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Dryspell Analysis Using Gridded Rainfall Data For Telangana

G. S. Pratyusha Kranthi*[ab], K. V. Rao[b], K. Padmakumari[a]

[a]Jawaharlal Nehru Technological University, Kakinada, India
[b]ICAR-Central Research Institute for Dryland Agriculture, Telangana, India

ABSTRACT

The study analyzes the spatial and temporal patterns of dry spells in Telangana using gridded rainfall data spanning 1961 to 2015. The analysis employs the Mann-Kendall test to identify trends in dry spell occurrences and their lengths. Results indicate considerable spatial variability, with southwestern and southern districts experiencing the longest and most severe dry spells, while northeastern and eastern districts encounter shorter durations. Although most locations exhibit a non-significant trend towards reduced dry spell lengths, higher elevation areas such as Vikarabad and Rangareddy show a significant decrease, highlighting the critical role of topography in influcing dry spell patterns. The study underscores the challenges including limitations of using gridded rainfall data, topographical complexities, and variability in defining dry spell thresholds, all of which affect the accuracy of results. Despite the challenges the research makes key contributions by providing a detailed regional analysis of dry spells and identifying critical zones of vulnerability. The study also highlights the critical need for regional-scale analysis to accurately assess local impacts and develop adaptive strategies tailored to the specific climatic and geographic conditions of different districts. Future research should incorporate recent data, consider climate change impacts, and integrate socio-economic factors to provide a holistic understanding of dry spell implications in Telangana.

Keywords: *Dry spells, Drought, Gridded data, Rainfall, Spatial Distribution, Agriculture, Mann-Kendall test*

Introduction

Dryspell is the primary indicator in monitoring drought and is one of the most applied approaches available to analyze drought [1]. In agricultural terms, a dry spell is often defined as a period of consecutive dry days with daily rainfall below a preselected threshold [2] [3] [4]. Number of consecutive days and threshold vary from region to region. The thresholds value, commonly used to define a dry spell length in various parts of the world are 0.1, 0.85, 1.0, 1.5, 2, 5.0, and 10.0 mm/day [5–9]. These dry periods disrupt the soil moisture balance, affecting crop germination and growth, and can lead to water stress in both rainfed and irrigated areas[10]. Also, the frequency and length of dry spells have a huge impact on the success and failure of crop production during rainy seasons. The spatiotemporal analysis of dry spells is important for improving water management strategies and reducing socio-economic losses [11]. Many studies were conducted to analyze dry spells and their trends using gridded data at a larger scale. [12] [13] analyzed trends and frequencies such as frequency of dryspells, total dry spell, and maximum and mean dry spells in the Malawi and Sudano-Sahelian regions respectively to investigate the spatial distribution and long-term trend of dry spells. [1]examined long-term spatial and temporal patterns of dry spells in the Calabria region of southern Italy between 1916 and 2006 to establish the trends of dry spells at annual and seasonal scales. However, Different regions have distinct climatic conditions, topographies, and weather patterns.

*Corresponding Author: ***G. S. Pratyusha Kranthi***

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The impact of dry spells varies significantly from one region to another, affecting agriculture, water resources, and ecosystems differently. Larger-scale analyses might overlook or generalize critical local variations, leading to less accurate assessments. Therefore, analyzing dry spells at a regional scale is essential to capture the spatial variability, and assess local impacts. Some authors like [14] [15] emphasized the importance of studying dry spells at the local scale, which groups similar stations together to be a homogenous region.

Telangana, a state in the southern part of India, relies heavily on agriculture, which in turn depends on the seasonal southwest monsoon for its water requirements. The southwest monsoon, spanning from June to September, brings about 80% of the annual rainfall to Telangana. For Telangana, timely and adequate rainfall during this period is essential for the cultivation of key crops such as rice, cotton, maize, and pulses. The onset and distribution of monsoon rains dictate sowing patterns and crop growth cycles. Any deviation, particularly in the form of dry spells, can lead to substantial agricultural losses and water scarcity. Understanding dry spells in Telangana during the southwest monsoon is vital for developing adaptive strategies to mitigate their adverse effects [16].

