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# Trends in Rainfall Pattern over Vidarbha Region of Maharashtra State, India

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Abstract—Atmospheric temperature is increasing day by day due to global warming and climate changes which are attributed towards the variability in rainfall. Worldwide, the knowledge about this change in climate system is important to resolve the critical issues of environment. Also, rainfall, being the predominant form causing stream flow, especially the flood flow in the majority of rivers in India, it is very much necessary to know about its pattern. The magnitude of rainfall varies with time. Differences in the magnitude of rainfall in various parts of a country at a given time and place in various seasons of the year are variable and need to be explored in the details. This variation is responsible for many hydrological problems, such as flood and droughts. In India, the study of rainfall during monsoon season (June to September) is very crucial for the economic development, disaster management, hydrological planning etc. The knowledge of mean rainfall and its variability on smaller spatial scale are important. The changing pattern of rainfall can be investigated by computing seasonality index of rainfall. In the present work, total annual rainfall data for the period 1901–2002 of Vidarbha region Maharashtra comprising four districts namely Akola, Wardha, Washim and Yavatmal is considered. This data is then analyzed for mean, standard deviation and skewness of coefficient to understand the rainfall variability of the region. By using this analysis, the seasonality index which is the measure of distribution of rainfall throughout the seasonal cycle is defined and used to classify the different rainfall in the region. Also the long term changes of the seasonality index are identified by the trend analysis to find the changing pattern of rainfall over the district scale. Present study will definitely provide a guideline for the researchers for sustainable development of water resources over all Maharashtra Regions.

**Keywords**- Rainfall, Seasonality index; Frequency analysis; Skewness coefficient.

## I. INTRODUCTION

There has There has been an increasing operational demand for daily/monthly rainfall analysis for a wide range of applications extending from the real time monitoring and prediction of flood events, climate analysis [1], climate diagnostic study [2], and global energy and water budget studies etc. Despite the increasing demands for high quality rainfall datasets, accurate quantitative documentation of regional rainfall analysis remains as one of the challenging tasks. This is primarily because of the large spatial and temporal variability of rainfall and manual error in rain-gauge station. Rainfall is the source of water that replenishes soil moisture, stream flows, lakes, glaciers, etc. India receives about 80% of its total rainfall during the monsoon season from June to September [3]. The variations and trends in rainfall have significant impacts on Indian agriculture as it is largely dependent on monsoon's rainfall. To provide the information to one and all concerned with water resources, it is necessary to make available a proper trend of rainfall which will provide spatial and temporal variability of rainfall. Such analysis is also required for social and economic planning to assess its impacts on global warming.

The Maharashtra state which is to the northwest of peninsular India is highly influenced by the southwest monsoon and the state is facing water scarcity almost every year. The past performances of the monsoon rainfall give an indication of scarcity of rainfall in the future scenario too. To check the past performances of rainfall, one should understand the climatology in a better way. The Vidarbha region is to the extreme east of the Maharashtra state and faces the problem of water scarcity every year. The annual rainfall of this region is less than that of Konkan but more than that of Marathwada. Due to the increased number of disaster events like flood water scarcity and its high impact on the economic and human life, it is necessary for the district administration to have district rainfall climatology and information about temporal variability of rainfall at the district levels for better disaster management and water resource management and planning. Also the distribution of rainfall throughout the seasonal cycle is as important as the total amount of monthly/annual rainfall, while evaluating its impact on hydrology, ecology, agriculture or in water use. As rainfall plays an important role in recharging the groundwater, it is very important to identify the historical changes in the mean annual rainfall. The time and duration of these seasons of high rainfall at a place or watershed is most important for the planning and design of agriculture or water management. But even in the absence of changes in annual total rainfall, changes in the seasonal receipt of rainfall greatly affect partitioning of water into runoff, evapotranspiration and infiltration and thus flood forecasting, stream discharge and ecosystem responses. The changing pattern of rainfall can be investigated by computing seasonality index of rainfall. The long term changes of rainfall is identify by the seasonality index and then it identified by the trend analysis.[4]A detailed knowledge of the rainfall regime at a place is an important prerequisite for agricultural planning and management.[5]Daily and monthly rainfall datasets are useful for studying intra-seasonal and inter-annual variations in the Indian summer monsoon [6] Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP)are the two important data sets, which have been utilized in a wide range of applications, including weather and climate monitoring, climate analysis, numerical model verifications and hydrological studies.[7] Generally, three kinds of data sources: gauge observations, estimates based on satellite observations and numerical model predictions are combined to produce rainfall analysis. But it is not sufficient to simply assemble the different rainfall estimates [8]. Taking the inspiration from this earlier work, in the present work , changing pattern of rainfall and its variability analysis is presented which will definitely be useful for hydrologic modeling, agricultural sector and for planning and management of water resources. Along with the rainfall pattern, seasonality index for total annual rainfall series of four districts of Vidarbha Maharashtra namely Akola, Wardha, Washim and Yavatmal for the period 1901–2002 is presented which will help for sustainable development of water resources of Maharashtra region.

