SRI LANKA JOURNAL OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT

SLJGEM (2025), Vol. 02 (01)

Journal homepage: www.sab.ac.lk/sljgem

A COMPARATIVE ANALYSIS OF METEOROLOGICAL DROUGHT ACROSS CLIMATIC ZONES IN SRI LANKA: FOCUS ON POLONNARUWA, KANDY, AND KURUNEGALA DISTRICTS.

Fasna MRF[1] & Herath HMKCW[2]*

[1,2]Department of Geography and Environmental Management, Sabaragamuwa University of Sri Lanka

ARTICLE INFO

Article History:
Received 10 Nov 2024
Accepted 08 May 2025
Issue Published Online 25 Jun 2025

SLJGEM (2025), Vol. 02, Issue (01), Pp.30-51

KEYWORDS

Dry zone
Intermediate zone
Meteorological drought
SPI Index
Wet zone

**Corresponding author*
E-mail address: fasnaf1999@gmail.com

https://orcid.org/0009-0008-3068-9757

ISSN 3051 5335X (Online)

Published by:

Department of Geography and Environmental Management, Faculty of Social Sciences and Languages, Sabaragamuwa University of Sri Lanka

ABSTRACT

Drought is a significant global concern, and its impacts are increasingly felt in Sri Lanka due to climate variability. This study analyzes meteorological drought across three distinct climatic zones in Sri Lanka; the Dry Zone, represented by Polonnaruwa District; the Wet Zone, represented by Kandy District; and the Intermediate Zone, represented by Kurunegala District. The study analyzed 30 years of monthly rainfall data (1993-2023) obtained from the Department of Meteorology, Sri Lanka using the Standard Precipitation Index (SPI). Polonnaruwa emerged as the most drought-prone region, experiencing drought in 21 of the last 30 years, with 170 drought months, 102 of which occurred during the Southwest monsoon period. Kurunegala recorded only one moderate drought year (2003) and a total of 56 drought months, with most occurring during the Northeast monsoon. Kandy showed an increasing trend in drought events, with moderate drought conditions becoming more frequent in recent years. A correlation between rising Land Surface Temperatures (LST) and increasing drought frequency was noted in Polonnaruwa, suggesting that climate factors significantly exacerbate drought conditions. The study recommends adopting drought-resistant crop varieties, promoting water recycling practices, and enhancing reforestation efforts to mitigate drought impacts in these districts.

How to Cite this Article: *Fasna MRF & Herath HMKCW (2025). A Comparative Analysis of Meterological Drought Across Climatic Zones in Sri Lanka: Focus on Polonnaruwa, Kandy and Kuranegala Districts, SLJGEM,02 (01), Pp. 30-51.*

1.INTRODUCTION

Drought is a global challenge that affects millions of lives and disrupts environmental and economic systems. It is commonly defined as a prolonged period of moisture deficit below expected levels, which impairs various activities such as agriculture, water management, and daily life (Wilhite et al, 2007). According to Wilhite & Glantz (1985), droughts are generally categorized into four types: meteorological, agricultural, hydrological, and socio-economic. Among these, meteorological drought is the most traditional and widely recognized perspective, focusing on deviations in precipitation patterns from historical averages (Dai, 2011). Essentially, all forms of drought originate from a deficiency in precipitation or meteorological drought (National Drought Mitigation Center, 2020).

Meteorological drought occurs when weather patterns lead to extended dry periods, resulting in a significant reduction in precipitation—typically more than 25% below normal levels (Punyawardena, 2002). This type of drought is particularly critical because it affects water availability, agriculture, and numerous socio-economic factors (Tennakoon, 1986). The intricate nature of meteorological drought lies in its ability to cause widespread socio-economic and environmental challenges. When prolonged dry periods occur, the water supply for agriculture, industry, and even domestic use becomes strained, leading to a ripple effect of problems for communities (Wilhite & Glantz, 1985).

In Sri Lanka, meteorological droughts are closely tied to three key meteorological situations that influence the country's rainfall patterns (Jayamaha, 1975). As an island nation located between latitudes 6° and 10° North and longitudes 80° and 82° East, Sri Lanka experiences two major monsoon seasons annually. The Northeast monsoon, from October to December, brings the highest amount of rainfall, while the Southwest monsoon, from May to October, affects the southwestern part of the country (Burchfield & Gilligan, 2016). Despite the seasonal rainfall, drought remains a common disaster in Sri Lanka, recognized as such by the Disaster Management Act of 2005 (Sri Lanka Disaster Management, Act, No. 13 of 2005).

Approximately two-thirds of Sri Lanka falls within the Dry Zone, which is highly vulnerable to drought due to variations in the monsoon patterns and extended dry periods. Agriculture, the primary economic activity in this zone, is particularly susceptible to drought (Basnayake et al., 2019). According to data from the Disaster Management Center, about 694,457 people across various provinces—Uva, Sabaragamuwa, Northern, North Central, Central, and Southern—were affected by drought in 2019. A year earlier, in 2018, drought had impacted 890,000 individuals across the country (Basnayake et al., 2019). The spatial and temporal variations in drought occurrence can be attributed to climatic shifts and changing monsoonal patterns. Drought most frequently strikes districts within the Dry Zone, such as Jaffna, Mannar, Mullaitivu, Batticaloa, Ampara, and Monaragala (ACAPS, 2019).

Meteorological drought in Sri Lanka is a multifaceted phenomenon shaped by complex interactions between global, regional, and local climatic factors (Suppaiah, 1996). Standard Precipitation Index (SPI) analysis reveals that Sri Lanka has experienced numerous drought years, including 1975-1976, 1982-1983, 1986-1987, 1988-1989, 2000-2001, 2001-2002, 2003-2004, 2013-2014, and 2016-2017 (Abeysingha et al, 2020). While the Dry Zone remains the most affected by drought, recent trends suggest that other regions are increasingly experiencing drought-like conditions due to climate change. It is essential to study how droughts manifest in different parts of Sri Lanka to develop more effective management strategies and responses.

1.1 Objectives of the Study

Primary Objective

- Examine the occurrence of Meteorological droughts, comparing the Dry, Wet, and Intermediate Zones of Sri Lanka with a focus on Polonnaruwa, Kandy, and Kurunagala Districts.

Secondary objectives

- To investigate the spatial and temporal occurrence of Meteorological Droughts in Polonnaruwa District, Sri Lanka's dry zone.
- To analyze the spatial and temporal occurrence of Meteorological Droughts in Kurunagala District, Sri Lanka's intermediate zone.
- To examine the spatial and temporal occurrence of meteorological droughts in Kandy district, Sri Lanka's wet zone.
- To identify the key factors influencing the occurrence of meteorological droughts in relation to LST and NDVI in Polonnaruwa, Kurunagala and Kandy district.

The primary objective of this study is to examine the occurrence of meteorological droughts across Sri Lanka's three major climatic zones—Dry, Intermediate, and Wet—by focusing on the representative districts of Polonnaruwa, Kurunegala, and Kandy. This overarching goal seeks to provide a comparative understanding of how drought events differ in frequency, intensity, and duration across varying climatic conditions. To support this main objective, the study also outlines several secondary (minor) objectives aimed at conducting detailed, district-specific analyses. These include investigating the spatial and temporal characteristics of meteorological droughts in **Polonnaruwa**, which lies in the Dry Zone and is known for its agricultural vulnerability; **Kurunegala**, representing the Intermediate Zone where transitional climate conditions prevail; and **Kandy**, situated in the Wet Zone with relatively high rainfall but still exposed to periodic dry spells. Together, these objectives will enable a comprehensive assessment of drought variability in Sri Lanka and contribute to the formulation of more targeted and regionally appropriate drought mitigation strategies.

