Study of Metrological Drought for Different Agro-Climate Regions: A Geographical Study of Uttar Pradesh

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Abstract

The study's objectives were to evaluate the meteorological drought, examine the trend and magnitude of rainfall, and create a drought prediction model for Uttar Pradesh's several agroclimatic zones using the Random Forest technique. Significant differences were found between Uttar Pradesh's agroclimatic zones when the trend and magnitude of rainfall were analyzed. There were patterns of rising rainfall in certain areas and falling rainfall in others. These trends' varying magnitudes also suggested the necessity of region-specific approaches to water management. Drought is a complicated phenomenon and a natural hazard caused by a severe event that results from a prolonged water scarcity. A greater demand for water than supply, below-average rainfall, uneven rainfall distribution, or a combination of all three could be the cause of this phenomenon. Drought is one natural hazard brought on by unusually low precipitation.

Keywords

Drought, Climate, Social activities, Rainfall, Agricultural, Social,.

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Introduction: -

A frequent natural calamity, drought can affect social, agricultural, economic, and societal activities (Ding et al., 2011). Drought is a complex and devastating natural disaster that significantly harms the economy, society, and environment. It is a recurring feature in almost every climate zone. Previous studies have shown that it is difficult to define drought exactly because it seems to vary across studies, organizations, and climatic zones. Most studies have defined drought as the ratio of evapotranspiration to precipitation. It's a long, unusually dry period with limited water for basic needs. A temporary and frequent natural calamity that causes significant financial losses is caused by a lack of precipitation. The non-structural nature of drought has made it more difficult to construct drought contingency strategies, as well as to produce timely, accurate, and trustworthy assessments of severity.

Longer drought duration affects human activity and the environment. Drought spans over a wide geographic area and is a temporary phenomenon with duration, scale, and severity. It is nearly usually characterized by a gradual start and a long duration. Therefore, understanding the characteristics of a drought and having a contingency plan are more important for governments in particular and for humanity in general. Assessing and categorizing the drought's severity is one of the most difficult aspects of handling it. Singh and Mishra (2010). It is restricted to structural damage with abrupt onset and termination. Because it is a complex, natural phenomenon, attempts are made to predict when it will begin, how long it will last, and how intense it will be.

Uttar Pradesh's Drought Situation

Drought is a serious calamity that also impacts the state of Uttar Pradesh. In terms of agriculture, the state is important since it produces more than 21 percent of the country's food grains. 17.69 million hectares, or 66% of the total cultivated land, are irrigated out of the 25.30 million hectares that have been seeded. About 25% of the irrigated land is made up of canals, 67% is made up of tube wells, and the remainder is made up of ponds, lakes, etc.

A third of the state's irrigated land and its entire rain-fed area are heavily reliant on monsoon rainfall. Precipitation is responsible for around 80% of all groundwater recharge. Between 70 and 80 percent of the yearly rainfall in our area is caused by the monsoon rains. The entire area of Uttar Pradesh is 240.93 lakh hectares (Anon., 2024c). Numerous natural catastrophes have occurred in the State over the years, seriously harming people, property, the environment, and plant and animal life. In Uttar Pradesh, notable natural disasters include:

1. It has been demonstrated that East Uttar Pradesh experiences significantly insufficient rainfall six to eight times a year, while West Uttar Pradesh experiences it ten times.
2. The years 2002 and 2004 had exceptionally severe drought conditions, with losses to crops, property, and animals estimated to be worth Rs. 7540 crores and Rs. 7292 crores, respectively (Anon., 2024c).
3. Because different agro-climatic regions have varying quantities of rainfall, climate, and soil, it is vital to analyze droughts according to their agro-climatic regions. This is because different types of droughts occur throughout Uttar Pradesh.

Regional Agroclimatic Conditions in Uttar Pradesh

A geographical area where crop production and agricultural operations are impacted by largely consistent weather conditions is known as an agro-climatic region. These regions are similar in terms of temperature, precipitation, and other environmental factors, and these characteristics are crucial in identifying the kind of crops that can be grown there. Because of differences in geography, soil types, and climate, Uttar Pradesh, a state in northern India, features a variety of agro-climatic zones. The state can be roughly categorized into the nine agroclimatic zones

Analysis of Trends

The purpose of trend analysis is to ascertain whether patterns of a given element are generally growing or shrinking over time. According to Duhan and Pandey (2013), trend analysis of rainfall is the use of statistical techniques to quantify the pattern of changes in a long-term rainfall dataset over a given time period. A statistical distribution is used to test for non-linear trends and turning points, and the Mann-Kendall test is a nonparametric test for finding patterns in data series (Mann, 1945; Basistha et al., 2009; Oguntunde et al., 2011). Many studies have successfully used the Mann-Kendall test to identify trends in hydrologic climatic variables, such as precipitation, that are statistically significant or insignificant in the context of climate change.