## II. STUDY AREA

Vidarbha region is one of the most challenging areas related to water resources management. As the region receives less than 75 percent [9] of expected rainfall, this region suffers from a drought after every six years, which leads towards serious water woes that ripple into uncertainties around agricultural productivity and drinking water. Figure No.1 shows the location of Vidarbha in Maharashtra, India. Total annual rainfall data of four districts of Vidarbha state in Maharashtra for the period 1901–2002 were collected from the Advance Centre for Water Resources Development and Management (ACWADAM) and India Water Portal

(IWP) (www.waterportal.org). This Annual rainfall data is analyzed by arithmetic mean method. Table1 shows the geographical Coordinates for four districts.

***Table 1.Geographic coordinates for four districts***

| Station | Year |
|---|---|
| Akola | 20°42'10.59"N, 76°59'57.97" E |
| Wardha | 20° 44' 39.15" N,77° 36' 09.58"E |
| Washim | 20°05'58.90"N, 77° 08'11.82" E |
| Yavatmal | 20°23'50.51"N 78° 07' 42.42"E |


***Figure 1.Map of Vidarbha***

## III. METHODOLOGY

Vidarbha region represents a mixed suite of rocks provide hydro-geological variety to the State of Maharashtra. Over-extraction of groundwater, miss-use and illegal water mining, uncertainties in rainfall, adds to the woes of Vidarbha. In last five years, water level has declined by 3m [10]. Due to lack of appropriate soil and water conservation measures as well as inefficient rain water harvesting structures, ground water level is decreasing day by day. Hydro-geological factors in the region, therefore changes in lateral and vertical aspects of porosity and permeability of various rocks formations. So considering above factors, there is a need to study rainfall variability. The annual rainfall data for this study was made available from (ACWADAM) and India Water Portal. Statistical parameters are calculated by using this data. The aim from this work is to know about the rainfall pattern, frequency analysis and seasonality index from the available data. Frequency analysis: In civil engineering application concerned with probability of occurrence of a particular extreme rainfall. Such information is obtained by the frequency analysis of the point-rainfall data. The Weibul's formula is used to calculate return period ($T_r$). Return period ($T_r$) is computed as follows. $T_r$ = n+1/m Where m is order of the observation and n is the size of sample. For more details readers are directed to P.J. Reddy, A Textbook of Hydrology. Seasonality index (SI): Seasonality index helps in identifying the rainfall regimes based on the monthly distribution of rainfall. It gives a detailed analysis of monthly/yearly precipitation across an area. Though the index only provides a relatively crude arithmetic description of precipitation seasonality, its ease of computation makes it an ideal tool for the study of spatial and temporal variation in seasonality, provided that complementary information on precipitation amount is also considered. Seasonality index (SI) is computed as follows. Where $X_n$ is the mean rainfall of month n and R is the mean annual rainfall.

 

## IV. RESULTS AND DISCUSSION

### 4.1. Statistical analysis

In Statistical analysis mean, standard deviation and Skewness coefficient are often provides behavior of random variable. Standard deviation is widely used in hydrological study to measure absolute dispersion for variability of distribution of data. Small standard deviation means high degree of uniformity of the observation and data series is homogeneous. If Skewness coefficient is positive or negative that mean data is asymmetrical but if Skewness coefficient is very small or negligible that means data is symmetrical. In this analysis Skewness coefficient is positive. Moving average is the graphical representation of rainfall data. The moving average curve smoothens out the extreme variation and indicate the trend or cyclic pattern if any more clearly. Hence Mean, standard deviation, skewness coefficient, Moving average, frequency analysis are presented in Table 2.