2.LITERATURE REVIEW

Drought is a significant environmental hazard that disrupts both ecological balance and human livelihoods, particularly in regions heavily dependent on rainfall for agriculture and water resources. It is broadly defined as a prolonged period of precipitation deficiency that results in water shortages, adversely affecting agriculture, ecosystems, and socio-economic activities (Wilhite, Svoboda, & Hayes, 2007). Droughts are typically categorized into four main types—meteorological, agricultural, hydrological, and socio-economic—with meteorological drought considered the foundational form, as it arises directly from a reduction in rainfall compared to historical averages (Wilhite & Glantz, 1985; NDMC, 2020).

Meteorological drought is characterized by an extended period of below-normal precipitation, often more than 25% below average levels (Punyawardena, 2002). This type of drought is particularly important because it affects water availability, food security, and economic stability. It is commonly analyzed using indices such as the Standardized Precipitation Index (SPI), which measures precipitation anomalies over various timescales and provides a quantitative assessment of drought severity (Dai, 2011). Several researchers, including Tennakoon (1986) and Suppaiah (1996), have highlighted the vulnerability of agriculture-based economies in regions like Sri Lanka to meteorological drought, especially in the Dry Zone where rain-fed farming systems dominate.

Sri Lanka's climate is shaped by its geographical position and monsoonal rainfall patterns, primarily governed by the Southwest monsoon (May–September) and the Northeast monsoon (October–December) (Jayamaha, 1975). Despite these seasonal rainfall inputs, drought remains a recurrent hazard, particularly in the Dry Zone, due to variability in monsoon onset, intensity, and distribution (Burchfield & Gilligan, 2016). The Disaster Management Act of 2005 officially recognizes drought as a natural disaster in Sri Lanka, emphasizing its persistent socio-economic consequences (Lanka & Management, 2005).

According to Basnayake et al. (2019), approximately two-thirds of the country lies within the Dry Zone, where communities are highly vulnerable to meteorological drought due to their reliance on seasonal rainfall and limited irrigation infrastructure. In 2019 alone, drought-impacted over 690,000 individuals, predominantly in the Uva, Sabaragamuwa, Northern, and North Central provinces. A year earlier, more than 890,000 people were affected across the country, revealing the scale and recurrence of drought events (Basnayake et al., 2019). Districts such as Jaffna, Mannar, Batticaloa, Monaragala, and Ampara are often identified as drought hotspots due to their climatic positioning and exposure to monsoonal fluctuations (Management, 2019).

To assess drought trends and frequency, previous studies have primarily relied on SPI-based methodologies. For instance, Abeysingha and Rajapaksha (2020) conducted a temporal analysis of SPI data to identify historical drought years in Sri Lanka, highlighting major events in 1975–1976, 1982–1983, 1986–1987, 2000–2001, 2013–2014, and 2016–2017. Their findings underscore the need for localized monitoring and mitigation strategies. However, most existing studies have either focused on national-scale assessments or examined drought conditions within a single climatic zone. There is a noticeable lack of comparative studies evaluating how meteorological droughts vary across Sri Lanka's three distinct climatic zones—Dry, Intermediate, and Wet.

This study aims to address this gap by conducting a comparative analysis of meteorological drought in three representative districts: Polonnaruwa (Dry Zone), Kurunegala (Intermediate Zone), and Kandy (Wet Zone). While earlier works provide important insights into drought occurrence and impacts, they often overlook intra-regional variations in drought severity and timing. By applying a consistent SPI-based methodology across these districts, this research seeks to offer a more nuanced understanding of spatial drought variability in Sri Lanka and contribute to the development of region-specific drought preparedness and management strategies.

3. Materials and Methods

3.1 Data Collection

This study employed quantitative research methods to achieve its objectives. Secondary data alone were required for the analysis. Generalized monthly rainfall data for 30 years (1993–2023) were obtained from the Department of Meteorology, Colombo, Sri Lanka. The data represent district-level rainfall patterns and were used to examine drought characteristics across the three major climatic zones—Dry, Wet, and Intermediate—with a specific focus on the Polonnaruwa, Kandy, and Kurunegala districts to facilitate comparative analysis.

Satellite images (2007, 2015, 2021) were used to create Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) maps. Landsat 5 and Landsat 8/9 (Collection 2 Level 1) images were downloaded from the USGS Earth Explorer for the years 2007, 2015, and 2021. The NDVI and LST maps were created for the Kandy, Kurunegala, and Polonnaruwa districts to assess environmental changes over time.

The Normalized Difference Vegetation Index (NDVI) is a standardized index, that represents relative biomass or vegetation greenness. It is calculated from the difference between the near-infrared (NIR) and red bands of multispectral satellite imagery, using the strong absorption of chlorophyll in the red band and the high reflectance of healthy vegetation in the NIR band (Bushi, 2022). In addition to that, Land Surface Temperature (LST) refers to the Earth's surface radiative skin temperature, measured using thermal sensors on remote sensing platforms. It is a key geophysical variable that reflects the surface energy and water balance within the land-atmosphere system (Li et al., 2013).

NDVI and LST are important for identifying the environmental conditions that influence meteorological droughts. Increasing LST values often indicate increased surface heating, while declining NDVI values reflect reduced vegetation cover. Together, these indicators can reveal shifts in climate patterns and the increasing risk of drought events.

3.2 Study area

This study focuses on three districts in Sri Lanka: Polonnaruwa, Kandy, and Kurunegala, each representing distinct climatic zones. Polonnaruwa is situated in the dry zone, Kandy in the wet zone, and Kurunegala in the intermediate zone.

Polonnaruwa, located in the North Central Province, lies in a flat valley along the Mahaweli River. The district extends between latitudes 7°40′ and 8°21′ N and longitudes 80°44′ and 81°20′ E, with an elevation ranging from 50 to 500 meters (Wijesekera et al., 2008). Its topography and climatic conditions make it particularly susceptible to

Kurunegala, located in the North Western Province, falls within the intermediate climatic zone. Positioned northwest of the central hills, it forms part of the 'coconut triangle' and covers an area of 4,900.62 square kilometers, featuring a mixed landscape of hills and flat terrains. The region is significant for agriculture, often experiencing diverse climatic variations.

Kandy, located in the Central Province within the wet zone, lies at an elevation of 501.75 meters above sea level and spans an area of 1,940 square kilometers. It is situated between latitudes 6°56′ and 7°29′ N, and longitudes 80°00′ and 80°25′ E (Dissanayake et al., 2020). Despite its high annual rainfall, the study of drought conditions in this region is crucial for enhancing the understanding of climate variability and improving drought prediction models.

While few studies have focused on meteorological droughts in Polonnaruwa, existing research highlights the district's vulnerability to drought. Nianthi (2014) examined farmers' responses to drought in the Medirigiriya Divisional Secretariat Division, showing that drought conditions are prevalent in the region. Additionally, reports from the Ministry of Agriculture & Plantation Industries (2023) document agricultural droughts affecting both Polonnaruwa and Kurunegala, as evidenced by crop damage in these areas. Although Kandy typically receives substantial rainfall, investigating drought conditions in the district contributes to academic research and supports future drought prediction efforts. These factors formed the basis for selecting Polonnaruwa, Kandy, and Kurunegala as the study areas.

