Assessing the drought extent using multiple indices of LANDSAT data -Case study of Coimbatore District

Immanual Jeyasingh R. Alex, Suguna Devakumari M.*, Isaac Manuel R. and Augustine R.
School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore, INDIA
*sugisathish@yahoo.com

Abstract
Coimbatore, a significant industrial and agricultural centre in Tamil Nadu, has experienced drought-related problems over the last 15 years, which have been made worse by climate change. Using Landsat satellite data, this study performs a spatial-temporal analysis of the drought in Coimbatore from 2010 to 2024 to evaluate changes in the frequency, length and intensity of drought occurrences. The vegetation health index (VHI) was developed to track drought conditions by evaluating data on land surface temperature (LST) and normalized difference vegetation index (NDVI).

The results underscore the worsening drought conditions by showing a significant loss in vegetation health and an increase in land surface temperatures across the research period. The VHI demonstrated efficacy in monitoring the onset and intensity of drought, providing insightful information for regional water management, agricultural planning and climate adaptation strategies. This research underscores the importance of remote sensing in understanding and mitigating the impacts of drought in vulnerable regions like Coimbatore.

Keywords: Landsat, drought, remote sensing.

Introduction

Coimbatore, a major industrial hub and agricultural region in Tamil Nadu, has increasingly faced the challenges of drought over the past decade and a half. The period from 2009 to 2024 has witnessed significant fluctuations in rainfall patterns, largely influenced by the broader impacts of climate change. These changes have intensified the frequency and severity of drought events, posing serious threats to both agriculture and the water security of the region. Coimbatore's semi-arid climate and reliance on the southwest monsoon make it particularly vulnerable to rainfall variability. As climate change alters monsoon patterns, the region has experienced more frequent droughts, leading to reduced agricultural productivity, strained water resources and broader socio-economic impacts.

To understand the evolving nature of drought in Coimbatore, it is crucial to analyse its spatial and temporal dimensions over this period. The use of remote sensing technology, particularly Landsat satellite data, provides a robust framework for monitoring these changes. Landsat's extensive archive offers a valuable resource for examining how drought conditions have developed over time and across different areas of Coimbatore.

This study conducts a spatial-temporal analysis of drought in Coimbatore from 2010 to 2024, utilizing Landsat data to assess changes in the extent, duration and intensity of drought events. The analysis aims to reveal trends that are indicative of broader climate change impacts, providing insights that are critical for local water management, agricultural planning and climate adaptation strategies. By understanding these patterns, this research contributes to the development of more effective responses to the challenges posed by drought and climate change in Coimbatore.

Study area

The Coimbatore district in Tamil Nadu, India, is renowned for its varied topography which includes hills, forests, agricultural plains and urban centres. Located between latitudes 10.5°N and 11.5°N and longitudes 76.5°E and 77.5°E is the district. The Western Ghats, which border the district on its western side and the lowlands and gently sloping plateaus make up the central and eastern regions of the Coimbatore district. The Noyyal river, which runs through the district from west to east, is the main river in the Coimbatore district.

Near the district's northern edge also flows the Bhavani river, a tributary of the Cauvery river. The district's height varies from the plains at roughly 400 meters (1,300 feet) to the Nilgiri hills at over 2,200 meters (7,200 feet). The Coimbatore district has a tropical climate that is both rainy and dry, with winter temperatures of 18°C (64°F) and summer temperatures of 35°C (95°F). Approximately 700 mm of rain fall on the area on average each year, with the majority coming from the southwest monsoon. In the western portion of the district, orographic rainfall is caused by the influence of the Western Ghats.

In the Coimbatore district, the soil types range from black cotton soil in the plains to red loamy and lateritic soils in the mountainous regions. The presence of alluvial soil along the riverbanks supports agriculture. The district has a mix of vegetation including tropical forests in the Western Ghats, scrublands in the plains and agricultural crops. The forested areas are home to diverse flora including teak, sandalwood and bamboo.

Material and Methods

Drought may be efficiently monitored over wide areas using remote sensing technology. Since satellite-borne remote sensing data offers a synoptic picture of the Earth's surface,

it can be used to assess the spatial distribution of drought incidence[1]. A number of remotely sensed drought indices including those for duration, intensity, severity and spatial extent, have been created and put to use[2]. Among those indices, one of the most often used methods for monitoring drought episodes is the normalized difference vegetative Index (NDVI), which serves as a probe for vegetative health[3,4]. It has been suggested that combining temperature and vegetation index will improve the method.