*Table2. Statistical analysis*

| **Descriptor (duration :102 years)** | **District** | | | |
|---|---|---|---|---|
| | **Akola** | **Wardha** | **Washim** | **Yavatmal** |
| Minimum rainfall | 415.5 | 522.42 | 430.16 | 495.5 |
| Mean, mm | 831 | 1044.85 | 860.32 | 991 |
| Standard Deviation | 172.45 | 200.85 | 188.92 | 216 |
| Skewness Coefficient | 0.353432 | 0.37836 | 0.285005 | 0.227282 |
| Trend for 10 years moving average, mm | Fairly constant | Slightly dipping during the last 50 years | Fairly constant | Fairly Constant |
| Changes in inter-annual variability (i.e. Rainfall Pattern) | Reduced in the last 40 years | Significant throughout | Reduced in the last 60 years | Fairly Constant |
| Frequency Analysis (75% and 50% dependable rainfall, mm) | 670 | 897.8 | 759.9 | 849.7 |
| | 772.4 | 1040.2 | 864.1 | 1006.5 |

From the table 2, the highest mean annual rainfall occurs in Wardha district while the least occurs in Akola district. Present analysis for Akola is homogeneous whereas for Wardha, Washim and Yavatmal it is dispersed. Akola and Yavatmal have similar long-term mean, but whole Akola shows reduced inter-annual variability whereas Yavatmal shows fairly constant variability for 102 years. Standard deviation is maximum in Wardha and minimum in Yavatmal. It is evident from these results that there are 3 years only where the rainfall was less than 50% of the mean average rainfall in Akola, where as there are only 2 years in which the rainfall values are less than the 50% of the mean average value of Wardha. Similarly there is only 1 year in which rainfall value is below mean average value for Washim and Yavatmal districts. Further it is observed that skewness coefficient is positive which indicates asymmetry of rainfall data. These results lead towards uncertainty of rainfall which makes the present effort very necessary in today's era to know more about the future conditions of rainfall which can be studied from the seasonality index and frequency analysis. And this suffices the aim of this paper to present the rainfall trend / pattern in the Vidarbha region.

### 4.2. Trends in Rainfall pattern

Changes in smaller scales are required to be identified for climate change studies. Figure 2 shows the trends in the rainfall over the four districts for 102 years (1901-2002). Wardha districts show significant rainfall throughout, Yavatmal district show fairly constant rainfall whereas Washim district show reduced rainfall in the last 60 years. There is no significant trend in the rainfall in any districts of Vidarbha for the months of November and December. No district has reported increasing trend in rainfall for February, March, April and May months. June to September indicates a major increasing in the rainfall pattern. Figure 2 shows the rainfall pattern for 102 years (1901-2002) of the four districts. 10 years moving average for the different district is mentioned in the Table 2. It is observed that rainfall data for four districts do not indicate consistent trend for the last 102 year period from 1901 to 2002.

