International Journal of Horticulture and Food Science

E-ISSN: 2663-1067
P-ISSN: 2663-1075
NAAS Rating: 4.74
www.hortijournal.com
IJHFS 2025; 7(5): 120-123
Received: 03-03-2025
Accepted: 08-04-2025

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Characterization of drought conditions using drought indices calculator (DrinC)

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DOI: https://www.doi.org/10.33545/26631067.2025.v7.i5b.306

Abstract
Accurate assessment of drought magnitude is crucial for evaluating its consequences and developing effective mitigation strategies. Drought indices serve as vital tools for monitoring and characterizing drought as they simplify complex climatic data. In this study, drought indices were calculated using the DrinC software for Anantapur district, an area known for low rainfall in Andhra Pradesh, India. Among 30 years, 6 years were affected by drought (lowest 20% below much normal) and the most affected years were 1992, 2002, 2003, 2009, 2013 and 2014 (Fig.1) as shown by decile method for Anantapur region. The SPI index showed a similar trend but identified only four years i.e., 2002, 2003, 2013, and 2014 as severely dry. The remaining drought years identified by the decile method, such as 1992 and 2009, were classified as moderately dry under SPI. The RDI index exhibited a similar trend to that of the SPI. The results demonstrated that these approaches can support the development of effective preparedness plans to address the impacts of drought.

Keywords: DrinC, drought, decile, SPI, RDI, low rainfall

1. Introduction

Drought is a natural hazard that can greatly impact both human activities and the environment. Examining the water balance and river flow at different reaches proved highly effective for creating targeted interventions to combat water scarcity (Tejaswini and Sathian, 2025) [8]. Hence, accurately assessing its magnitude is crucial for evaluating its consequences and developing effective mitigation strategies. Drought indices serve as vital tools for monitoring and characterizing drought, as they simplify complex climatic data and quantify anomalies in terms of severity, duration, and frequency. Additionally, these indices are valuable for conveying clear and understandable information about the intensity of drought events to a broader audience. Geographical information system and remote sensing in combine, they provide a valuable information for policy makers, resource managers and planners for efficient use of resources (Lakshmi *et al.*, 2022) [1]. The spatial database systems which are readily available can be modified and used for any other regions (Rao *et al.*, 2016) [5].

Drought indices help in identifying and analysing drought by simplifying complex climatic processes and quantifying climatic variations in terms of severity, duration, and frequency. Moreover, these indices are valuable tools for conveying drought severity information in a clear and accessible format to all stakeholders (Tsakiris *et al.*, 2013) [10]. The results produced by these indices are useful to a wide range of users, including students, academic researchers, policymakers, and financial institutions, aiding in decision-making, proactive management, and drought mitigation planning. Statistical tools serve as powerful instruments for drawing reliable conclusions and quantitatively comparing datasets (Sridevi *et al.*, 2024) [6]. Correlation analysis is useful for connecting water quality metrics (Alothman *et al.*, 2022) [1]. In addition to water quality studies, the field of material science has also increasingly applied statistical methods in recent years (George *et al.*, 2022) [2]. While drought indices can be calculated manually through specific equations and procedures, they can also be computed using dedicated tools or software. In this study, the DrinC (Drought Index Calculator) software was employed to calculate various drought indices.

DrinC is a user-friendly software designed to calculate various indices such as Deciles, Standardized Precipitation Index (SPI), Streamflow Drought Index (SDI), and

Reconnaissance Drought Index (RDI), which are used to assess drought severity and examine patterns in drought occurrence. In a country like India, where drought occurs either consecutively or at intervals of 5 to 7 years, addressing the concerns of farmers, industries, and other stakeholders remains a significant challenge for policymakers (Gupta *et al.*, 2011) [3]. Various approaches are currently used by governments to declare drought, but there is a pressing need for standardized methods, especially in a country with diverse agroecological zones like India. Drought indices serve as valuable tools for administrators and policymakers in evaluating drought impacts. Therefore, in this study, drought indices were calculated using the DrinC software for Anantapur district, an area known for low rainfall in Andhra Pradesh, India.