When the land surface temperature (LST) and the NDVI are combined, there is a strong link that provides helpful information to identify Using agricultural drought as a warning system in advance[5]. The vegetation health index (VHI) has shown a higher capability and a better applicability in detecting dryness, despite the introduction of numerous vegetative drought indicators based on remote sensing data[6,7].

Throughout the observation period, it takes into account the thermal state of the vegetation (TCI) as well as the vegetation condition (VCI). Consequently, vegetation drought stressed by temperature is then evaluated by VHI[7,8]. Land surface temperature (LST) and normalized difference vegetation index (NDVI) data can be used to calculate both parameters. The long term series of 2009, 2014, 2019 and 2024 dry season Landsat data was used in this research to compute the VHI due to the availability of reasonably good high resolution data.

In this study, Landsat is taken into consideration because of its open-access policy and its relatively good temporal and spatial resolution for monitoring drought[9,10]. This study aims to determine the extent of the drought in the Coimbatore district of Tamil Nadu, India. To ascertain the different conditions of drought extent in both regencies during these eras, an inter-comparison of the drought for the long-term sequence of 2009, 2014, 2019 and 2024 is also carried out.

Results and Discussion

The extent of the drought in the Coimbatore district of Tamil Nadu was tracked using Landsat data. In order to determine variations in the health of the plants during the dry season in 2009, 2014, 2019 and 2024, stacked NDVI layers were created. High NDVI values indicate healthy and thick vegetation and NDVI has emerged as the primary technique for describing vegetation phenology[11]. The study regions' spatial variance in vegetation health is indicated by the variety in NDVI.