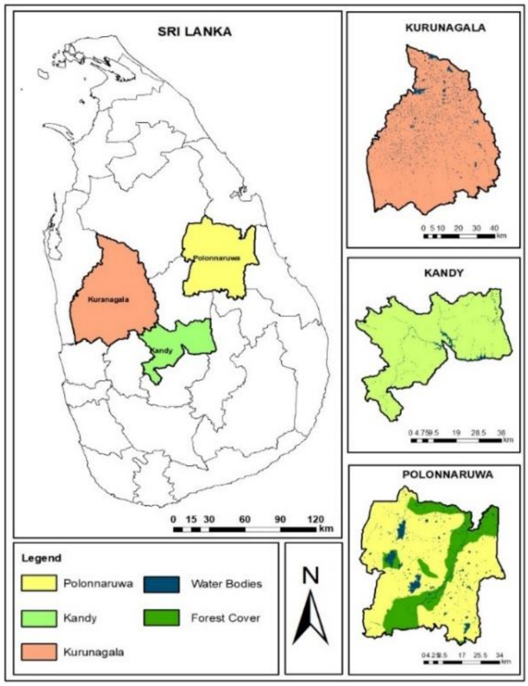

Figure 1: Study area map

Source:1: 50,000 Digital Data, Survey Department of Sri Lanka, 2008

3.3 Analysis Techniques

This study employed both spatial and temporal analysis techniques to meet the requirements of a geographical study. Two main approaches were utilized: statistical analysis and Geographic Information System (GIS) analysis. GIS analysis was conducted using ArcGIS 10.8 for the creation of all maps, while MS Excel and MS Word were used for data processing and organization.

For the analysis of rainfall data, the Standard Precipitation Index (SPI)was applied. The SPI, developed by McKee et al. (1993), is a widely accepted method for monitoring long-term drought conditions. The method was validated as effective for drought analysis by Alami et al. (2017).

The calculation of SPI involved the following steps:

1. Collection of actual rainfall data for the study area.

2. Calculation of the mean rainfall and the standard deviation (SD).

3. Application of the SPI formula:

$$SPI = \frac{(X_i - X_m)}{SD}$$

Where,
X_i – actual rainfall amount
X_m – average of rainfall
SD – standard deviation

The SPI index was used to classify drought severity based on the following categories:

Table 1: Classification of Drought Severity Using the Standard Precipitation Index (SPI)

Drought classes	SPI Value
Extremely wet	≥2.0
Severe wet	1.50 to 1.99
Moderately wet	1.0 to 1.49
Near Normal	0.99 to -0.99
Moderate drought	-1.0 to -1.49
Severe drought	-1.50 to -1.99
Extreme drought	≤ -2.0

Source: McKee et al, (1993)

The SPI analysis provided a detailed assessment of rainfall variability and drought conditions in the study area, facilitating a comprehensive understanding of the temporal patterns of drought.

4. Results

4.1 Comparative Analysis of Drought Occurrence in the Dry, Wet, and Intermediate Zones (Polonnaruwa, Kandy, Kurunegala Districts)

The analysis focuses on the occurrence of droughts, wet conditions, and near-normal conditions in the Polonnaruwa, Kandy, and Kurunegala districts, which represent the dry, wet, and intermediate zones, respectively. These districts experience varying amounts of rainfall from the northeast, southwest, and first and second inter-monsoonal periods. Based on the rainfall amounts, the Standard Precipitation Index (SPI) values reveal the drought, wet, and near-normal conditions in each district from 1993 to 2023 (Table 2).

Drought Events (1993–2023):

The Polonnaruwa district experienced 21 moderate drought years within these 30 years. These droughts occurred in the years 1993, 1995–1997, 1999–2000, 2002, 2005–202010, 2012–2014, and 2018–2022, highlighting the severity of drought conditions in the dry zone. Notably, Polonnaruwa did not experience any severe or extreme droughts during this period. (Table 2)

In contrast, the Kurunegala district, located in the intermediate zone, recorded only one moderate drought year, in 2003. Meanwhile, the Kandy district, situated in the wet zone, experienced moderate droughts in three years: 2004, 2011, and 2015.

Wet Events (1993–2023):

In terms of wet events, Polonnaruwa had only three wet years: 1994, 2011, and 2015. The Kurunegala district recorded the highest number of wet years, with 15 wet events identified. Kandy district had six wet years recorded during the study period.

Near-Normal Conditions:

Near-normal conditions were the most frequent in the Kandy district, with 21 years classified as near-normal. The Kurunegala district followed, with 14 near-normal years, while Polonnaruwa had the fewest near-normal years, indicating that it experienced greater climate variability compared to the other two districts.

Based on SPI calculations (Table 2), the Polonnaruwa district experienced the highest frequency of drought events and the fewest wet events when compared to Kandy and Kurunegala districts. This highlights Polonnaruwa district is most vulnerable to meteorological droughts.

Table 2- Classification of drought, wet, and near-normal years in Polonnaruwa, Kandy, and Kurunegala districts (1993–2023)

Year	Kandy SPI V.	Kurunegala SPI V.	Polonnaruwa SPI V.	Year	Kandy SPI V.	Kurunegala SPI V.	Polonnaruwa SPI V.
1993	1.105	0.210	-1.316	2009	0.464	0.924	-1.012
1994	-0.410	-0.966	1.377	2010	1.100	0.218	-1.388
1995	0.403	0.972	-1.375	2011	-1.134	-0.164	-1.319
1996	0.612	0.797	-1.410	2012	0.813	0.595	1.298
1997	-0.359	1.364	-1.005	2013	0.653	0.759	-1.408
1998	-0.377	1.368	-0.991	2014	0.225	1.076	-1.412
1999	0.930	0.457	-1.387	2015	-1.013	-0.347	-1.360
2000	1.064	0.273	-1.338	2016	-0.458	1.387	-0.929
2001	1.402	-0.546	-0.856	2017	-0.559	1.404	-0.845
2002	0.282	1.058	-1.341	2018	0.229	1.047	-1.346
2003	1.324	-1.091	-0.233	2019	-0.149	1.292	-1.143
2004	-1.222	1.226	-0.004	2020	-0.292	1.344	-1.051
2005	0.168	1.131	-1.300	2021	0.518	0.880	-1.398
2006	0.360	1.004	-1.364	2022	0.013	1.218	-1.231
2007	1.300	0.169	-1.131	2023	-0.925	1.388	-0.463
2008	-0.349	1.361	-1.012				

Note: - Moderate drought – Moderate wet - Near normal condition

Source: Created by authors base on analysis

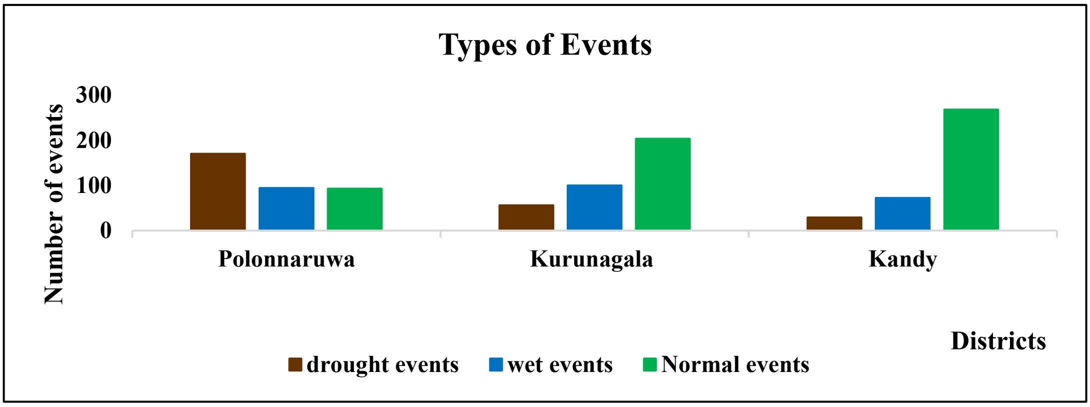

Figure 2: Drought, wet, and near-normal months in Polonnaruwa, Kandy, and Kurunegala districts (1993–2023).

