Meteorological drought analysis using the Standardized Precipitation Index In RAJASTHAN

A Mini-Project Report

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GEOHAZARD SCIENCE AND ENGINEERING

Submitted by

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ABSTRACT

Climate variability, mainly the annual air temperature and precipitation, has received great attention worldwide. The magnitude of this climate variability changes with variations in location. Rajasthan comes under the arid and semi-arid zone of India in which monsoon is a principal element of water resource. Due to erratic and scanty rainfall in this zone, agriculture is dependent on the monsoon. The objective of the present study is to assess the meteorological drought characteristics using Drought Indices with the help of EXCEL and XLSTAT from the historical rainfall records of the Alwar, Bharatpur, Dausa, and Karuli districts of Rajasthan State by using standardized precipitation index (SPI). Trend analysis of annual rainfall was carried out for all 4 districts using the data period between 1982 and 2022 at the 5% level of significance. Sen's slope estimator was also applied to identify the trend.

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INTRODUCTION

A prolonged period of time, months or even years, during which there is a shortage of water in an area is characterized by drought. Water comes from a variety of sources, including subterranean aquifers and surface water bodies like rivers and lakes. Drought results from prolonged dry weather and insufficient precipitation, which is usually caused by precipitation levels that are consistently below average over a prolonged period of time. This prolonged period of dry weather reduces stream flow, depletes subsurface water reserves, and dries out the soil, making the scarcity of water worse. Drought has far-reaching effects that go beyond just reduced water availability; it also has a significant negative influence on the local ecosystem and agriculture. Even brief but severe drought spells have the potential to cause significant harm, leading to localized economic downturns and difficulties. Therefore proactive measures are imperative to mitigate the adverse effects and build resilience against future drought events.

CHAPTER – 2

2.1 LITERATURE REVIEW

Drought is frequently defined according to disciplinary perspective. Bandyopadhyay (1988) lists four types of droughts, namely (1) meteorological drought, (ii) surface water drought, (iii) groundwater drought, and (iv) soil-water drought.The National Commission on Agriculture in India defines three types of droughts, namely, meteorological, agricultural and hydrological droughts. Meteorological drought is defined as a situation when there is a significant decrease from normal precipitation over an area (i.e. more than 25 %). Agricultural drought occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity and causes crop stress and wilting. Hydrological drought may be a result of long-term meteorological droughts which result in the drying up of reservoirs, lakes, streams, and rivers, and a fall in groundwater level.

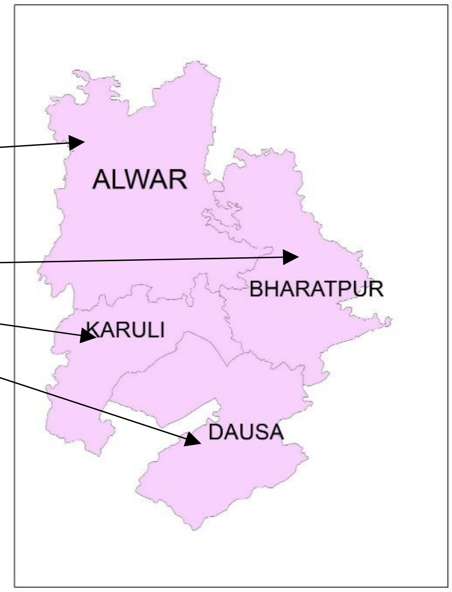
Sr.no	Authors	Findings	Remarks
1	Mehta, D., & Yadav, S. M. (2021). An analysis of rainfall variability and drought over Barmer District of Rajasthan, Northwest India. *Water Supply*, *21*(5), 2505-2517.	Trend analysis of seasonal and extreme annual monthly rainfall was carried out for the Barmer District of Rajasthan State using the data period between 1901 and 2002 at the 5% level of significance. Sen's slope estimator was also applied to identify the trend. Temporal analysis is useful to predict and identify the possible drought severity and its duration in the study region.	The study delves into rainfall variability and drought within Barmer District, employing rigorous analyses such as trend assessments, drought indices, and impact evaluations. By scrutinizing these factors, it aims to comprehend the region's susceptibility to drought and its repercussions on the local ecosystem and inhabitants.
2	Swain, S., Mishra, P. (2024). A simplistic approach for monitoring meteorological drought over arid regions: a case study of Rajasthan, India. *Applied Water Science*, *14*(2), 36.	Drought severity classifications (i.e., Drought-I, Drought-II, and Drought-III) are proposed based on the DPI values. The DPI is used to characterize and assess the meteorological drought years based on annual and monsoonal precipitation over nineteen districts in Western Rajasthan, India, during 1901–2019.	Droughts in arid regions are exacerbated by water scarcity exacerbated by climate change. In India, droughts profoundly affect agriculture, economy, and food security. To monitor and assess drought severity, indices such as the Palmer Drought Severity Index (PDSI) are employed, crucial for timely interventions and resource management amidst evolving climatic conditions.