The occurrence of dry spells in Telangana during the southwest monsoon can be attributed to several factors, including climate variability, geographic location, and atmospheric conditions. Most of Telangana lies in the rain shadow region of the Western Ghats, which influences its rainfall distribution. While the state does receive substantial monsoon rains, the spatial and temporal distribution is often erratic. Several climatic phenomena contribute to the occurrence of dry spells. El Nino and La Nina events, for instance, have a significant impact on monsoon patterns. El Nino, characterized by the warming of the central and eastern Pacific Ocean, tends to weaken the southwest monsoon, leading to reduced rainfall and more frequent dry spells in India, [17] [18]including Telangana. Prolonged dry periods can lead to crop failure, reduced yields, and increased vulnerability to pests and diseases. For a predominantly agrarian state like Telangana, such impacts can result in significant economic losses. Farmers often face financial distress due to crop damage and the increased costs of irrigation and other adaptive measures. However, not many studies have looked at studying characteristics of dry spells in Telangana using gridded data, according to the literature. The main objective of this study is to analyze the spatial pattern of dry spells in Telangana state during southwest monsoons, its frequency distribution, and the estimation of the long-term trend and evaluation of the regional areas most affected by dry events. At the same time, this study also evaluates the extent to which gridded data is useful in and analyzing dry spells at a regional scale.

Material and methods

Telangana is a state located between 15°55'N to 19°55'N latitude and 77°10'E to 81°50'E longitude in the southern-central part of the Indian peninsula on the high Deccan Plateau. The annual rainfall is between 900 and 1500mm in northern Telangana and 700 to 900mm in southern Telangana, from the southwest monsoons. Telangana is a semi-arid region and has a predominantly hot and dry climate. Summers start in March, and peak in mid-April with average high temperatures in the 37–38 °C range. The monsoon arrives in June and lasts until late September with about 755 mm of precipitation. This period has the highest total rainfall, reflecting the primary contribution of the southwest monsoon (Fig.1). The average elevation of the plateau area is about 500 meters, higher in the west and southwest and sloping downward toward the east and northeast, where it meets the discontinuous line of the Eastern ghat ranges. the western part of the state is mostly hilly with an altitude generally varying from 300m to 600m and some parts is having an altitude of 600 m to 850 m (Fig. 2).

Many studies like [19] [20] used IMD gridded rainfall data to study spatial variability of dry spells at larger scales. For the present study also 0.25 x0.25degree resolution gridded daily rainfall data obtained from IMD for the period 1961 to 2015 is used. A box plot of a summary of monthly, seasonal, and annual precipitation is provided in (Fig.1). Among various indicators used by different authors for dry spell analysis, the most common indicators used are the mean and the maximum length of dry spell. Many authors suggested different thresholds for detecting a dry spell, [21]used 0.1 mm, 1 mm, 5 mm, and 10 mm thresholds for defining dry spells to analyze seasonal and yearly dry spell characteristics in China. [22] used 0.1 mm and 1.0 mm thresholds to check if they could influence the relative variation of the dry spell distribution in Greece. [23]pointed out that using a 10 mm threshold avoids scenarios where a few light rainfall days might interrupt an otherwise extended period of dryness. According to [24] [25] [26] sometimes, these thresholds are considered insufficient for crop use. Rainfall amounts less than 1.0 mm is supposed to evaporate directly before any use [27] [28] [29]. In the present study, a day is classified as having no rain if the recorded rainfall is less than 2.5 mm, and consecutive 7 days with less than 2.5mm is considered a dry spell, as adopted by the India Meteorological Department (IMD). Additionally, the meteorological year is considered because, due to the climatic characteristics of the study area, there is a high likelihood of experiencing rainy days at the beginning or end of each year. After detecting dry spells, the mean and maximum length of dry spells and trends in dry spells are evaluated for the study period.

Mann-Kendall test is a non-parametric test widely used by several researchers almost in all fields for identifying any trends in time series data [30]. In the context of dry spell trend analysis, this test is applied to evaluate whether there is a statistically significant trend in the occurrence of dry spells over the study period. The MK statistic is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

where x is the data value at times k and j, and n is the length of the data set.

$sign(x_j - x_k)$ = 1 if $x_j - x_k > 0$

= 0 if $x_j - x_k = 0$

= -1 if $x_j - x_k < 0$

Variance of S is calculated as

$$Var\ (S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^{n} t_i i(i-1)(2i+5)]}{18}$$

Where t_i is the number of ties of extent i.