Source: Created by authors base on analysis

Analysis of Monthly Drought, Wet, and Near-Normal Conditions (1993–2023):

Figure 2 presents the distribution of drought, wet, and near-normal months in the Polonnaruwa, Kandy, and Kurunegala districts between 1993 and 2023. Polonnaruwa experienced 170 drought months and 94 wet months over this period. In contrast, the Kurunegala district recorded 56 drought months and 100 wet months, with near-normal conditions being the most prevalent. In the Kandy district, 29 drought months and 72 wet months were observed, with near-normal conditions also being the most frequent.

4.2 Seasonal Analysis of Drought, Wet, and Normal Events in Polonnaruwa, Kandy, and Kurunegala Districts (1993–2023)

A seasonal analysis was conducted to assess the distribution of drought, wet, and near-normal events in the Polonnaruwa, Kandy, and Kurunegala districts over the period from 1993 to 2023. The data for each district were categorized according to the Northeast Monsoon, Southwest Monsoon, and the 1st and 2nd inter-monsoon periods (Figure 3).

During the Northeast Monsoon, the Kurunegala district recorded the highest number of drought events, with 38 drought months. In comparison, Kandy experienced 5 drought months, and Polonnaruwa had 4 moderate drought months (Table 3). Polonnaruwa also recorded the highest number of wet months (66), while Kurunegala had the fewest wet months. Normal conditions were most frequent in the Kandy district during this monsoon season (Figure 3).

The Southwest Monsoon exhibited a significant concentration of drought months in Polonnaruwa, with 102 moderate drought months recorded. In contrast, both Kandy and Kurunegala experienced only 8 moderate drought months each during this season (Table 3). In terms of wet events, Kurunegala recorded 50 wet months, while Kandy and Polonnaruwa had 10 and 14 wet months, respectively. Normal conditions were more prevalent in the Kurunegala district, although drought events were more common in Polonnaruwa during the Southwest Monsoon. Kurunegala experienced more wet events than both Kandy and Polonnaruwa during this period (Figure 3).

During the first inter-monsoon period, Polonnaruwa experienced 36 drought months, while Kandy and Kurunegala recorded 7 and 1 drought months, respectively (Table 3). In the second inter-monsoon period, Polonnaruwa experienced 28 drought months, Kurunegala 9, and Kandy 9 (Figure 3).

Table 3 summarizes the distribution of drought months across the districts during the different seasons. Polonnaruwa is the most drought-prone district, experiencing a total of 170 drought months, with the highest concentration during the Southwest Monsoon (102 months). Kurunegala experienced fewer drought months overall (56), with the majority occurring during the Northeast Monsoon (38 months). Kandy recorded a relatively moderate number of drought months (29) across all seasons.

Table 3:Seasonal Distribution of Drought Months in Kandy, Polonnaruwa, and Kurunegala Districts (1993–2023)

Season	***Kandy***	***Polonnaruwa***	***Kurunegala***
Northeast monsoon	5	4	38
Southwest monsoon	8	102	8
First inter monsoon	7	36	1
Second inter monsoon	9	28	9
Total	29	170	56

Source: Created by the Authors based on the analysis based on data from the Department of Meteorology,Colombo,Sri Lanka

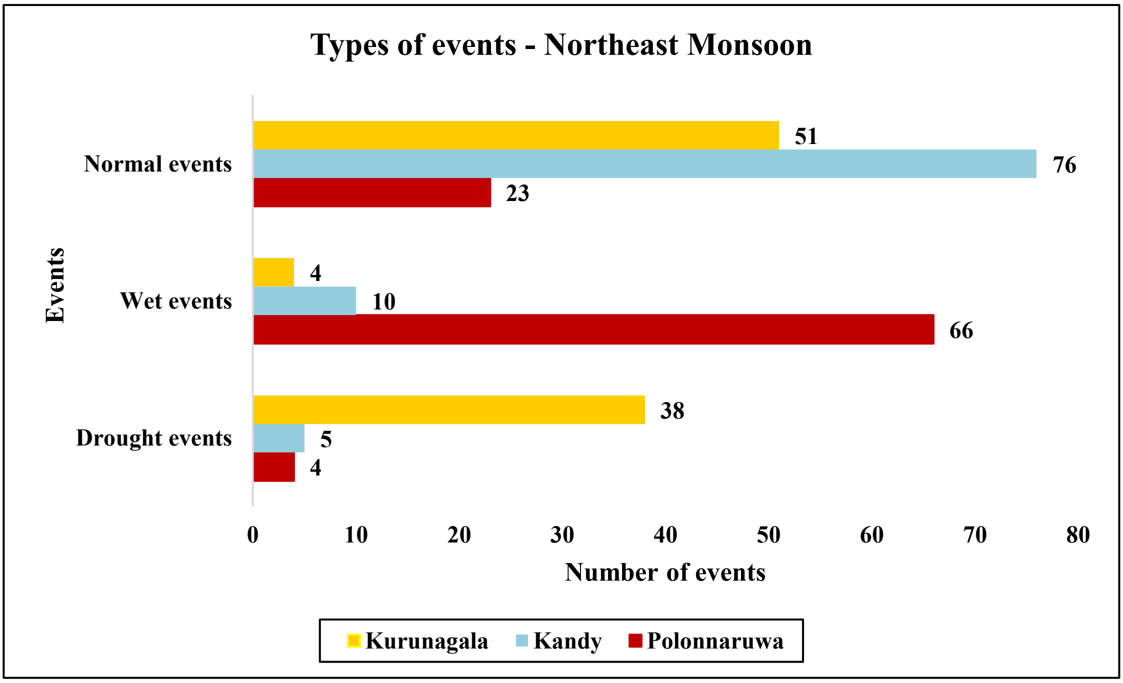

Figure 3: Seasonal Distribution of Drought, Wet, and Normal Events in Polonnaruwa, Kandy, and Kurunegala Districts (1993–2023).

Source: Created by authors base on analysis

4.3 Comparative Analysis of Drought Months in Kandy, Kurunegala, and Polonnaruwa Districts (1993–2023)

The occurrence of drought months across Kandy, Kurunegala, and Polonnaruwa varies significantly, largely influenced by the monthly rainfall patterns and the effects of monsoon rains. Monsoonal rainfall plays a critical role in triggering drought events, and the impact of these rains fluctuates from month to month. As a result, each district is affected by droughts at different times due to the variability in monsoonal precipitation (Table 4).

Table 4: Monthly Distribution of Drought Events in Kandy, Kurunegala, and Polonnaruwa Districts (1993–2023)

Months	Kandy	Kurunegala	Polonnaruwa
January	0	14	0
February	2	9	2
March	6	1	15
April	1	0	21
May	2	1	16
June	2	0	27
July	0	0	25
August	1	5	17
September	3	3	17
October	4	2	20
November	5	8	8
December	3	13	2

Source: Created by the authors based on Analysis with the Department of Meteorology, Colombo, Sri Lanka Data

Polonnaruwa consistently experiences a higher number of drought months, particularly from March to October. The district records the highest number of drought months in June, with 27 drought months during the study period, highlighting its greater vulnerability to drought conditions. Other months with significant drought occurrences in Polonnaruwa include April (21 months), May (16 months), and July (25 months), further demonstrating its susceptibility to prolonged dry periods during the year. (Table 4)

In contrast, Kurunegala shows a concentration of drought months in January (14 months) and December (13 months), with relatively fewer drought events recorded throughout the rest of the year. This suggests that the district is more affected by droughts during specific months rather than experiencing prolonged drought periods.