2. Materials and Methods

2.1 Study area

Anantapur district, located at 14.68°N and 77.6°E with an average elevation of 335 m, falls under the hot arid agro-ecological zone with dry summers and mild winters. The terrain includes 14% hills and ridges, 27% undulating lands, 54% gently to very gently sloping plains, and 5% valleys. Due to its geographic location, it receives limited rainfall (535 mm annually) being in the rain shadow of the Western Ghats and distant from the eastern coast. The district's soils originate from granite, granite-gneiss, and Dharwar landforms, supporting diverse topography. Among the 34 soil families, Anantapur and Penukonda soils are most widespread. Maximum and minimum temperatures, daily rainfall records were used for running the software. Drought indices such as Deciles, Standard Precipitation Index (SPI), and Reconnaissance Drought Index (RDI) were calculated. These indices were computed using the DrinC software, which applies both log-normal and gamma distribution methods. The analysis was carried out for time scales of one year, six months, and three months.

2.2 Summary of Drought Indices Calculator

It is designed to calculate various drought indices for different types of drought (meteorological, agricultural, hydrological) across diverse regions. It emphasizes low data requirements, making it suitable for arid and semi-arid areas with limited data availability. DrinC includes four indices: RDI, SDI, SPI, and PD. RDI, SPI, and PD focus on meteorological drought, with RDI also applicable to agricultural drought due to its use of precipitation and potential evapotranspiration. RDI can be applied to agricultural drought analysis, as it effectively represents the water balance and is especially valuable when reference periods align with the crop's developmental stages (Tsakiris *et al.*, 2010) [11]. SDI addresses hydrological drought, using streamflow as the key input. DrinC also offers multiple calculation methods, enabling flexible, comparative analysis tailored to user needs.

2.3 Drought indices

Deciles are determined by the cumulative frequency distribution of ranked monthly and annual total precipitation, with values between 5 and 6 indicating normal conditions. SPI represents the number of standard deviations the observed precipitation deviates from the long-term mean. Positive SPI values indicate above-median precipitation, while negative values indicate below-median precipitation. A highly negative SPI signifies severely dry conditions. The Reconnaissance Drought Index (RDI) provides a more accurate measure of water deficit and is useful for drought monitoring and assessment. It is calculated using both cumulative precipitation (P), which is measured, and potential evapotranspiration (PET), which is estimated. Positive RDI values indicate wetter-than-average conditions, while negative values reflect drier-than-average periods.

2.4 Drought indices calculation

DrinC allows users to tailor drought analysis to suit specific study goals. It provides results on a monthly or period-based scale, enabling direct comparison of drought severity across defined intervals. The default reference period in DrinC is the hydrological year (October to September), with standard time steps of 1, 3, 6 months, and annual. Users can also customize time intervals and select different starting months using dropdown menus and radio buttons, which is especially useful for aligning drought analysis with crop growth stages or seasonal variations. Exports to MS Excel can be done either as separate files for each index or as a single consolidated file, with an option to automatically generate graphs. Furthermore, the 'multi-points mode' enables users to upload annual or seasonal data for multiple locations and compute drought indices iteratively, making it highly effective for producing spatial drought maps.

3. Results and Discussion

The study area experiences a dry climate with average annual rainfall of 535 mm. Approximately, 60% of rainfall occurring during the southwest monsoon season during which the average maximum temperature recorded as 32.1 °C, while the average minimum temperature was recorded as 23.2 °C.

3.1 Drought Indices

Drought indices such as Decile, Standard Precipitation Index and Reconnaissance Drought Index were calculated using DrinC calculator and results were presented in the following sections.