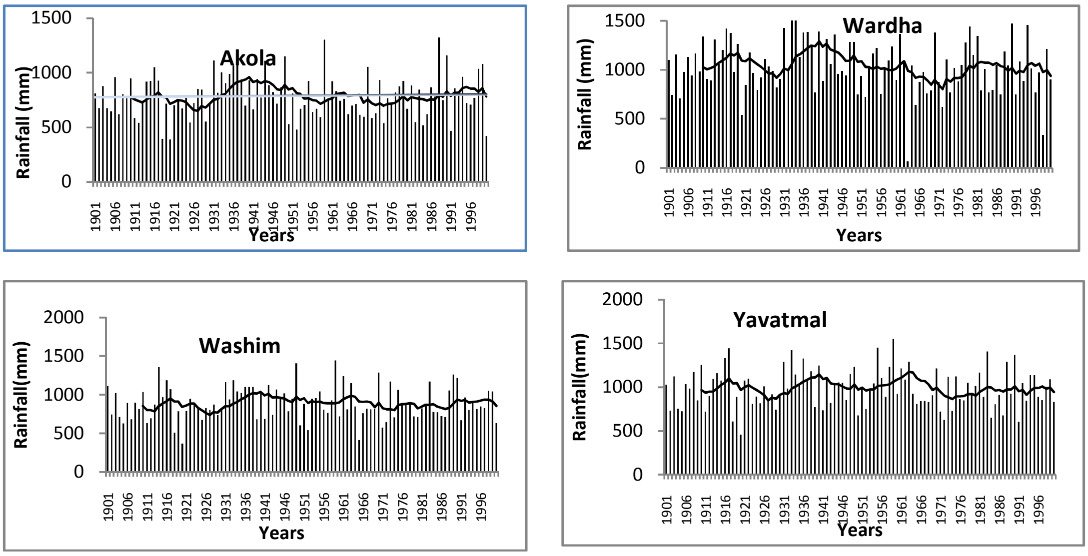


*Figure 2.102 year rainfall plots for four districts*

## 4.3. Frequency analysis

The result of the frequency analysis depends upon the length of available data. The estimation of parameters is the selection of the distribution becomes unreliable when the observed data happens to be very small. Hence the long duration data for 102 years (1901 -2000) is used to obtain the frequency analysis. Generally a minimum of 30 year of data is considered as essential. However, frequency analysis should not be adopted if the length of records is less than 10 year [11]. This graph between exceedence (Ex) probability (Return Period) in year as the abscissa and corresponding rainfall as a ordinate. Figure 3 shows the probability plots for four districts. From the figure 3, it is seen that 75% and 50 % dependable rainfall for wardha district are highest and least for Akola. These results obtained from extrapolation. These results are approximate because extrapolation is usually influenced by a few end points. It is evident from the above results that for Akola district, 670 mm rainfall is expected in the next 75 years as against 831 mm where as that of for Wardha district, 897.8 mm rainfall is expected in the next 75 years as against 1044mm, for Washim, 759.9 mm rainfall is expected in the next 75 years as against 860mm and for Yavatmal, 849.7mm rainfall is expected in the next 75 years as against 991 mm. These important values one can relate to the variability of rainfall and its occurrence in different years. This is helpful to take decision about construction of hydraulic structures for water conservation. So that to use the available Ground water resources more efficiently. This tends to prove helpful for the planning and management of water resources. All four districts shows increasing trend in August months rainfall. Seasonality Index is in between 0.8 to 0.99 which indicates markedly seasonal rainfall with a long drier season. From the results it is palpable that these four districts are under long drier season. Therefore more efforts to be planned to conserve the water resources in the said region or it can be said that the region is very prone to ground water development schemes. In other words it can be said that the watershed development is must in the Vidarbha region for next upcoming years.

 

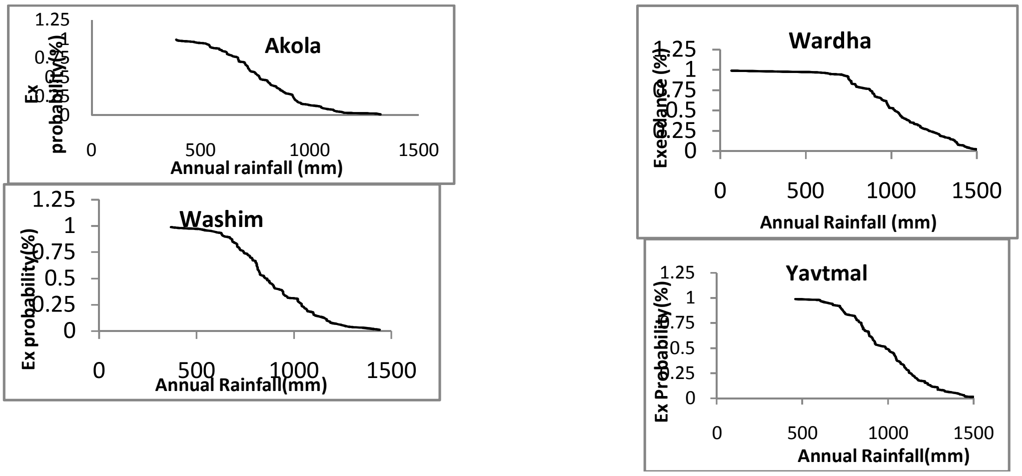


*Figure 3.Exceedence (Ex) Probability Vs rainfall*

### 4.4. Seasonality index

Seasonality Index checks the changes in rainfall pattern. The computation of seasonality index for all the four districts is found for the periods 1901–2002. Seasonality index helps in identifying the rainfall regimes based on the monthly distribution of rainfall. Theoretically, the SI can vary from zero (if all the months have equal rainfall) to 1.83 (if all the rainfall occurs in one month).Table 3 shows the different class limits of SI and representative rainfall regimes [1].