Kandy experiences comparatively fewer drought months overall, with a more even distribution of drought occurrences throughout the year. The district records its highest number of drought months in November (5 months), but no single month shows an extreme concentration of drought events. This indicates that Kandy is less prone to extended drought conditions compared to Polonnaruwa and Kurunegala. (Table 4)

4.4 Factors Influencing the Occurrence of Meteorological Droughts in Polonnaruwa, Kandy, and Kurunegala Districts in Relation to LST and NDVI

Rising land surface temperatures (LST) and reduced vegetation cover, as measured by the Normalized Difference Vegetation Index (NDVI), play a significant role in influencing meteorological droughts. As temperatures rise and vegetation cover diminishes, rainfall patterns are disrupted, leading to increased frequency and intensity of drought events. This analysis examines the relationship between these factors across the Polonnaruwa, Kandy, and Kurunegala districts, considering data from 2007, 2015, and 2021.

Table 5: Relationship between NDVI, LST, and Drought Events in Polonnaruwa (2007, 2015, 2021).

Year	NDVI	LST	Drought events
2007	H: 0.64 L: -0.15	H: 32 L: 14	38
2015	H: 0.56 L: -0.18	H: 28 L: 15	42
2021	H: 0.61 L: -0.13	H:35 L:16	

Source: Created by authors base on analysis

Polonnaruwa, there is a clear negative correlation between LST and NDVI, as shown in Table 5. Vegetation cover (NDVI) decreased from a high of 0.64 in 2007 to 0.61 in 2021, while LST increased from 32°C in 2007 to 35°C in 2021. This temperature rise corresponds with an increase in drought events, from 38 in 2007 to 42 in 2021.

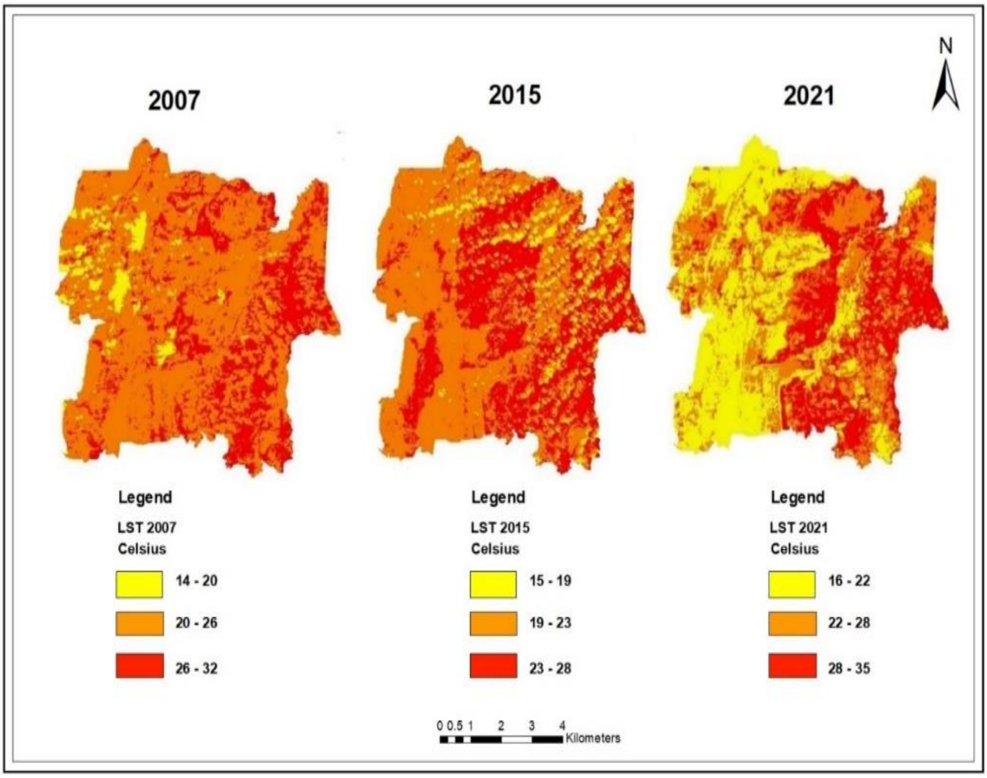

Figure 4. LST maps of Polonnaruwa district (2007, 2015 and 2021)

Source: USGS (Landsat 5 – 2007; and Landsat 8/9 – 2015, 2021); Map created by the authors

These findings indicate that higher land surface temperatures exacerbate drought conditions while decreasing vegetation cover intensifies these effects. The strong positive correlation between LST and drought events underscores the vulnerability of Polonnaruwa to meteorological droughts (Figure 4, Figure 5).The increase in LST is mapped against the decrease in NDVI, highlighting the direct impact that rising land surface temperatures have on drought frequency (Figure 4) The significant increase in drought events in Polonnaruwa is closely tied to the reduced vegetation cover, making it clear that the district's susceptibility to drought is heightened by both these factors.

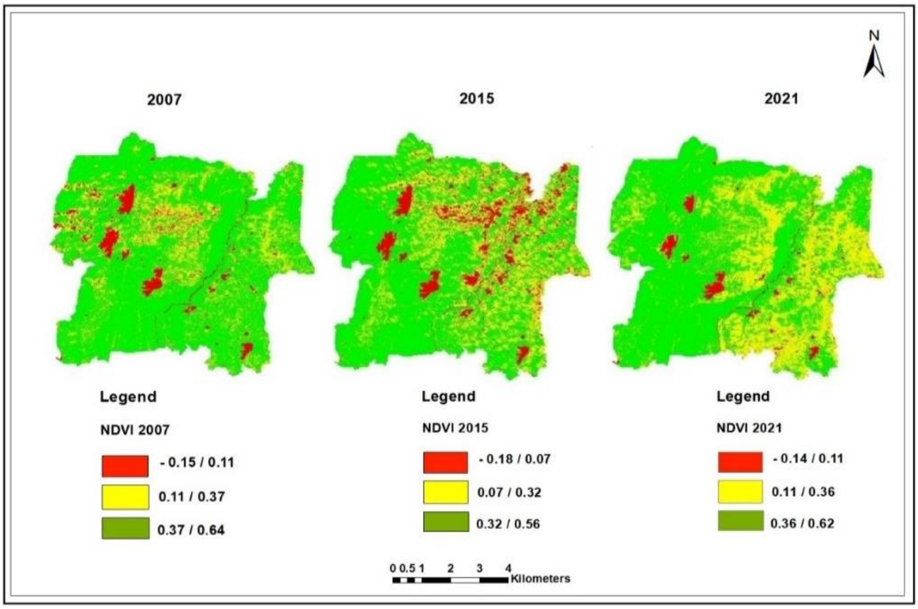

Figure 5:. NDVI maps of Polonnaruwa district (2007, 2015 and 2021)

Source: USGS (Landsat 5 – 2007; and Landsat 8/9 – 2015, 2021); Map created by the authors

Kurunegala, the data presented in Table 6 reveal a substantial decline in NDVI from 0.75 in 2007 to 0.60 in 2021, alongside an increase in LST from 27°C to 33°C during the same period. Despite this increase in temperature, the number of drought events decreased from 15 in 2007 to 6 in 2021, suggesting a negative correlation between LST and drought events. This is an interesting anomaly, likely due to Kurunegala's unique climatic conditions, where regular rainfall during the monsoon periods balances the impact of rising temperatures. SPI calculations also show that Kurunegala experiences both normal and wet conditions during most years (Figure 6, Figure 7).

