Hydrology Term Paper

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Abstract.

Rajasthan state is considered as the most sensitive and vulnerable in India comparatively, when rainfall and drought are concerned. So, rainfall indices and Standardized Precipitation Index (SPI) were obtained by using 35 years data (1971-2005) for over 31 stations. From the analysis of rainfall indices, it is observed that few stations situated in east and south-eastern side in the state have shown high negative change for annual and monthly rainfall but not such negative change is observed in the case of average number of wet days for the same stations. Similarly from SPI drought analysis both short term and long term, higher tendency of mild droughts is observed than moderate and severe droughts with a noticeable increase in occurrence of severe droughts on longer time scales. The study describes importance of SPI and rainfall indices in understanding the climate change impacts and droughts to provide better assessment and management aspects for the society.

1 Introduction

One of the major challenges of agricultural systems is how to mitigate the impacts of droughts. Droughts impact agricultural systems economically as well as environmentally. With respect to economic impacts, droughts damage agricultural production,and can cause economic damage to industries connected to agricultural production, in addition to causing unemployment as a result of reduced production. From an environmental perspective, droughts can deprive crops and soils of essential precipitation as well as increase the salt content in soils and irrigation systems.

An objective evaluation of the drought condition in a particular area is the first step for planning water resources in order to prevent and mitigate the impacts of future occurrences of drought. It is characterized in terms of spatial extension, intensity and duration. Generally rainfall deficiencies over a long time period leads to severe droughts events . Mainly four types of droughts are mostly observed , meteorological (lack of precipitation), agricultural (lack of root zone soil moisture), hydrological (drying of surface water storage),socioeconomic drought (lack of water supply for socioeconomic purpose) and these drought types are generally interlinked with each other. There are several drought indices that are commonly used, such as the Palmer Index, the Crop Moisture Index and the Standardized Precipitation Index (SPI). It is recommend for agricultural and hydrological drought analysis by WMO (World Meteorological Department), because it is very simple, spatially consistent, probabilistic in nature and peculiar with the ability to represent droughts on both spatial and temporal scales, so it provides better results. Multi-time scale results such as 3, 6 ,12, 24 months from SPI represents impacts of drought on different water availabilities like for soil moisture, water reserves, steam water and ground water etc.

One of the differences between the Palmer Index and the SPI is that the characteristics of the Palmer Index vary from site to site while those of the SPI do not. Another difference is the Palmer Index has a complex structure with a very long memory, while the SPI is an easily interpreted, simple moving average process . This characteristic makes the SPI useful as the primary drought index because it is simple, spatially invariant in its interpretation and probabilistic, allowing it to be used in risk and decision making analysis. The SPI is also more representative of short-term precipitation than the Palmer Index and is thus a better indicator for soil moisture variation and soil wetness. This characteristic makes the SPI useful as the primary drought index because it is simple, spatially invariant in its interpretation and probabilistic, allowing it to be used in risk and decision making analysis.

The present study is based on analysis of rainfall and drought events , with respect to the climate change. Negative or positive changes in rainfall indices were observed along with spatio temporal analysis of droughts using short term (3-6 months) and long term (12-24 months) SPI methods to obtain GIS based critical area maps, for better understanding of climate change impacts.

2 Study Area

Rajasthan state is situated between 23° 30’ – 30° 11’ N and 69° 29’- 78° 17’ E at the northwestern region of India, covering a widespread area of 3,42,239 km^2 (10.4% of the country).

It has population of about 68 million and 75% of this population resides in rural areas and directly dependent upon rainfall availabilities for agriculture and other use.

3 Methodology

35 years (1971-2005) district-wise data is taken from Government of Rajasthan water resources website for daily rainfall [Link to the data]. The data was in pdf format and hence converted into excel sheet first for the following analysis.

3.1 Rainfall indices

3 different kinds of rainfall indices were calculated using the data for different perspectives

1. Change in average annual rainfall
2. Change in average number of wet days (with rainfall > 0 mm)
3. Month wise change in monsoonal rainfall

3.1.1 Data Preprocessing & Method

For the calculation of above indices, firstly the data was accumulated and converted into monthly and annual data. Then for the change to be found in average annual rainfall and number of wet-data, the data was divided into half i.e. two periods of 17 years (1971-88) and (1989-2005). Average annual rainfall value and average number of wet days (with rainfall > 0 mm) was caclulated for both the periods and then changes were analysed (for all the districts in Rajasthan).

3.2 Standardized Precipitation Index (SPI)

The standardized Precipitation Index (SPI) was developed by MCKEE et al. [1993]. The SPI index is based on precipitation alone making its evaluation relatively easy compared to other drought indices, namely the Palmer Index and the crop moisture index. A major advantage of the SPI index is that it makes it possible to describe drought on multiple time scales. The SPI was also determined to be the best drought index for representing the variability in Indian droughts, and hence used in this study.