Experiments that don't assume anything about the population being studied are known as nonparametric tests. Information pertaining to any one parametric category of probability distributions has no bearing on it. Non-parametric methods are also referred to as distribution-free tests because they don't employ an underlying population.

Machine Learning

There are many different methods, approaches, and algorithms used in the subject of machine learning. The topic of machine learning experienced a resurgence

in recent decades as a result of the exponential increase in computing capacity after the notorious AI winter. One of the biggest challenges in drought forecasting is choosing and developing an appropriate prediction model (Mishra and Singh, 2011). In the past, researchers have attempted to reproduce ground-based drought indicators by connecting data from many sources using data-based models. Leo Breiman and Adele Cutler created the well-known machine learning method Random Forest, which combines the results of multiple decision trees to get a single conclusion. Its adoption has been fuelled by its adaptability and simplicity of usage, as it can manage both regression and classification problems.

Random Forest regression is a powerful machine-learning technique for regression applications. It's an ensemble learning method that combines multiple decision trees to produce predictions. The Random Forest approach is well known for its adaptability, robustness, and capacity to handle challenging datasets. The Random Forest regression technique creates an ensemble, or "forest," of decision trees (Kardani et al., 2022). Each decision tree is trained using a random subset of the attributes and a random subset of the training data. Randomization is used during training to reduce overfitting and improve the generalization ability of the model.

The rationale for this Research

The goal of this study is to fill in the knowledge gaps about Uttar Pradesh's meteorological drought, which has been caused by a lack of data and inaccurate forecasts. The study's conclusions will be useful to decision-makers, including farmers, governments, and other stakeholders, in their future planning to mitigate the effects of drought. Furthermore, the results of this study may influence further research in this field by other academics who are interested in it. This study aims to use modern machine-learning techniques to increase the accuracy of drought forecasts for Uttar Pradesh.

Objectives

1. To examine the trend in rainfall and its magnitude for Uttar Pradesh's various agroclimatic zones.
2. To evaluate the drought conditions in Uttar Pradesh's various agroclimatic zones.

Review of Literature

Güçlü (2020) examined the enhanced trend analysis visualization at Istanbul Medeniyet University in Istanbul, Turkey, by contrasting it with the traditional Mann-Kendall test and ITA. Results showed that, for Turkey's Mediterranean, Black Sea, and continental climate zones, the suggested methodology offers distinct trend conditions compared to the traditional MK trend test and ITA approach. The Mann-

Kendall (MK) test and the straight forward Sen Innovative Trend Analysis (ITA) approach were used to evaluate 50 years' worth of rainfall data at different stations in Turkey. A new trend analysis methodology with a unique graphical representation was proposed.

At the Department of Water Recourses Engineering, University of Duhok, Iraq, Aswad et al. (2020) used the Mann-Kendall and Sen's Slope estimator test to examine the trend in rainfall for Sinjar district on a yearly and monthly basis. Sen's Slope estimator and the MK test were used to create a time series model based on the Sinjar district's 70 years of rainfall data.

At the Mempawah Climatology Station in West Kalimantan, Indonesia, Aditya et al. (2021) used the Mann-Kendall and Sen's Slope estimator test to analyze the rainfall trend. Sen's slope estimator and the MK test were employed in this investigation to ascertain the long-term monotropic trend and variability at 12 sites between 2000 and 2019. On the other hand, Sungai Kunyit showed a significant trend (at 95% confidence level) with a slope value of -33.20 mm/year. This pattern suggests that Sungai Kunyit will have future dry spells.

At the Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Andhra Pradesh, India, Agarwal et al. (2021) used Mann Kendall and Sen's Slope approach to analyze the interpretation of rainfall trends. Parametric and nonparametric tests were used in this work to examine trends and variability in daily, seasonal, and annual precipitation. From 1981 to 2016, daily and seasonal data were obtained from the Indian Meteorological Department of Pune (IMD). A 95% level of confidence or a 5% level of significance was used for the statistical analysis. Although the MK test analysis indicates a strong and positive trend in rainfall over the region, the amount of rainfall appears to have changed.

At the United Nations University Institute for Integrated Management of Material Fluxes and of Resources in Ammonstrasse, Germany, Gadedjisso-tossou et al. (2021) carried out a study to examine the Mann-Kendall test of rainfall and temperature trends and their implications for rain-fed cereal yields in northern Togo. The Mann-Kendall (MK) test and Sen's Slope (SS) method were used in this study to examine the trends in monthly and annual rainfall as well as minimum and maximum temperatures (Tmin and Tmax) for the various crops. This study found that Dapaong had higher rainfall (7.79 mm/year) than other places like Mango (0.67 mm), Niamtougou (4.57 mm/year), and Kara (2.20 mm/year). At Kara, Tmax rose by 0.13, 0.13, and 0.32 °C every ten years.