Table 6: Relationship between NDVI, LST, and Drought Events in Kurunegala (2007, 2015, 2021)

Year	NDVI		LST		Drought events	
2007	H: 0.75 L: -0.79	↓	H: 27 L: 12	↑		↓
2015	H: 0.58 L: -0.17		H: 32 L: 17		15	
2021	H: 0.60 L: -0.25		H: 33 L: 11		6	

Source: Created by authors base on analysis

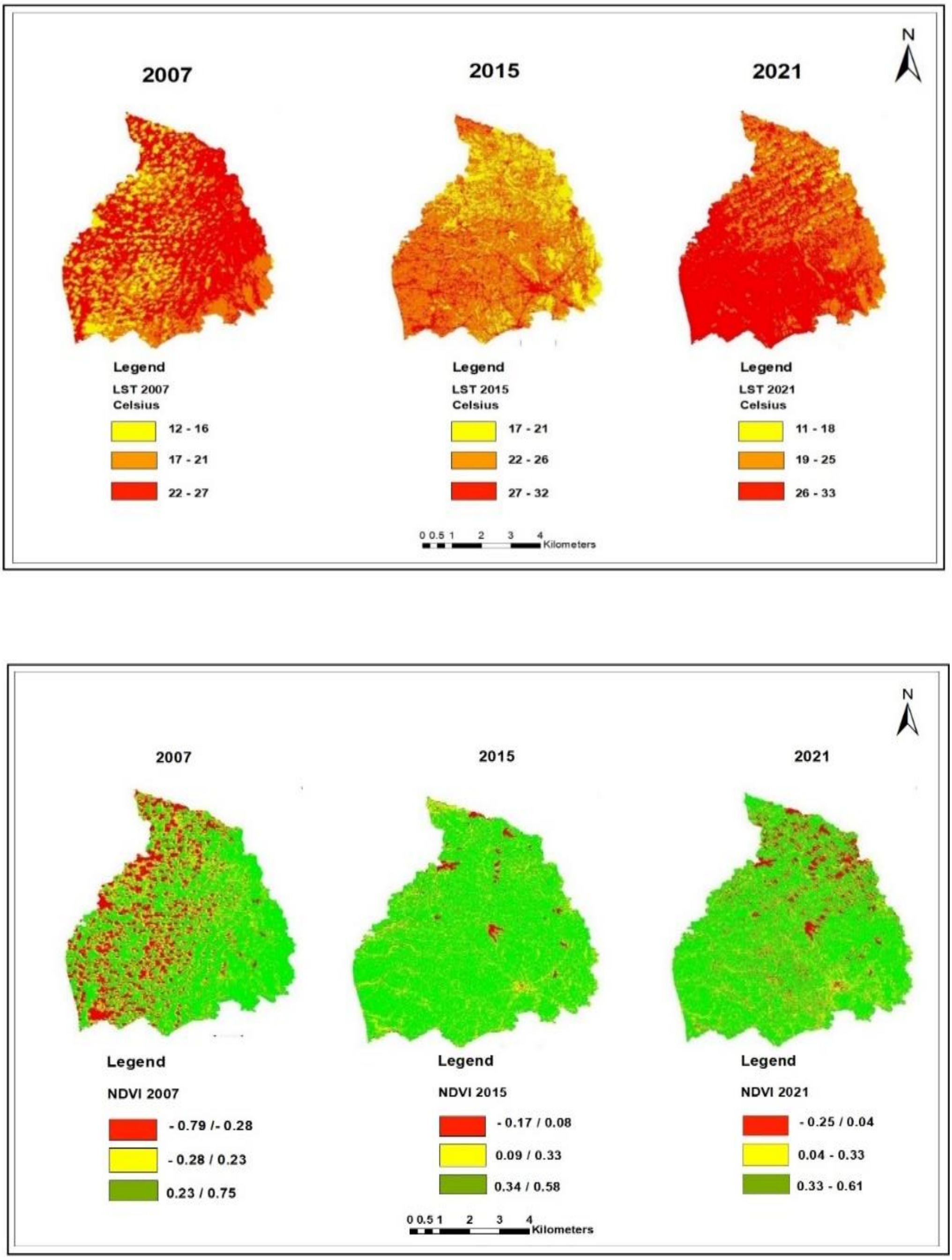

Figure 6: LST and NDVI Correlations in Kurunegala (2007–2021).

Source: USGS (Landsat 5 – 2007; and Landsat 8/9 – 2015, 2021); Map created by the authors

In Figure 6, the decrease in NDVI is plotted against the LST increase, showing that while the temperature is rising and number of drought events is decreasing in Kurunegala. This district's stable rainfall patterns during key periods mitigate the effects of high temperatures, maintaining overall climatic stability.

In Kandy, as shown in Table 7, vegetation cover decreased from 0.79 in 2007 to 0.58 in 2021, while LST remained relatively stable, ranging between 28°C and 32°C. Despite the reduction in vegetation cover, the number of drought events in Kandy showed little variation, with 7 drought months in 2007 and 11 in both 2015 and 2021. This stability suggests that other environmental factors, such as Kandy's higher elevation and geographic location, may help mitigate the impact of rising temperatures and maintain a relatively constant number of drought events (Figure 8).

Table 7: Relationship between NDVI, LST, and Drought Events in Kandy (2007, 2015, 2021)

Year	NDVI		LST		Drought events	
2007	H: 0.79 L: -0.41	↓	H: 32 L: 9	↓	7 11	↑
2015	H: 0.56 L: -0.12		H: 28 L: 9			
2021	H: 0.58 L: -0.14		H: 29 L: 9			

Source: Created by authors base on analysis

In Figure 8, the relationship between NDVI and LST is highlighted, showing the minimal impact of temperature increases on drought frequency in Kandy. The moderate increase in drought events between 2007 and 2021, despite falling vegetation cover, indicates that Kandy's environmental conditions may buffer the effects of rising temperatures on drought severity.

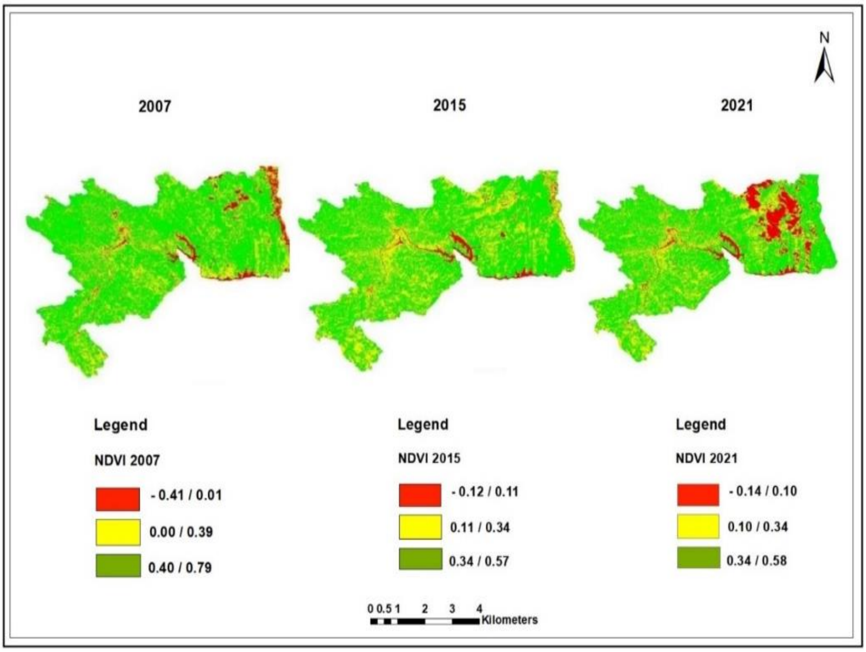

Figure 7: NDVI maps of Kandy district (2007, 2015 and 2021)

Source: USGS (Landsat 5 – 2007; and Landsat 8/9 – 2015, 2021); Map created by the authors