2.2 STUDY AREA

Rajasthan is the largest State of India with an area of 342,000 km2.The perception of droughts and drought-prone areas in Rajasthan often diverges from the objective data at hand. A prevalent belief holds that the western arid part of Rajasthan, characterized by its high rainfall variability, suffers more severely from drought compared to other parts of the region, where the eastern and southern areas supposedly experience higher and more consistent rainfall. However, a thorough analysis of meteorological data paints a different picture.

When examining the standard deviations (SD) of annual rainfall across various regions, it becomes evident that the southern and eastern parts of Rajasthan exhibit higher SD values compared to the western region. Specifically, the average SD of annual rainfall in the southern region stands at 182 mm, while in the eastern region, it averages 207 mm. In contrast, the western region demonstrates a lower average SD of 118 mm. This data challenges the common belief that the western arid region is disproportionately affected by drought, suggesting instead that the eastern and southern regions experience greater variability and unpredictability in their rainfall patterns, potentially contributing to their vulnerability to drought conditions.

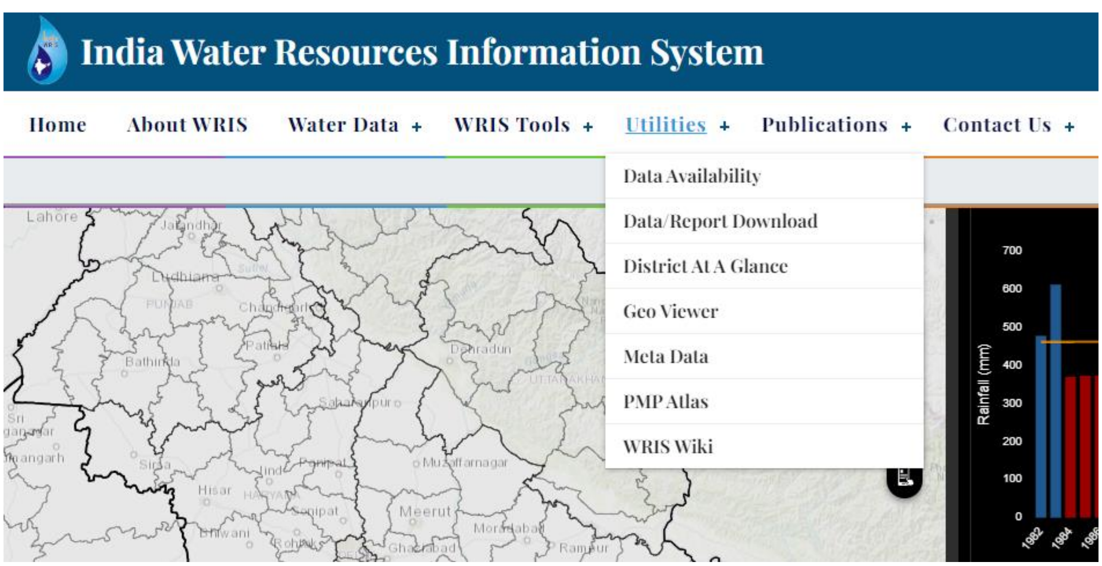
(fig -1)



(fig -2)