In the Gummidipoondi sub-basin in Tamil Nadu, India, Mohammed Junaid and Santhanakrishnan (2021) investigated the rainfall trend analysis using the Mann-Kendall test and Sen's Slope estimator. Monthly, annual, seasonal, and annual daily

maximum rainfall trends were determined by processing daily rainfall data spanning 30 years (1990 to 2019). The trend and its magnitude are determined using the same data; a sharp decline in trend is seen during the North East monsoon season.

Using the Mann-Kendall and Sen's Slope estimator tests, Frimpong et al. (2022) examined the temperature variability in Ghana's Accra and Kumasi metropolitan areas. This study examined the temperature and temperature trends in both cities using in-situ measurements from a single meteorological station in each city from 1986 to 2015. Overall, there were more warm days, according to the temperature indicators that were examined, and the minimum temperature was increasing in comparison to the maximum temperature. Mann Kendall and Sen's slope revealed significant trends in both cities' annual and seasonal (dry and wet) minimum temperatures.

Using the Innovative Trend Analysis (ITA) approach and the Mann-Kendall test, Oufrigh et al. (2023) evaluated the trends at the Department of Agronomy Biological Systems and Geomatics Research Laboratory Mascara, Algeria. We used monthly and seasonal rainfall data from 38 locations from 1975 to 2015. According to the monthly rainfall MK test, 82% of the stations show no appreciable trends. However, the ITA approach indicates that 41% (58%) of stations in the high rainfall component, 56% (33%) of stations in the low rainfall component, and 53% (40%) of stations in the average show positive (negative) trends.

At the Department of Geography, University of Calcutta, Kolkata, India, Das et al. (2020) used the Standardized Precipitation Index to study the meteorological drought over the Luni River basin in Rajasthan, India. Long-term monthly precipitation data from 39 rain gauge stations (1973–2016) were used in the study. The long-term (24, 12, and 9 months) and short-term (6, 3, and 1 month) SPI calculations were used to identify drought episodes and determine the percentage of the region affected by severe drought conditions.

Dukat et al. (2022) used the Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) indices at the Climatology Department of Adam Mickiewicz University in Poznañ, Bogumi³a Krygowskiego, Poland, to estimate trends in drought occurrence and severity at mid-latitude European stations. For six mid-latitude European sites, the number of dry months from 1951 to 2015 was determined, and the pattern of their occurrence was analyzed. Additionally, a pattern regarding drought severity was found for each site during the summer months when the indicators fell below zero.

At the Department of Environment and Climate Change, Ethiopian Civil Service University, Addis Ababa, Ethiopia, Worku (2024) used SPI and SPEI to

OVERVIEW AND RESULTS

The study's objectives were to evaluate the meteorological drought, examine the trend and magnitude of rainfall, and create a drought prediction model for Uttar Pradesh's several agroclimatic zones using the Random Forest technique. Significant differences were found between Uttar Pradesh's agroclimatic zones when the trend and magnitude of rainfall were analyzed. There were patterns of rising rainfall in certain areas and falling rainfall in others. These trends' varying magnitudes also suggested the necessity of region-specific approaches to water management.

The frequency, intensity, and length of drought occurrences in the research area were revealed by the evaluation of meteorological drought using a variety of drought indices, including the Standardized Precipitation Index (SPI) and the Percent of Normal Precipitation (PNP). The findings emphasized the necessity of proactive drought management and mitigation strategies by highlighting the susceptibility of specific regions to drought.

Using a Random Forest approach, which incorporated the advantages of Random Forest and other machine learning techniques, the study then concentrated on creating a drought prediction model. Historical rainfall and drought data were used to train and validate the model, and a variety of statistical measures were used to assess its performance. The model showed encouraging outcomes in forecasting drought conditions, offering stakeholders and decision-makers in the area a useful tool.

Examining meteorological drought trends and using the results to create a practical model that would evaluate all the various drought conditions in Uttar Pradesh's agroclimatic zones was the goal of this study. The following conclusions are drawn from this study after a thorough analysis and interpretation of the findings:

- Rainfall in the Vindhyan and Bundelkhand regions is significantly declining both annually and during all seasons. Rainfall in the semi-arid and southwestern plains is significantly declining throughout the winter, monsoon, and yearly cycles.
- An examination of SPI indices in Uttar Pradesh's several agroclimatic zones showed that there had been no drought for a number of years, indicating adequate precipitation levels that maintained ecosystem stability, agriculture, and water supplies.
- In certain years, there were cases of mild to moderate drought that affected water supplies and agricultural operations. To overcome these obstacles, solutions for drought mitigation and efficient water management are essential.
- Severe droughts in several areas, including Vindhyan and Bundelkhand, highlighted the necessity of effective agricultural and water management

techniques. To lessen the effects of severe droughts and increase resilience to climatic unpredictability, preemptive interventions and ongoing monitoring are crucial.

- Historical weather data was used to train and validate the Random Forest regression model, and a variety of statistical measures were used to evaluate the model's accuracy.
- After extensive research and investigations, it was found that random forests could accurately simulate and predict meteorological droughts in various UP agroclimatic zones.

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