3.1.1 Decile method

Among 30 years, 6 years were affected by drought (lowest 20% below much normal) and the most affected years were 1992, 2002, 2003, 2009, 2013 and 2014 (Fig.1) as shown by decile method for Anantapur region. The data indicate that drought in the region follows a cyclic pattern, typically recurring every 3 to 10 years. However, there were instances of consecutive drought years, such as in 2002-2003 and 2013-2014. Interestingly, no drought events were recorded during the 10-year period from 1992 to 2002, suggesting a possible shift in rainfall and climatic patterns during that time.

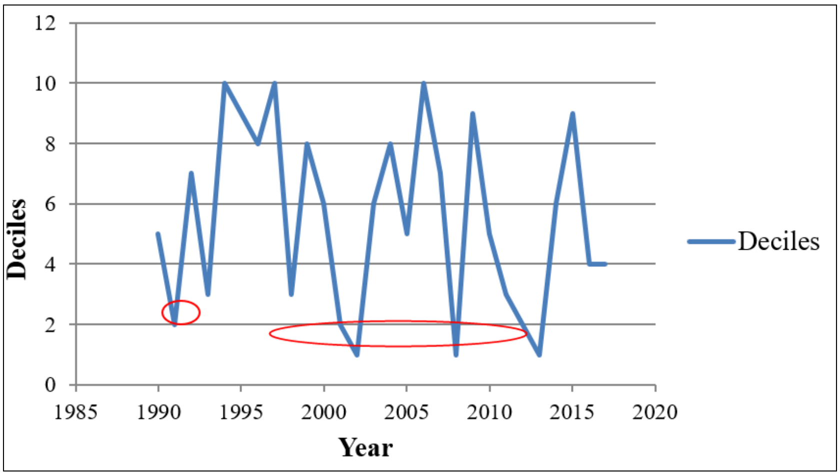

Fig 1: Decile-Based Drought Index for the Anantapur Region

3.1.2 Standard Precipitation Index (SPI)

The SPI index showed a similar trend (Fig. 2) but identified only four years i.e., 2002, 2003, 2013, and 2014 as severely dry. The remaining drought years identified by the decile method, such as 1992 and 2009, were classified as moderately dry under SPI. This indicates that SPI provides a clearer measure of drought severity compared to deciles and is more effective for assessing impacts on crop yields, drinking water availability, and other drought-related factors (Tigkas *et al.*, 2014) [9]. Therefore, SPI is considered a more reliable indicator of drought severity. Among the 30 years analysed, none were classified as extremely dry, and only four years were categorized as severely dry due to significantly lower rainfall during those periods.

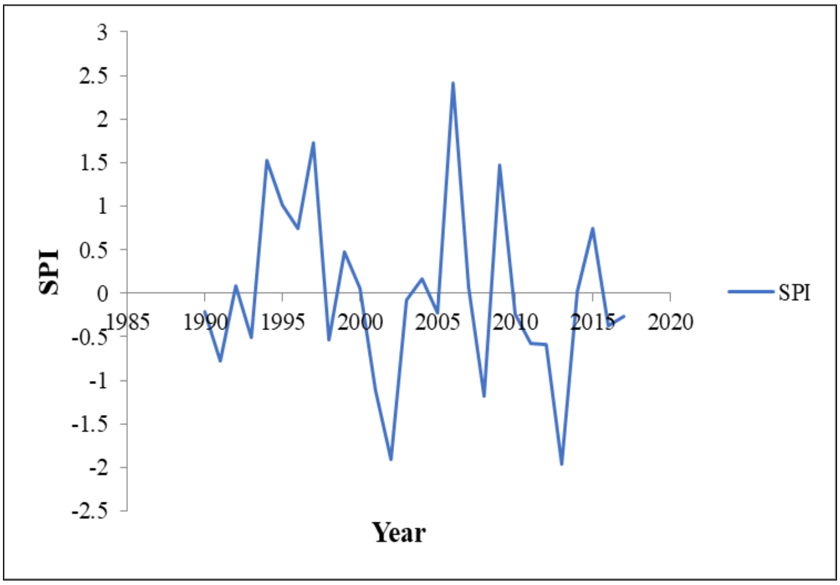

Fig 2: Standardized Precipitation Index (SPI)-Based Drought Assessment for the Anantapur Region

3.1.3 Reconnaissance Drought Index

The RDI index exhibited a similar trend to that of the SPI (Fig. 3), and both indices provided a clearer indication of drought severity compared to the decile method.