2.3 DATA ACQUISITION

Rainfall data from Bharatpur, Alwar, Dausa, and Karauli districts was collected annually over the past 40 years (1982-2022) from India wris.



https://indiawris.gov.in/wris/#/rainfall

(fig. -3)

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3.1 DROUGHT INDICES

Drought indices are quantitative measurements that combine information from one or more variables (indicators), such as evapotranspiration and precipitation, into a single numerical value to describe the extent of drought. Drought indices are a reflection of various events and circumstances; they can be used to show anomalies in the climate-related to dryness (primarily based on precipitation) or to indicate effects related to agriculture and hydrology that take time to manifest, like decreased reservoir levels or soil moisture loss.

Major operational drought indices are seven drought indices that are frequently used in forecasting, monitoring, and planning operations.

1. Percent of normal
2. Standardized Precipitation Index (SPI)
3. Palmer Drought Severity Index (PDSI)
4. Normalized Difference Vegetation Index (NDVI)
5. Vegetation condition index(VCI)
6. Standardized Precipitation Evapotranspiration Index (SPEI)

3.2 STANDARDIZED PRECIPITATION INDEX (SPI)

The Standardized Precipitation Index (SPI) offers several advantages in assessing drought conditions. Its ease of calculation and modest data requirements make it a practical tool for drought monitoring. Moreover, its independence from the magnitude of mean rainfall allows for comparability across diverse climatic zones. Despite these strengths, SPI relies on the assumption of normal distribution, posing challenges for shorter periods. However, its versatility in evaluating rainfall over various intervals—three, six, nine, and twelve months—renders it capable of capturing both short-term and long-term drought impacts. This makes it invaluable for discerning drought severity across different time frames and climatic regions, thereby aiding in informed decision-making and resource allocation for drought management strategies

SPI duration	Phenomena reflected	Application
1 month SPI	Short-term conditions	Short-term soil moisture and crop stress (especially during the growing season)
3 month SPI	Short- and medium-term moisture conditions	A seasonal estimation of precipitation
6 month SPI	Medium-term trends in precipitation	Potential for effectively showing the precipitation over distinct seasons. e.g., for California, the 6 month SPI can effectively indicate of the amount of precipitation from Oct. to Mar.
9 month SPI	Precipitation patterns over a medium time scale	If $SPI_9 < -1.5$ then it is a good indication that substantial impacts can occur in agriculture (and possibly other sectors)
12 month SPI	Long-term precipitation patterns	Possibly tied to streamflows, reservoir levels, and also groundwater levels

(fig 4)

CHAPTER – 4

4.1 METHODOLOGY

The index has the advantages of being easily calculated, having modest data requirements, and being independent of the magnitude of mean rainfall and hence comparable over a range of climatic zones. It does, however, assume the data are normally distributed The SPI is of course the same as the Standardized Rainfall Anomaly, defined by Jones and Hulme (1996) and widely used in the analysis of desiccation in drylands.

Standardized Precipitation Index (SPI), is calculated as

SPI = $\frac{X - X}{s}$

X = Precipitation for the station

X = Mean precipitation

s = Standardized deviation

$$s = \sqrt{\frac{\sum(X - \overline{X})^2}{n - 1}}$$

n= number of data

(C. T. Agnew,2000)

After calculating of SPI of each district from 40 years data the result is shown in the table

Dates		ACTUAL (mm)	mean	SD	SPI	desc
1982		549.05	576.098	147.7208228	-0.1831	Near normal
1983		768.44			1.302034	Moderately wet
1984		522.7			-0.361479167	Near normal
1985		555.31			-0.140724913	Near normal
1986		338.64			-1.607478184	Severely dry
1987		344.79			-1.565845597	Severely dry
1988		553.14			-0.155414786	Near normal

SPI CLASSIFICATION TABLE

2.0 or more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

Total Drought Events				
Districts	EXTREMELY DRY	SEVERELY DRY	MODERATELY DRY	TOTAL
BHARATPUR	0	2	5	7
ALWAR	0	5	2	7
KARULI	0	2	6	8
DAUSA	0	1	8	9

4.2 MANN KENDALL TEST

The analysis conducted on a 40-year time series of rainfall and temperature involved the Mann–Kendall (MK) test and Sen’s slope (SS) estimator. These methods assume a linear trend in the time series. The MK test determines trends by comparing sequential data points, with positive values suggesting an upward trend and negative values indicating a downward trend. A two-tailed test was performed at a 95% confidence level for both rainfall and temperature time series. Sen’s slope estimator measures the magnitude of a trend, with positive values indicating an increasing trend and negative values suggesting a decreasing trend.

