (Fig. 1).

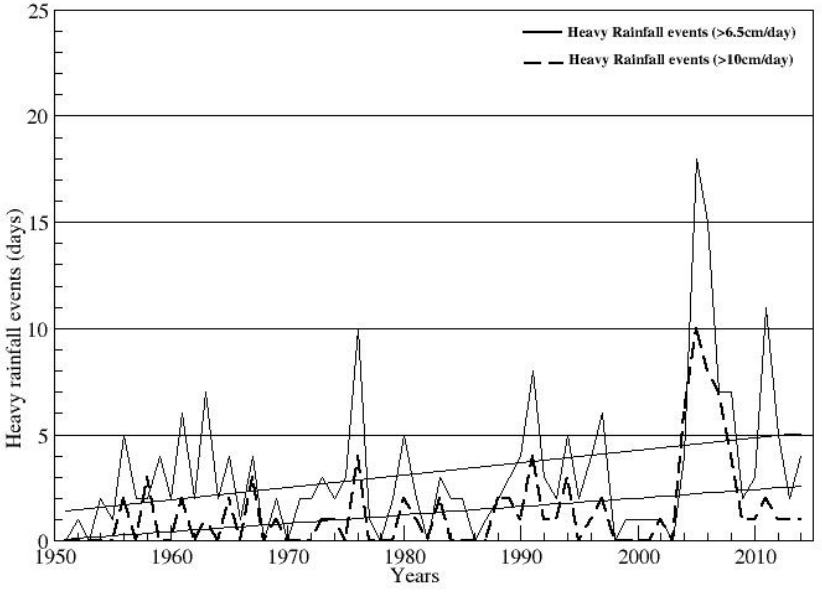
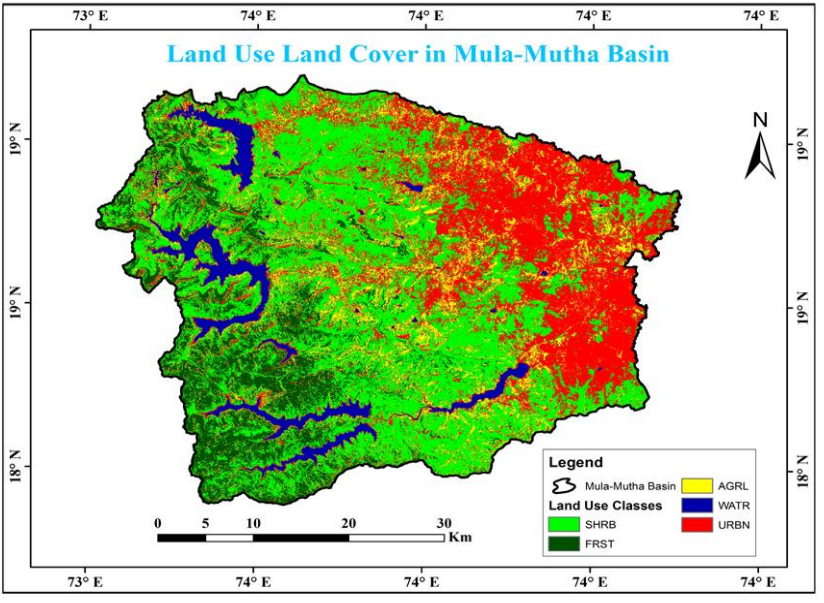


Fig. 2.Time series plot of heavy rainfall events of Pune District

Fig.2 shows the temporal variations in the extreme rainfall events defined as rainfall day with rainfall exceeding 6.5cm and 10cm. Trend lines have been fitted for these 2 time series. It is seen that both extreme events are increasing significantly at 5 % level. Figure also indicates that during years 2005 and 2011, Pune district received exceptionally heavy rainfall events. Rise in the series can be attributed to these 2 years.



Map. 7. Landuse and Landcover map of Mula-Mutha basin.

Land use / Land cover data has been prepared from the satellite image as LISS III. Fig shows the The SWAT land use land cover was appropriately selected from the in-built SWAT database in the map and reclassified (Map.7).

The land use Land cover classification indicates the dominance of semi-natural vegetation in the catchment, with forest covering the higher elevations in the west, and shrubland and agriculture dominating the lower elevations. shrubland is higher accounts in the catchment which is 40.38% (open land,grass land,barren) Agricultural land mainly located in proximity to rivers and dams accounts for only 12%(rice,sugarcane and mix cropland) of the catchment, The eastern part of the catchment is dominated by

the city of Pune and its surrounding settlements accounts 26.40% (high density urban area). Water body accounts only 4.90% which is very low found in Reservoirs,river etc.

SUMMARYAND CONCLUSIONS:

Mula-Mutha basins are the sub basins of the Bhima river basin. Bhima River is a tributary of the Krishna river of the peninsular India. Mutha river basin has a large Water scarcity problem in recent years due to increasing population, Industrialization and also due to increasing Water demand from different sectors such as irrigation, power generation, industry and domestic purpose. To cope up with this demand water supply should be appropriate and optimum. For better management of existing sources it is necessary to have knowledge about the rainfall processes and their temporal changes at a place. It is also necessary to know about the reservoir information providing the water to the city.

Seasonal rainfall of the Pune District as a whole is 50cm while annual rainfall is 60cm. Post monsoon season contributes nearly 12% to the annual. July-August are the chief rainy months contributing 60% to the annual rainfall. While reservoir area receives more than 200cm of rainfall annually, except for Khadakwasla dam site. Lonavala station receives maximum rainfall of 400cm in a year which is located in western ghat region, while eastern part of the Pune district receives very less amount of rainfall of 30cm. Southwest monsoon and Annual rainfall shows increasing trend

while Pre and post monsoon season shows decreasing tendency. These changes are statistically insignificant at 5 % level of Significance. Seasonal temperatures are increasing significantly over the Pune District, Which in turn affects the water cycle by increasing the Evaporation rate.

Pune District maximum rainfall of 35cm has been received on 26th July 2006 when Santacruz station in Mumbai received 94.9 cm rainfall. Years 1961, 1991 and 2005 corresponds to extreme rainfall events. Increasing tendency has been observed for 1-3 day extreme rainfall over Pune district, though statistically insignificant. Both extreme events are increasing significantly at 5 % level. During 2005 and 2011, Pune district received exceptionally heavy rainfall events. Numbers of extreme events are increasing. Rise in the events can be attributed to these heavy rainfall events of the recent years. Pune District and specifically Area on the western part, where reservoirs are located, receives good amount of rainfall when off shored trough is active and/or monsoon trough is in its normal or southern position. Heavy rainfall days are increasing significantly in this area. This will result in flooding to the downstream areas if not stored properly.

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