*Table3. Seasonality Index (SI) classes and associated different rainfall regimes*

| Rainfall regime | Seasonality index (SI) |
|---|---|
| Very equable | ≤0.19 |
| Equable but with a definite wetter season | 0.20–0.39 |
| Rather seasonal with a short drier season | 0.40-0.59 |
| Seasonal | 0.60-0.70 |
| Markedly seasonal with a long drier season | 0.80-0.99 |
| Most rain in 3 months or less | 1.00-1.19 |
| Extreme, almost all rain in 1–2 months | ≥1.20 |

For finding the seasonality index, three seasons were considered, namely Pre Monsoon (Feb-May), Monsoon (June-Sep) and Post Monsoon (Oct-Jan). The seasonality index has been computed for all four the districts and shown in Figure 4. The lower seasonality index value indicates better distribution of monthly rainfall among the months of the year. The seasonality index for Akola is more as compare to others three districts. Wardha, Washim and Yavatmal shows all most same seasonality index. Seasonality for all four districts is determined. Markedly long drier season has the values between 0.8 to 0.99 for all four districts. Low value of seasonality index indicates regime with shorter dry season and high value indicates most of the rain occurs within few months (2–3 months). An increasing trend in seasonality index is thus an indicator of alarming situation for the agriculture.

 

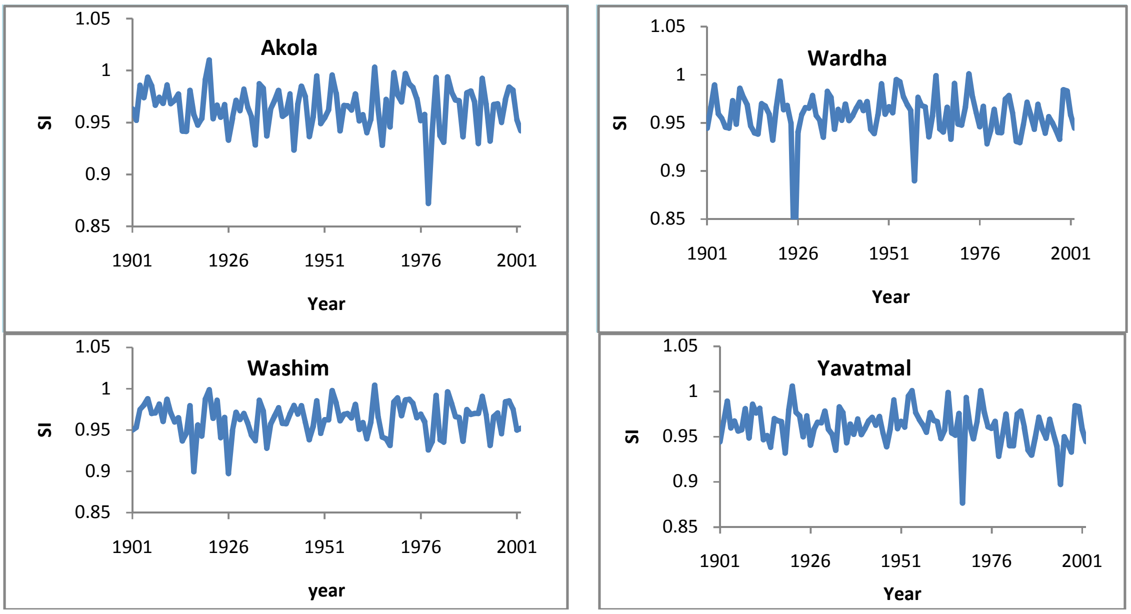


*Figure 4.Seasonality Index, SI for four districts*

### 4.5. Changes in Seasonality index

In order to find out whether these change are significant or not, we have further carried out the trends in seasonality index series ($SI_k$). Seasonality index ($SI_k$) time series for each of the districts for each year k has been calculated using the formula [5].

$$\overline{SI_k} = \frac{1}{R_k}\sum_{n=1}^{12}\left|X_{nk} - \frac{R_k}{12}\right| \qquad (2)$$

Where$X_{nk}$the rainfall of month of the year k and Rk is is the total annual rainfall for the year k. The mean of seasonality index of a specific period calculated from the equation 2, may differ slightly with the seasonality index calculated from equation 1.Table 4 summarizes the values of the seasonality index (SI) for 102 years and obtained by equation 1 and $SI_k$ obtained by equation 2. $SI_k$ has increasing trend for the districts of Wardha, Washim, and Yavatmal.