Additionally, Kendall’s tau, a measure of correlation, was calculated to assess the strength of the relationship between variables. This statistic ranges from -1 to +1, with positive values indicating a positive correlation and negative values indicating a negative correlation.

Considering autocorrelation or serial correlation is essential in time series analysis, as it reflects the correlation of a variable with itself over successive time intervals. Autocorrelation increases the likelihood of detecting significant trends even in the absence of true trends. Therefore, it's crucial to account for autocorrelation before testing for trends.

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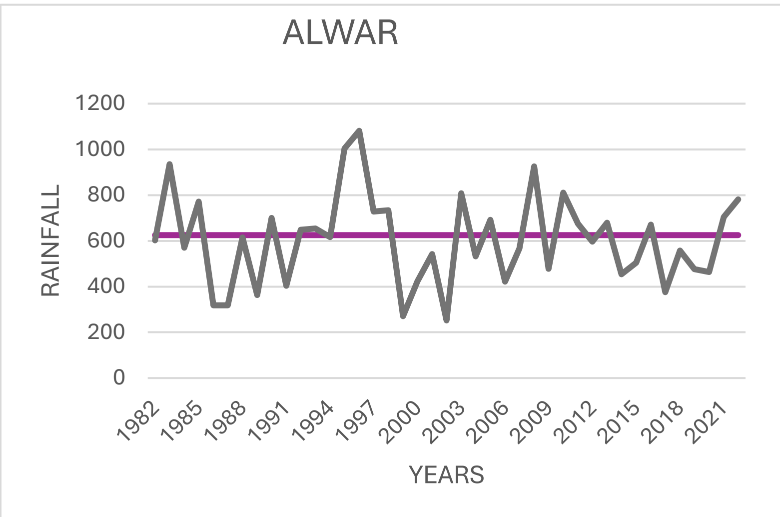
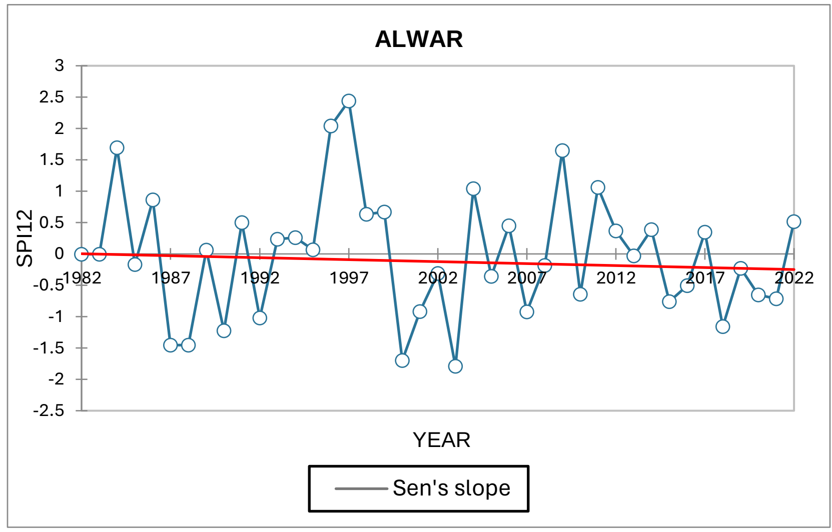
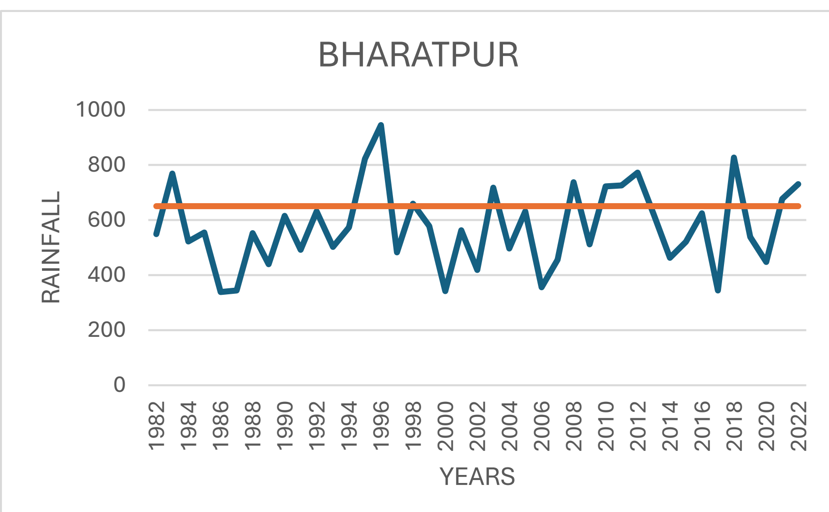
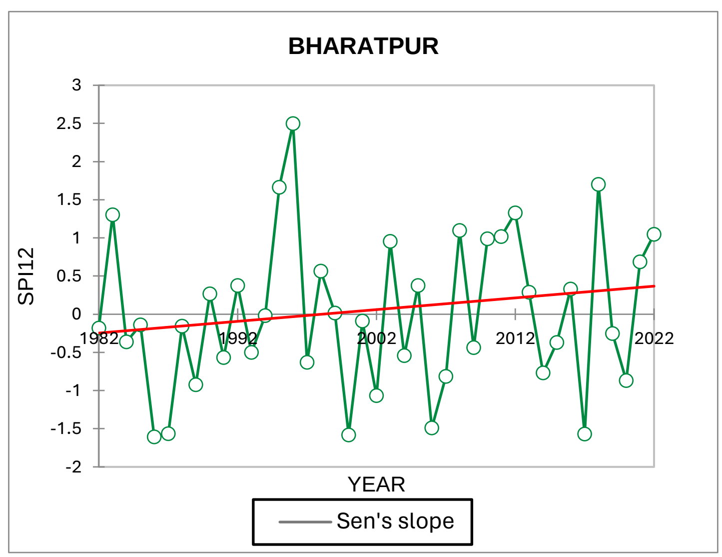
RESULTS AND DISCUSSION