The standardized test statistic Z, computed by:

$$Z = \frac{S-1}{\sqrt{Var(S)}}\ if\ S > 0$$

$$Z = 0\ if\ S = 0$$

$$Z = \frac{S+1}{\sqrt{Var(S)}}\ if\ S < 0$$

The probability p-value can be obtained from the standard normal distribution (Z-distribution) using the computed Z value. Depending on the nature of the test (one-tailed or two-tailed), the p-value is calculated as:

$$p = 1 - \Phi\ (Z) = 1 - \frac{1}{\sqrt{2\pi}} \int_0^Z e^{-t^{2/2}} dt$$

Here, Φ (Z) is the cumulative distribution function (CDF) of the standard normal distribution. A significance level of 0.05 was chosen to test the hypotheses. For a two-tailed test with a 0.05, if the calculated Z value is greater than 1.96 or less than -1.96, the null hypothesis is rejected, If the calculated Z value falls between -1.96 and 1.96, the null hypothesis cannot be rejected, indicating no significant trend.

Results and Discussions

Probability Distribution of Dry Spells Durations

The probability distribution of dry spell duration is analyzed using the 75th, 90th and 95th percentile for the study period (Fig. 3). The 75th percentile shows a more widespread occurrence of longer dry spells (18 to 29 days) compared with 90th which shows a concentration of severe dry spells in fewer regions (15 to 25 days). Whereas the 95th percentile highlights the rarest and most extreme dry spells (13 to 24 days), affecting a minimal portion of the area. The districts Jogulamba Gadwal, Wanaparthy, Mahabubnagar, and Nagarkurnool with the longest dry spells are concentrated in the southwestern and southern parts of Telangana. This observation can be substantiated by the findings of [31] who highlighted the significant role of orography in influencing rainfall amounts and distribution in a region. In Telangana, the orographic features, such as the presence of the Deccan Plateau and various hill ranges, affect the southwest monsoon's progression and the distribution of rainfall. The southwestern and southern parts of Telangana, being more elevated and having complex terrain, tend to experience rain shadow effects, which result in reduced rainfall. This reduced rainfall contributes to longer dry spells in these districts. The central, eastern, and southeastern districts, Jayashankar Bhupalpally, Mahabubabad, Khammam, and Bhadradri Kothagudem appear to experience shorter dry spells. The eastern parts of Telangana are characterized by lower elevations and more gentle terrain compared to the southwestern parts, which facilitates a more uniform distribution of monsoon rainfall. Additionally, these regions are closer to the coastal areas, which helps in receiving more moisture-laden winds from the Bay of Bengal.

Average and MaximumLength of Dry spells

The seasonal average and the maximum length of dry spells in Telangana are presented in figure 4. By observing the spatial distribution of these values, the study area can be divided into distinct zones. For the mean length of dry spells, the northeastern and eastern parts of Telangana, including districts such as Jayashankar, Bhadradri Kothagudem, Mahabubabad, Warangal Rural, Mancherial, Peddapalle, Adilabad, and Komaram Bheem, show shorter durations, typically less than 26 days. These regions receive more consistent and frequent rainfall. Slightly longer mean dry spells, ranging from 27 to 28 days, are observed in districts like Suryapet, Karimnagar, Jagtial, and parts of Kamareddy and Medak. In contrast, the central part of Telangana, including districts like Siddipet, Jangaon, Nizamabad, Sangareddy, Vikarabad, and parts of Medak, experiences mean dry spells of 29 to 30 days suggesting moderate rainfall frequency. Moving towards the southwestern and southern regions, districts such as Rangareddy, Yadadri Bhuvanagiri, and Medchaland Mahbubnagar face mean dry spells averaging 31 to 32 days. Even longer mean dry spells of 33 to 34 days are seen in parts of Rangareddy, Nalgonda, and Wanaparthy. The longest mean dry spells, exceeding 34 days, are found in Nagarkurnool and Jogulamba Gadwal, indicating infrequent rainfall and significant dry periods.

The maximum length of dry spells follows a similar spatial distribution pattern. The northeastern districts experience the shortest maximum length of dry spells, less than 45 days. Districts such as Nirmal, Jagtial, Karimnagar, Rajanna Sircilla, Medak, Kamareddy, and parts of Warangal Rural have slightly longer maximum dry spells, ranging from 46 to 50 days. In the central region, the maximum dry spell length extends to 51 to 55 days. The southwestern and southern districts face maximum dry spells of length 56 to 60 days. Longer maximum dry spells of 61 to 65 days are observed in parts of Rangareddy, Nalgonda, and Wanaparthy, while the southernmost districts of Nagarkurnool and Jogulamba Gadwal experience the longest maximum dry spells, exceeding 65 days.