The computation of the SPI requires fitting a probability distribution to aggregated monthly precipitation series (3, 6, 12, 24, 48 months). The probability density function is then transformed into a normal standardized index whose values classify the category of drought characterizing each place and time scale. The SPI can only be computed when sufficiently long (at least 30 years) and possibly continuous time-series of monthly precipitation data are available hence 35 years of data was selected for this study (1971-2005)

According to normal distribution, it can be calculated by taking the difference of the precipitation from the mean for particular time scale then dividing by the standard deviation,

$$SPI = \frac{X - X_m}{\sigma}$$

Where X is precipitation for the station, X_m is mean precipitation and σ is standardized deviation. The long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero. Drought event occurs when SPI is continuously negative and reaches an intensity of -1 or less and ends when the SPI becomes positive. Daily rainfall data for each station were converted into monthly data and changed into a standard three column format (year, month, precipitation) and then SPI for 3, 6, 12, 24 months were calculated.

Normal conditions are established from the aggregation of two classes: $-1 <$ SPI < 0 (mild drought) and $0 \leq$ SPI ≤ 1 (slightly wet). SPI values are positive or negative for greater or less than mean precipitation, respectively.

SPI drought classes		
Serial No.	Criteria for SPI values	Type of Drought
1.	0.00 to 0.99	Mild Drought
2.	-1.0 to -1.49	Moderate Drought
3.	-1.5 to -1.99	Severe Drought
4.	-2 and less	Extreme Drought
5.	More than 0	Above Normal Drought

4 Results & Discussion

4.1 Rainfall indices

Different rainfall indices were generated calculating the change occurred between the two periods of 17 years (1989- 05 and 1971- 1988).

All the stations have shown both kinds of change, negative or positive depicting the climate change impacts on rainfall indices. Higher negative change is mainly observed in few stations from eastern and southeastern parts of the state in the case of average annual and monthly monsoonal rainfall whereas no such negative change is observed in eastern side stations for average number of wet days though observed in few western stations.

Mainly east and south east part of the state is identified as more vulnerable to climate change from the above results. Higher negative change is observed despite the fact that these areas receive high rainfall than other parts of the state. Thus a rainfall index significantly describes about climate change impacts and very important tool to estimate the change and related consequences over any region.

4.2 SPI indices

SPI results are categorized as short term and long term analysis in order to provide comparative analysis and suggesting short and long term measures accordingly.

4.3 Short term (3 months) & Mid term (6 months)

Results from 3 months and 6 months SPI are categorized as short term analysis because it provides estimation of drought impacts on short time scale, mainly drought frequencies for mild, moderate and severe types of drought were obtained and stations with higher drought frequencies were highlighted with red color symbols in the maps. The 3 month SPI is useful for short and medium term moisture conditions for agriculture, and provides a seasonal precipitation estimation, which represents deviation in precipitation totals. For example, the 3-month SPI at the end of February compares the December–January February precipitation total in that particular year with the December January February precipitation totals of all the years. The same is true for 6 months totals and calculated in similar manner. It can be very effective in showing the precipitation over distinct seasons and information from a 6-month SPI may also begin to be associated with anomalous stream flows to be associated with anomalous stream flows and reservoir levels.

Short term analysis shows that there is a higher probability of mild droughts than moderate or severe droughts in majority of the districts situated in central part of the state, in both 3 and 6 months SPI. There is a noticeable change in frequency percentages, it decrease for mild droughts and increase for severe droughts along the increase in the time scale. By identifying the critical stations, a short term measures can be suggested for those areas to fulfill the agricultural requirements, attaining optimum soil moisture and reducing agricultural drought vulnerabilities. It is good to take proper measures early in response to mild drought which may turn into severe droughts on longer time scales.

4.4 Long Term (12 months)

Long term SPI describes the long time impacts of droughts on stream flow, reservoir storage and ground water level, thus ultimately it is related to hydrological droughts. Higher percentages of occurrence are observed for mild droughts than moderate or severe droughts covering most of the districts in the state. Whereas some stations situated in northwestern part of the state have shown higher frequencies for moderate and severe droughts. An increase in frequency percentages was be noticed in long term analysis. It is observed that there is a high probability of hydrological drought and depletion of ground water, stream flow in the critical areas. Thus; there is a prior need to adopt water conservation and management practices in those areas

5 Conclusion

The study provides a comprehensive knowledge of change in rainfall indices and spatio-temporal extents of droughts due to climate change in Rajasthan. High negative change in rainfall indices have obtained for the eastern and southeastern parts of the state despite of having higher long time averages than other parts in the state. Similarly SPI drought index depicts that droughts in the state varies spatially and temporally from mild to severe, for all districts. Study shows higher percentage of occurrence of mild drought in the state covering large area, whereas severe drought frequency increases on long time scale. Short term analysis shows the loss of soil moisture and agricultural droughts and it requires short term measures like good irrigation system, and crop rotation for the critical areas. Similarly in long term analysis shows the impacts of droughts on stream flow and other surface water resources so proper conservation and management system and recharge capacities should be develop.

6 References

The referenced research papers and (data + code) has been attached here - `https://drive.google.com/drive/folders/1y_N4CQTuo3DjnV50gExonhiffKrjr_qZ?usp=sharing`

1. Link to the data - `http://www.water.rajasthan.gov.in/content/water/en/waterresourcesdepartment/WaterManagement/IWRM/annualrainfall.html#`

2. Assessment of Meteorological Drought Using Spatial Information Technology - Giridhar V S S Mittapalli (Similar study for Telangana State taken as a reference).

3. Drought forecasting using new machine learning methods - Jan Franklin Adamowski Et Al (for the insight into SPI and caclulations)