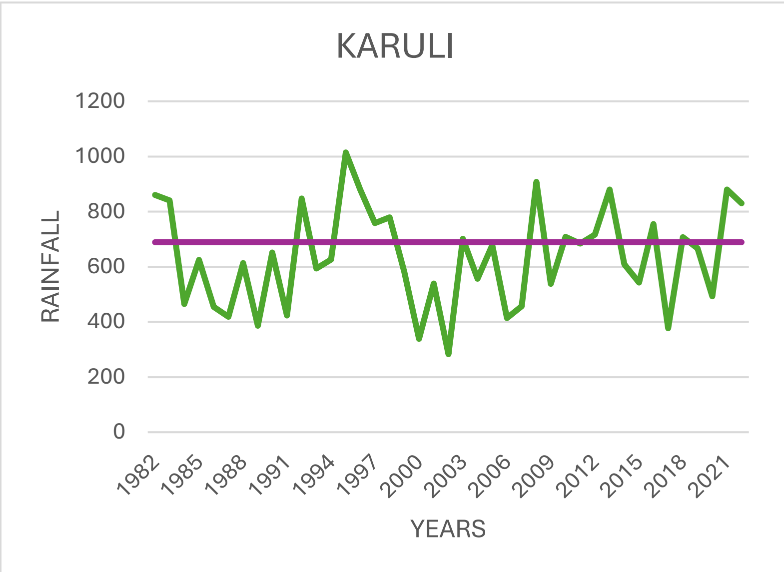


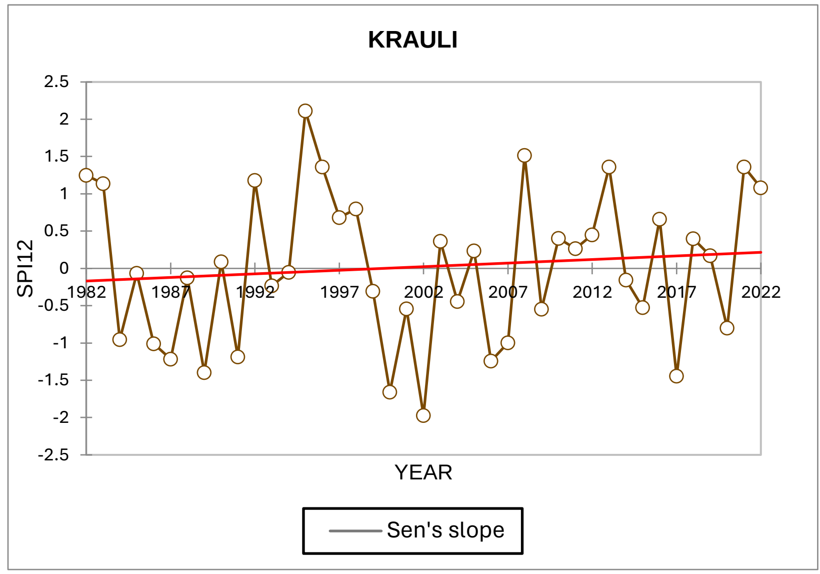


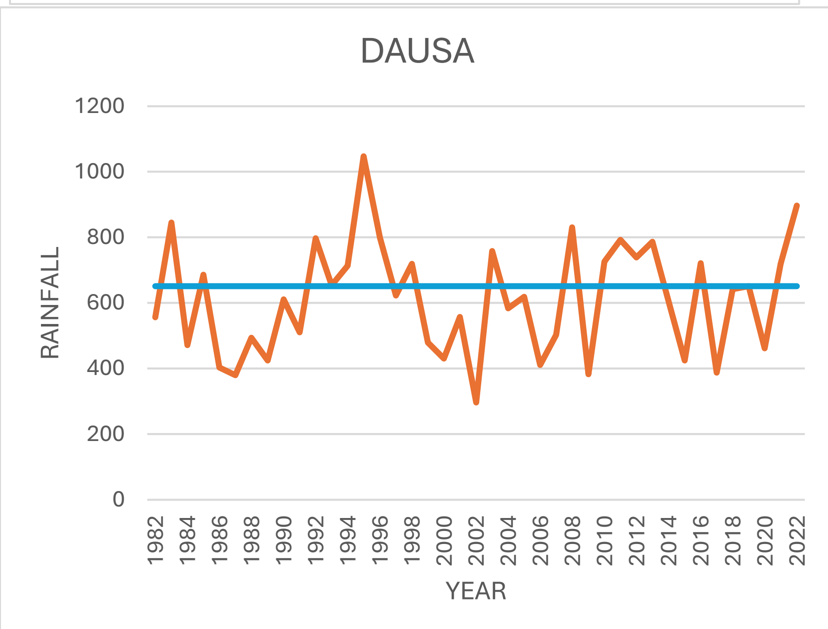


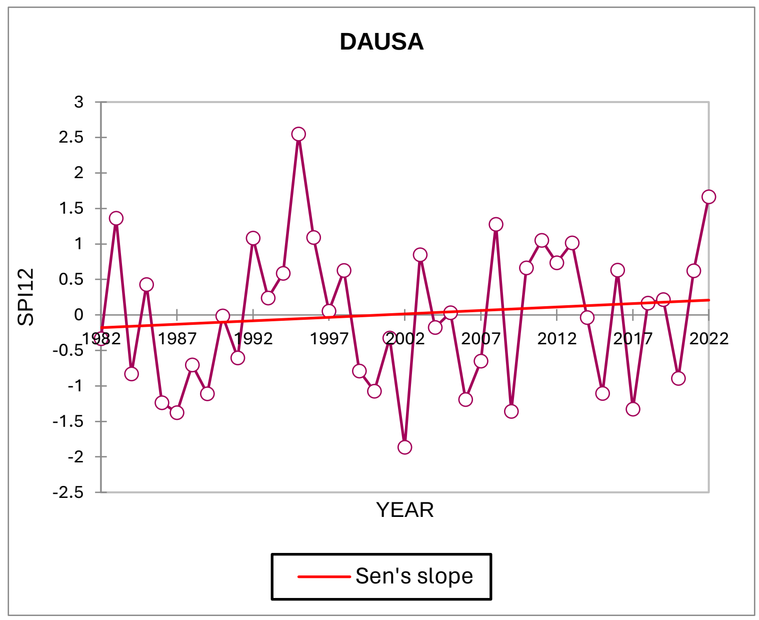


Series\Test	Kendall's tau	p-value	Sen's slope
ALWAR	-0.045	0.043	-0.006
BHARATPUR	0.124	0.031	0.015









Series\Test	Kendall's tau	p-value	Sen's slope
DAUSA	0.088	0.051	0.010
KRAULI	0.068	0.049	0.010