These observations highlight a clear gradient in both mean and maximum dry spell lengths across Telangana, with the northeastern regions enjoying more consistent rainfall and shorter dry spells, while the southern and southwestern regions face prolonged periods without rain, posing greater challenges for water resource management and agriculture.

Temporal Variability of the Dry Spell Lengths

The trend analysis of the dry spells in Telangana reveals several noteworthy patterns. Most of the dry spell series presented serial correlations in the data during the southwest monsoon. Consequently, the non-parametric Mann-Kendall (MK) test was applied to both annual and seasonal dry spell values after pre-whitening the data using von Storch's procedure. The current analysis indicates that dry spell trends in Telangana are predominantly characterized by non-significant changes (Fig. 5), with a slight inclination towards a decrease in dry spell days in most locations. The results of the trend analysis indicate that 6.6% of the data points exhibit a significant negative trend, suggesting a reduction in the length of dry spells. This reduction is most prominent in districts such as Vikarabad, Rangareddy, and parts of Mahabubnagar, which fall in higher elevation zones, where a small fraction of locations show a significant reduction in dry spell days, indicating an improvement in dry conditions. The majority of locations (75 %) exhibit a downward trend in dry spell days, but this trend is not statistically significant. This suggests that there may be a decrease in the frequency or duration of dry spells, but the evidence is not strong enough to conclusively state that this is a systematic change. Positive trends, whether significant or not, were relatively rare, comprising only 18%of data points and exhibiting no significant influence on the overall trend. The current analysis indicates that dry spell trends in Telangana are predominantly characterized by non-significant changes, with a slight inclination towards a decrease in dry spell days in most locations. However, the high variability necessitates ongoing monitoring and adaptive strategies to mitigate potential impacts. Future research and more robust data are essential to draw definitive conclusions and develop effective adaptation plans. These results highlight the localized nature of dry spell trends and emphasize the need for region-specific analyses to accurately understand and address the impacts of climate variability on dry spell occurrences. The predominance of non-significant trends suggests that dry spell patterns in Telangana are influenced by high variability. This could be due to natural climate variability, changes in monsoon patterns, or other regional climatic factors.[32] provided a comprehensive trend analysis using the Mann-Kendall test, revealing significant variability in dry spell patterns across India, including Telangana. The findings align with the observation that most locations in Telangana exhibit non-significant changes in dry spell duration, with a slight inclination towards a reduction in dry spell days. The reduction is particularly noted in districts at higher elevations, such as Vikarabad, Rangareddy, and parts of Mahabubnagar, supporting the notion that orographic effects and elevation influence dry spell trends. These insights also underscore the need for continuous monitoring and region-specific analyses to develop effective adaptation strategies in response to climate variability and its impact on dry spells in Telangana and other regions.

Conclusions

This study provides a comprehensive analysis of dry spells during the southwest monsoon in Telangana, highlighting their spatial patterns, frequency distribution, long-term trends, and the regions most affected. The results reveal significant spatial variability in dry spell characteristics across the state, with southwestern and southern districts experiencing the longest and most severe dry spells, while northeastern and eastern districts enjoy shorter and less severe dry periods. The temporal trend analysis indicates a predominantly non-significant decrease in the length of dry spells, although some regions show a significant reduction.

Understanding these patterns is crucial for developing adaptive strategies to mitigate the adverse impacts of dry spells on agriculture, water resources, and socio-economic conditions in Telangana. Gridded data has demonstrated exceptional value in studying dry spells across Telangana, yet for a more accurate analysis of dry spell trends, regional-specific data such as mandal-level rainfall data is indispensable to address the unique climatic challenges faced by different parts of the state. Given the high variability in dry spell occurrences, ongoing monitoring, and adaptive measures are essential to enhance resilience against climate variability and ensure sustainable agricultural practices and water resource management.

Future research should focus on incorporating more recent data and exploring the potential impacts of climate change on dry spell patterns. Additionally, integrating socio-economic factors and farmer adaptation strategies into the analysis can provide a more holistic understanding of the implications of dry spells and inform policy decisions.