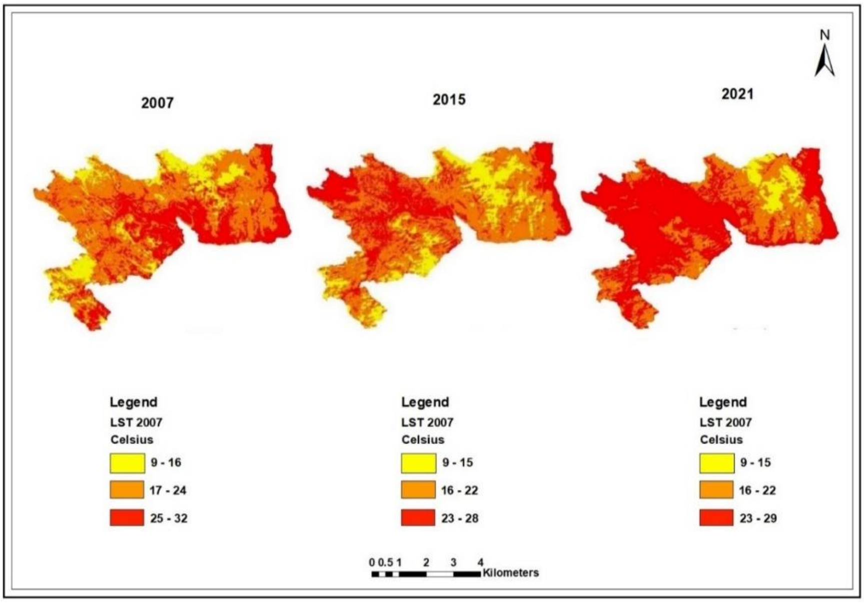

Figure 8: LST maps of Kandy district (2007, 2015 and 2021)

Source: USGS (Landsat 5 – 2007; and Landsat 8/9 – 2015, 2021); Map created by the authors

The overall analysis demonstrates a negative correlation between NDVI and LST across all three districts, with increasing temperatures and decreasing vegetation cover significantly affecting drought frequency. Polonnaruwa shows the strongest positive correlation between LST and drought events, with rising temperatures and reduced vegetation cover directly leading to more frequent droughts (Table 5, Figure 4). Kurunegala, despite experiencing rising temperatures, shows a decrease in drought events due to its stable rainfall patterns (Table 6, Figure 6, Figure 7). Kandy, with its stable LST and moderate drought variation, suggests other factors mitigate the temperature impact on droughts (Table 7, Figure 8). These findings underscore the critical role that land surface temperature and vegetation cover play in influencing meteorological droughts in these regions.

5. Discussion

The findings of this study indicate that Polonnaruwa is particularly vulnerable to meteorological droughts, experiencing 21 moderate drought years and 170 moderate drought months between 1993 and 2023. This pattern of moderate drought conditions, often persisting for 2 to 3 consecutive years, is a notable characteristic of the Polonnaruwa district. Similar findings have been reported in the dry zone of Sri Lanka, where Herath and Nianthi (2021) identified a five-year drought cycle in the Anuradhapura and Vavniya districts. This cyclical pattern underscores the vulnerability of dry zone regions to prolonged drought conditions.

Comparative data from other dry zone districts further highlight the susceptibility of the Polonnaruwa district to drought. Rajendram (2019) identified 11 moderate drought years and only one severe drought year in the Mannar district between 1991 and 2018. In contrast, Polonnaruwa experienced moderate drought conditions for 21 out of the 30 years studied, demonstrating a higher frequency of moderate droughts. Both Polonnaruwa and Mannar experienced moderate droughts during the same years—1999, 2005, 2006, 2007, and 2013—indicating shared climatic patterns across these dry zone districts. Additionally, in the Batticaloa district, Rajendram (2021) reported 17 moderate drought years, 6 severe drought years, and 2 extreme drought years over 149 years. These findings suggest that moderate droughts are more common than severe or extreme drought events in dry zone districts, which is consistent with the results from Polonnaruwa.

A more detailed analysis of seasonal drought patterns reveals that Polonnaruwa experienced more drought events during the first inter-monsoon (36 moderate drought months) compared to the second inter-monsoon period (28 moderate drought months). These findings align with the study by Herath and Nianthi (2021), who reported similar patterns in the Anuradhapura and Vavniya districts, where 3 and 5 drought events, respectively, were recorded during the first inter-monsoon, while only 2 events occurred during the second inter-monsoon. This suggests that the first inter-monsoon period is more prone to droughts in the dry zone, which further exacerbates the region's vulnerability to meteorological droughts.

When compared to international studies, similar trends are observed in other regions susceptible to drought. For instance, Ndlovu and Demlie (2020) found that in the KwaZulu-Natal (KZN) province of South

Africa, 1992, 1993, and 2015-2016 were the most extreme dry years, while 1984 and 2000 were identified as extreme wet years. In both regions, dry years tend to outnumber wet years, reflecting broader patterns of climate variability in dry and semi-arid regions. In contrast, the Kurunegala district, which lies in the intermediate zone of Sri Lanka, experienced 15 significant wet years, with only one moderate drought year in 2003. This finding highlights the relative resilience of the intermediate zone to meteorological droughts compared to the dry zone.

However, despite the relatively lower frequency of droughts in Kurunegala district, the Ministry of Agriculture & Plantation Industries' crop damage reports for 2023 revealed the highest level of crop damage in Kurunegala, suggesting the occurrence of agricultural drought. Interestingly, SPI calculations for 2023 classified the year as moderately wet in Kurunegala. This discrepancy suggests that agricultural droughts may not always align with meteorological droughts as measured by SPI. Other factors, such as uneven rainfall distribution, soil moisture depletion, or crop sensitivity to the timing of rainfall, may contribute to agricultural drought even during years classified as wet by meteorological indices. Therefore, Kurunegala, despite belonging to the intermediate zone, may still face significant agricultural challenges, underscoring the complexity of drought dynamics across different climatic zones.

Polonnaruwa remains the most drought-prone district based on meteorological data, it is crucial to recognize that agricultural impacts of drought may vary across regions, as evidenced by the situation in Kurunegala. This highlights the importance of region-specific drought mitigation strategies that consider both meteorological and agricultural factors in managing drought risk.

6. Conclusion and Recommendations

6.1. Conclusion

This study has highlighted the vulnerability of Polonnaruwa, Kandy, and Kurunegala districts to meteorological droughts, with Polonnaruwa being the most affected. Over the period from 1993 to 2023, Polonnaruwa experienced 21 moderate drought years, with 170 moderate drought months, making it the most drought-prone district among the three. During the southwest monsoon, Polonnaruwa recorded 102 moderate drought months, the highest of any district. In contrast, during the northeast monsoon, Kurunegala experienced the most drought months (38), while Polonnaruwa had the fewest (4).

The inter-monsoon periods also displayed significant drought variation. Polonnaruwa experienced 36 and 28 moderate drought months during the first and second inter-monsoon periods, respectively, with droughts being more prevalent during the first inter-monsoon. This pattern underscores the variability of drought conditions across different climatic periods in the dry zone.

In terms of environmental factors, significant changes in NDVI and LST were observed in Polonnaruwa between 2007 and 2021, corresponding to an increase in drought frequency. The rising land surface temperatures and decreasing vegetation cover in Polonnaruwa contributed significantly to its heightened drought vulnerability. In contrast, changes in LST and NDVI in Kurunegala had less of an impact on drought events. In Kandy, despite decreases in both LST and vegetation cover, drought events increased, indicating the complex interaction of environmental factors with drought patterns.