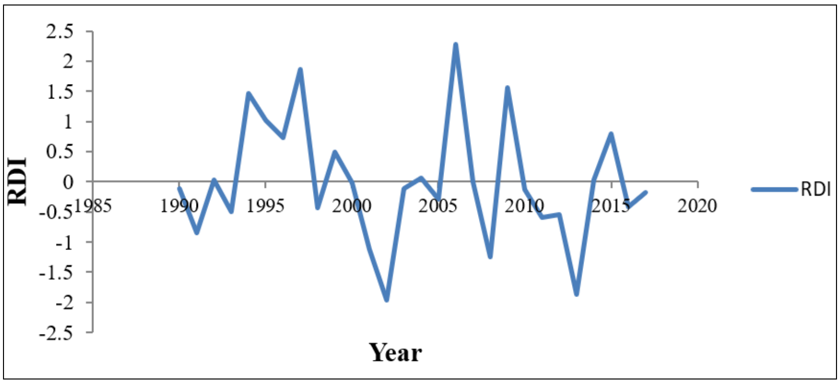

Fig 3: Drought index by RDI for Anantapur Region

3.2 Regression Analysis
The results revealed a strong correlation between RDI and SPI, consistent with findings from earlier studies (Surendran *et al.*, 2017) [7]. Drought years can be effectively predicted using the regression equation provided in the graph, even when only rainfall data is available to calculate RDI. The high R^2 value of 0.995 indicates a strong relationship between annual SPI and annual RDI, confirming that the linear regression model provides an excellent fit (Fig. 4).

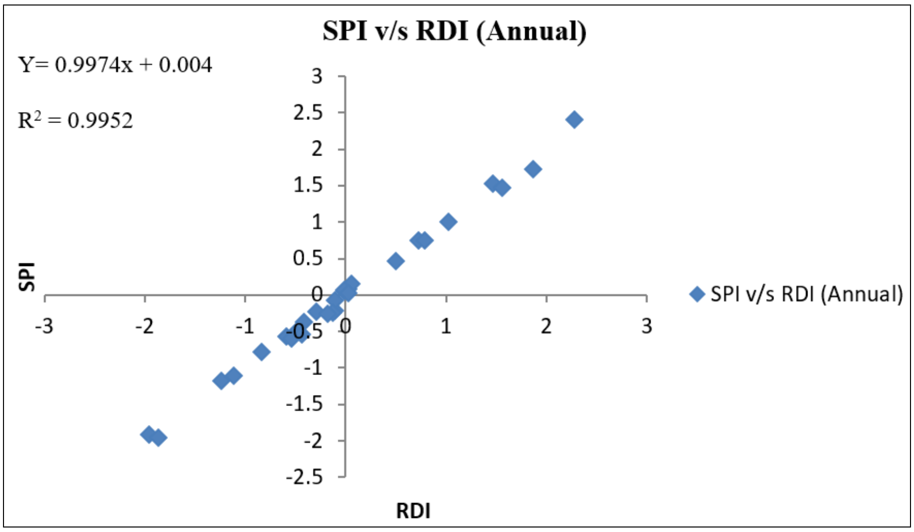

Fig 4: SPI Annual Vs RDI annual comparison

4. Conclusion
DrinC offers a simple and flexible interface for calculating drought indices, taking various factors into account. It computes indices such as Deciles, Standardized Precipitation Index (SPI), and Reconnaissance Drought Index (RDI). The results demonstrated that these approaches can support the development of effective preparedness plans to address the impacts of drought. Insights from such studies serve as valuable tools for formulating strategic measures to manage droughts and reduce their effects across various economic sectors.

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