Based on data from the Standardized Precipitation Index (SPI), all four districts identified 2002 as a drought year. While Bharatpur, Dausa, and Karauli showed rising rainfall patterns, the Alwar district showed declining trends in rainfall. Precipitation variability turns out to be the main cause of drought events. Drought frequency is greatly impacted by factors like low precipitation levels, large variations in average rainfall, and the overall influence of climate change, particularly regional and global warming. These dynamics highlight the intricate interactions between climatic shifts and environmental factors, making adaptive strategies necessary to lessen the negative consequences of drought events in these areas.

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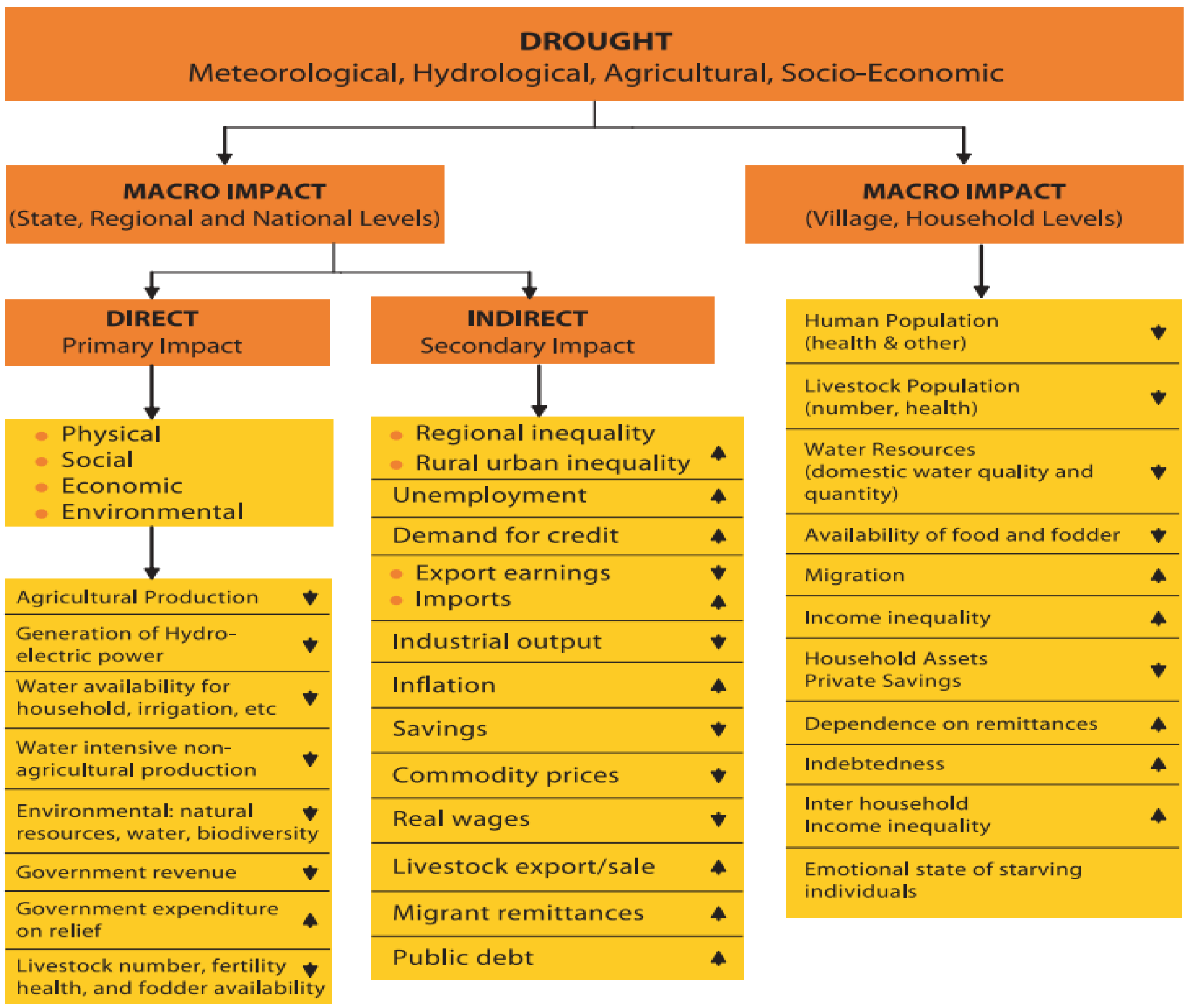
5.1 IMPACT