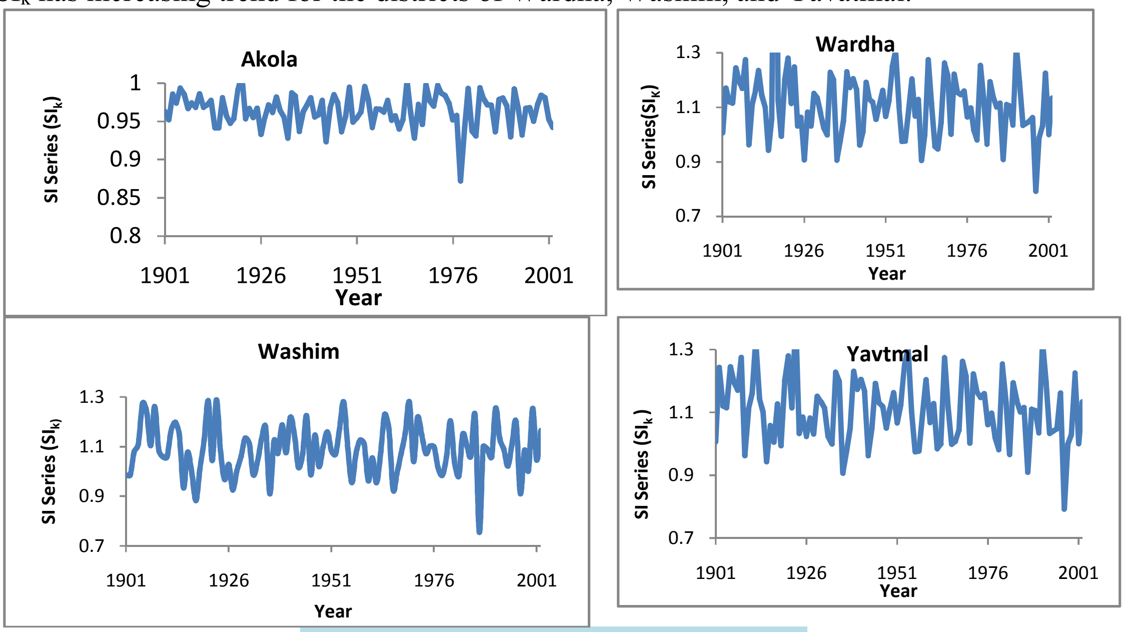


*Figure 5.Seasonality Index, $SI_k$ For four districts*

## VI. CONCLUSION

| Sr. No | Districts | Seasonality Index, SI (Eqn 1) | Seasonality Index, $SI_k$(Eqn 2) |
|---|---|---|---|
| 1 | Akola | 0.872136 | 0.086943 |
| 2 | Wardha | 0.944193 | 1.006406 |
| 3 | Washim | 0.94999 | 0.986515 |
| 4 | Yavatmal | 0.944193 | 1.006751 |

The rainfall data for the 102 year period (1901 to 2002) is studied to understand the rainfall patterns for the four districts of Vidarbha region of Maharashtra state. The frequency analysis, rainfall variability analysis and seasonality index were determined with the help of calculations and plots. It can be said that rainfall pattern obtained from the seasonality index for Vidarbha region will be definitely helpful not only to nurture the watershed development activities in that region but also to provide the guidance around important aspects of soil and water conservation such as ground water recharge activities. It is clear from the seasonality index (0.85 to 1) and frequency analysis (75% exceedence probability: 650 to 850mm rainfall) that Akola, Wardha, Washim and Yavatmal are dry regions and within next 75 years the rainfall will continue with the same pattern as is explained in the result analysis. The analysis suggested here is quite useful not only for private agencies , decision makers in water resources areas but also for the Government bodies who are involved in making water policies, projects on conservation and irrigation. This type of study will prove its vital importance in all water scarcity areas and can be explored further as a backbone before design and implementation of any water supply scheme is taken up at the regional level.

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