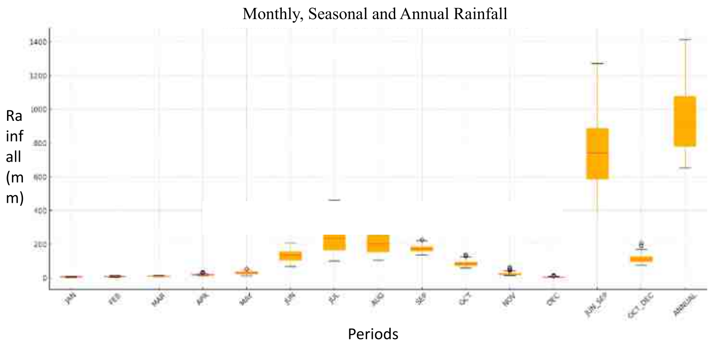

Figure 1 : Rainfall Distribution of the study area

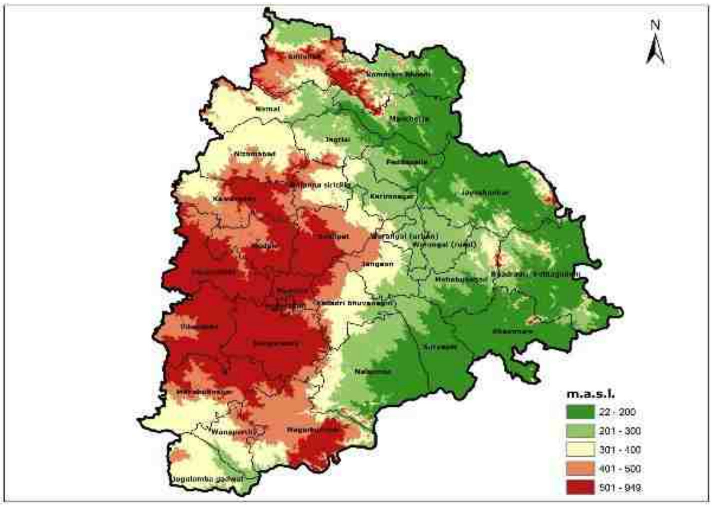

Figure 2: Digital Elevation Model of the study area

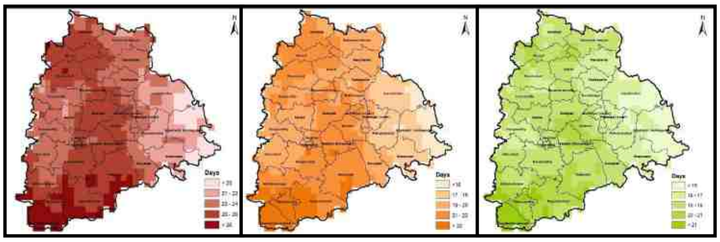

Figure 3: Spatial distribution of the (a) 75th (b) 90th (c) 95th percentiles of dryspell durations during southwest monsoons

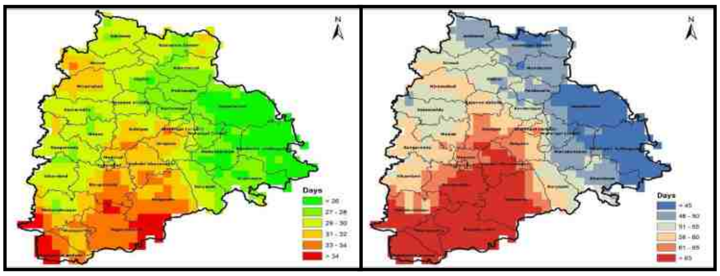

Figure 4: (a) Mean (b) Maximum length of dryspell during southwest monsoons

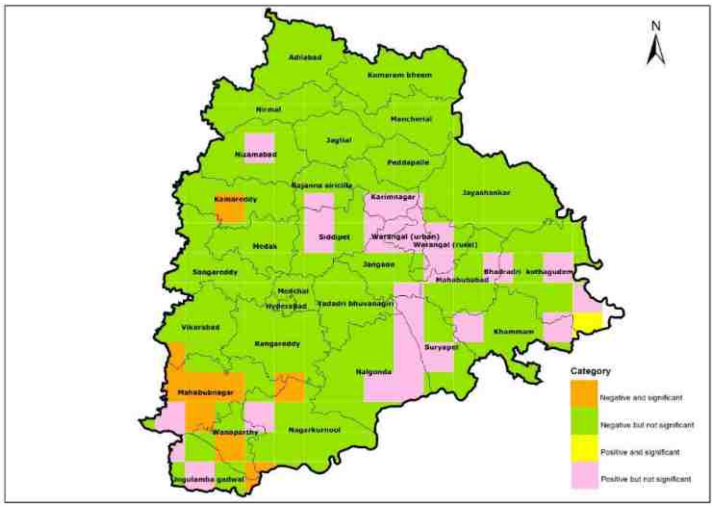

Figure 5: Spatial distribution of the trend analysis on dry spell durations during southwest monsoons

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