The down arrow shows that – These things are reducing for an area that has a great impact of drought.

The up arrow shows that – These things are increasing for an area that has a great impact on drought

5.2 MITIGATION

Mitigation for meteorological drought involves actions and strategies aimed at reducing the impacts of drought conditions caused by insufficient precipitation. Here are some simple bullet points explaining mitigation strategies for meteorological drought:

Early Warning Systems- Implement and maintain systems to monitor meteorological conditions and forecast drought events. Provide timely alerts to stakeholders and decision-makers to enable early response.

Water Conservation and Efficiency - Promote water-saving practices in agriculture, industry, and households. Invest in efficient irrigation techniques and technologies to optimize water use.

Drought-Resistant Crop Varieties- Develop and promote the use of drought-tolerant crop varieties and agricultural practices. Encourage crop diversification to reduce dependence on water-intensive crops.

Drought Contingency Planning-Develop and implement drought contingency plans at regional and national levels. Establish triggers and response actions based on anticipated drought severity.

Water Management and Infrastructure - Invest in water storage facilities (e.g., reservoirs, ponds) to capture and store excess water during wet periods. Upgrade water distribution systems to improve efficiency and reduce losses.

Public Awareness and Education - Educate communities about drought risks and the importance of water conservation. Promote public participation in water-saving initiatives and behavior changes.

Policy and Regulation - Enforce regulations on water use and allocation during drought periods. Develop policies to incentivize drought mitigation measures and sustainable water management practices.

Research and Innovation - Invest in research and innovation for developing new technologies and strategies to mitigate drought impacts. Support scientific studies on climate change and its effects on meteorological patterns.

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CONCLUSION

Drought monitoring and assessment for improved management strategies and policy development are lacking in numbers of underprivilege drought-prone and economically backward regions in India, and such studies are exaggerated the spatial, temporal, and trend behavior of meteorological drought events through the SPI values of the in Rajasthan.

Climate change influences the trend of long-term rainfall that contributes to severe hazards like drought and flooding Because of the unequal rainfall distribution and the mismatch between water demand and its availability, storage structures are essential for controlling the natural flow to meet the requirements for water.

Because of climate change, the supply of freshwater is likely to decrease in many river basins
Due to global warming, rainfall pattern changes, which affects the cycle of hydrology.

According to the data analysis, the rainfall pattern in Alwar district is changing because its SPI values and rainfall are decreasing, potentially leading the district into drought conditions.

In comparison, the other three districts—Bharatpur, Dausa, and Karauli are showing sufficient rainfall patterns, with values greater than normal normal, indicating that these areas may not experience drought conditions

CHAPTER – 8

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