The study confirms that the dry zone, particularly Polonnaruwa, is most susceptible to meteorological droughts, followed by the intermediate zone (Kurunegala), with the wet zone (Kandy) being the least affected. The findings emphasize the need for targeted strategies to mitigate the impacts of drought in these regions.

6.2 Recommendations

To address the growing threat of meteorological droughts in Sri Lanka, particularly in the Polonnaruwa and Kurunegala districts, several key recommendations are proposed:

1. Rainwater Harvesting: Improving rainwater harvesting methods is essential, especially in Polonnaruwa and Kurunegala. Local communities should be encouraged to use rain barrels and tanks to collect and store rainwater for use during dry periods.

2. Drought-Resistant Crops: The Ministry of Agriculture should promote the cultivation of drought-resistant crops in Polonnaruwa and Kurunegala. Crops such as drought-resistant paddy and vegetables will help maintain agricultural productivity during drought conditions.

3. Drought Monitoring and Early Warning Systems: The Disaster Management Centre (DMC) and the Department of Meteorology should enhance the monitoring of drought conditions by closely tracking river and reservoir water levels as well as weather patterns. Advanced drought monitoring systems can enable early intervention and preparedness, reducing the impact of severe droughts.

4. Use of Advanced Technologies Geographic: Information Systems (GIS) and Normalized Difference Vegetation Index (NDVI) should be utilized to monitor desertification trends, especially in Polonnaruwa. Continuous monitoring of NDVI values can help identify areas at risk of desertification, allowing for timely interventions to protect vegetation cover.

By implementing these recommendations, Sri Lanka can better mitigate the effects of meteorological droughts, particularly in the dry and intermediate zones, and ensure that communities are more resilient to the challenges posed by climate variability.

7. References

Abeysingha, N. S., & Rajapaksha, U. R. L. N. (2020). SPI-Based Spatiotemporal Drought over Sri Lanka. *Advances in Meteorology*, *2020*. https://doi.org/10.1155/2020/9753279

Alami, M. M., Hayat, E., & Tayfur, G. (2017). Proposing a Popular Method for Meteorological Drought Monitoring in the Kabul River Basin, Afghanistan. *International Journal of Advanced Engineering Research and Science*, *4*(6), 103–110. https://doi.org/10.22161/ijaers.4.6.12

Assessment Capacities Project (ACAPS). (2019, August 23). *Sri Lanka: Drought*

[Briefing note]. https://www.acaps.org/fileadmin/Data_Product/Main_media/20190823_acaps_start_briefing_note_sri_lanka_drought_0.pdf

Basnayake, A., Jayasinghe, L., Nauki, T., & Weerathunga, S. (2019). *Disaster management in Sri Lanka: A case study of administrative failures*. *August*, 1–12. https://www.veriteresearch.org/wp-content/uploads/2019/07/Verité-Research_Disaster-Management-in-Sri-Lanka-A-Case-Study-of-Administrative-Failures.pdf

Burchfield, E. K., & Gilligan, J. (2016). Agricultural adaption to drought in the Sri Lankan dry zone. *Applied Geography*, 92-100.

Bushi, R. (2022). The normalized difference index (NDVI). Applied Vegetation Science, 5, 88–90.

Dai, A. (2011). Drought under global warming: a review. Wiley Interdisciplinary Reviews: *Climate Change*, 2011, 2:45–65.

Dissanayake, D. M. S. L. B., Morimoto, T., Murayama, Y., Ranagalage, M., & Perera, E. N. C. (2020). Analysis of life quality in a tropical mountain city using a multi-criteria geospatial technique: A case study of Kandy city, Sri Lanka. *Sustainability (Switzerland)*, *12*(7). https://doi.org/10.3390/su12072918

Great Britain Meteorological Office. (1951). *The Meteorological Glossary.* New York: Chemical Publishing Co.

Herath, C., Zhou, W., & Wang, J. (2024). Comparison of meteorological drought in the dry and wet zones of Sri Lanka. *Ecological Frontiers*. https://doi.org/10.1016/j.ecofro.2024.10.002

Herath, C., & Nianthi, R. (2021). Meteorological droughts in the dry zone of Sri Lanka. *8th International Symposium Water Quality and Human Health: Challenges Ahead.* Peradeniya: Peradeniya University of Sri Lanka.

Jayamaha G.S. (1975). An analysis of drought in Sri Lanka. J*ournal of Sri Lanka Meteorological Society*, 42A (2):133-14

Khan, A. A., Safdar, Q., & Khan, K. (2020). *Figure : Drought types, causes, effects and mitigation measures Figure : Drought types, causes, effects and mitigation measures*. *September*, 2–3. https://doi.org/10.13140/RG.2.2.29296.69120

Lanka, S. R. I., & Management, D. (2005). *PARLIAMENT OF THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA DISASTER MANAGEMENT*.

Li, Z.-L., Tang, B.-H., Wu, H., Ren, H., Yan, G., Wan, Z., ... Sobrino, J. A. (2013). Satellite-derived land surface temperature: Current status and perspectives. Remote Sensing of Environment, 131, 14–37.

Management, D. (2019). *Disaster Management Centre*. *October*, 10–12.

McKee T.B, Doesken N.J, Kleist J. (1993). Drought monitoring with multiple time scales. Paper presented at the Preprints, Eighth Conference on Applied

Climatology, Anaheim, California.

Ministry of Agriculture and Plantation Industries. (2023, 8 29). *Amount of crop damage reported as of 29.08.2023 - The amount of paddy fields damaged due to the prevailing drought condition has increased up to 58,766 acres.* Retrieved from agrimin.gov.lk: https://www.agrimin.gov.lk/web/index.php/en/en/news

National Drought Mitigation Center. (2020). *Types of drought.* University of Nebraska–Lincoln. May 25, 2025, from https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx

Ndlovu, M. S., & Demlie, M. (2020). *Assessment of Meteorological Drought and Wet Conditions Using Two Drought Indices Across KwaZulu-Natal Province, South Afric*.

Nianthi, R. (2014). *Farmers ' Responses to Drought : Dry Zone of Sri Lanka : (Case Study in Medirigiriya)*. *5*(6), 33–39.

Punyawardena B.V.R., T.M.J.Bandara, M.A.K.Munasinghe, N.J. Banda and S.M.VPushpakumara. (2003). *Agro-ecological Regions of Sri Lanka*. Natural Resources Management Center, Department of Agriculture, Peradeniya.

Rajendram, K. (2019). *An Assessment of Drought in Mannar District, Sri Lanka*. *November*, 1–13. https://doi.org/10.33642/ijhass.v4n11p1

Rajendram, K. (2021). *Rainfall Variability and Drought Occurrences in the Batticaloa District, Sri Lanka*. *39*(August), 30–45.

statista. (2022). Sri Lanka: Sri Lanka. *Situation Report*, *64*(2), 177–186.

Suppiah, R. and Yoshino, M.M. (1984). *Rainfall variations of Sri Lanka Part 1: Spatial and temporal patterns*. Archives for Meteorology, Geophysics, and Bioclimatology, Series B 34(4): 329 - 340.

Wijesekera, N. T. S., Leelananda, H. H., De Silva, S., & Jayamaha, S. U. B. (2008). Identification of the Spatial Distribution of Environmental Development Needs using GIS - a study of ruPolonnaruwa District, Sri Lanka. *Engineer: Journal of the Institution of Engineers, Sri Lanka*, *41*(5), 34. https://doi.org/10.4038/engineer.v41i5.7102

Wilhite, D. A., & Glantz, M. H. (1985). Glantz,1987. *Understanding the Drought Phenomenon: The Role of Definitions*. http://digitalcommons.unl.edu/droughtfacpub%0AWilhite,