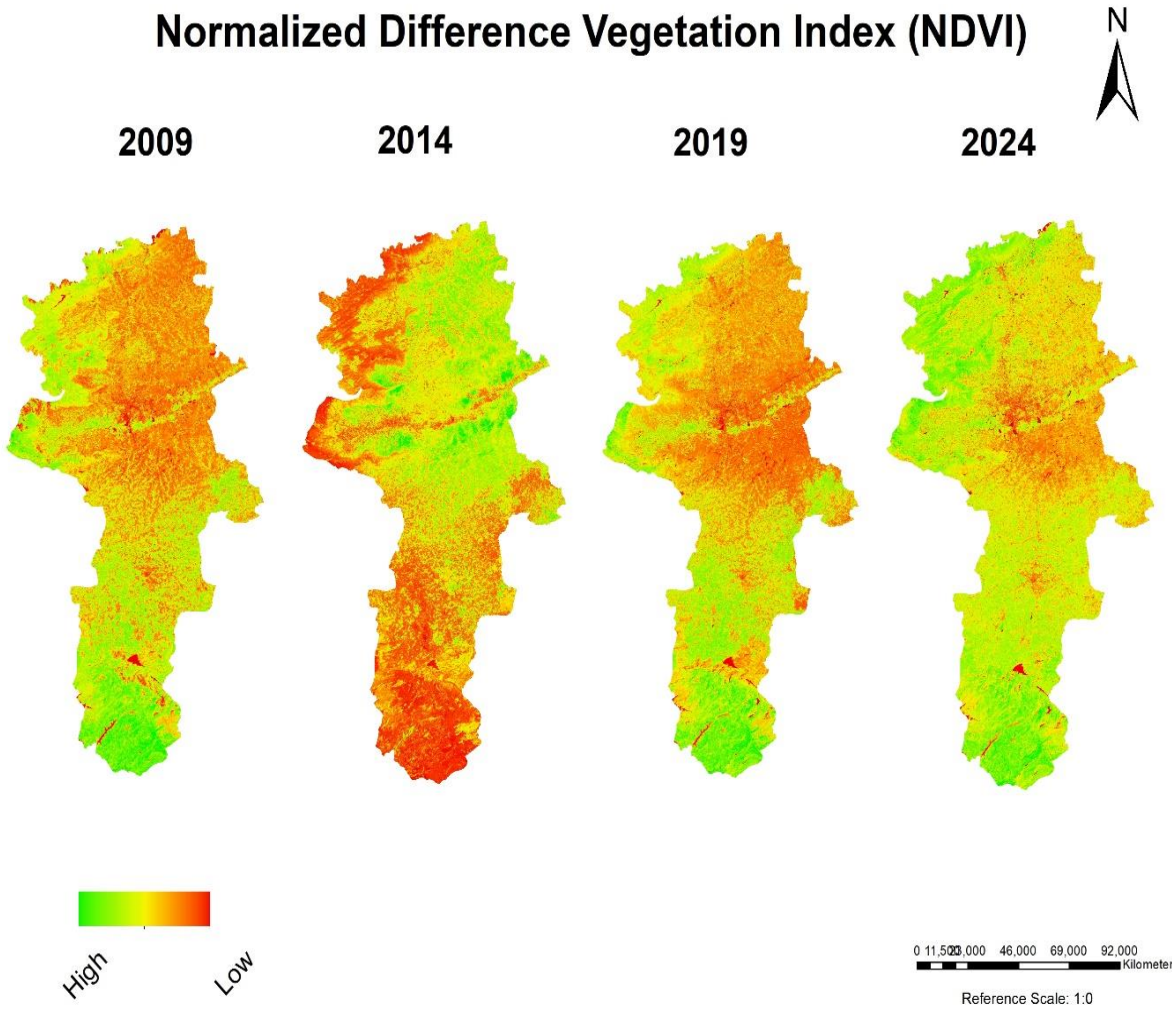
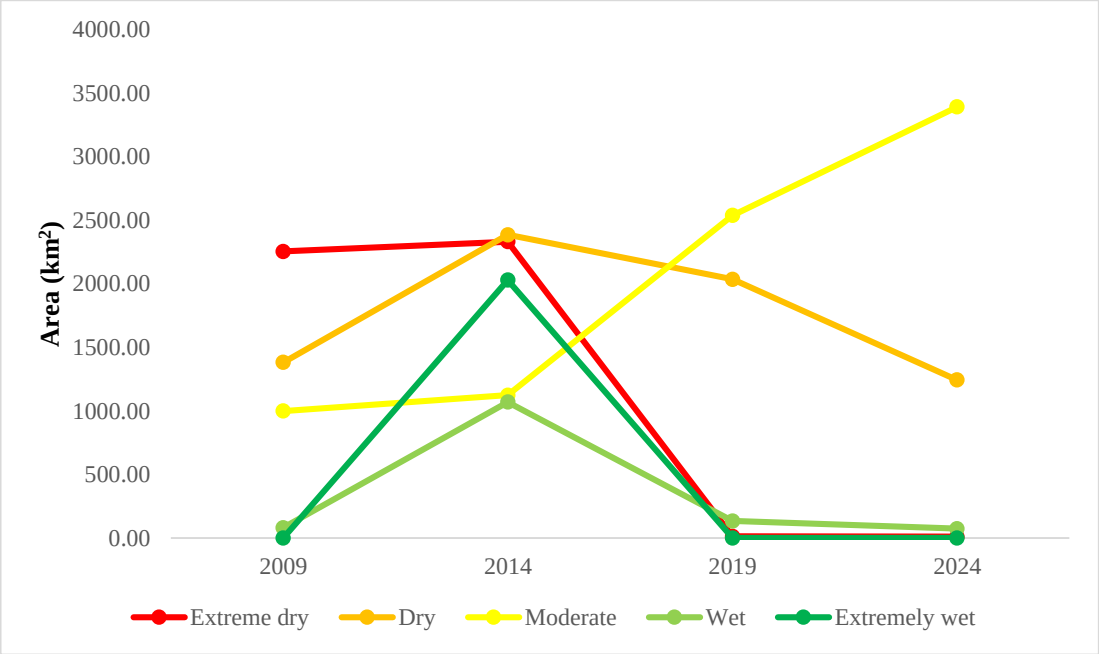


Fig. 1: Displaying the dynamic values of NDVI for each year.

Table 1
Illustrating how the NDVI value tends to drop during the observation period

Index Used	Drought Class Severity	2009	Area (%)	2014	Area (%)	2019	Area (%)	2024	Area (%)
NDVI	Extreme dry	2253.72	47.79%	2330.52	26.08%	11.84	0.25%	9.37	0.20%
	Dry	1380.91	29.28%	2384.34	26.69%	2035.07	43.15%	1242.54	26.35%
	Moderate	997.69	21.16%	1123.07	12.57%	2537.02	53.79%	3390.76	71.91%
	Wet	80.74	1.71%	1068.42	11.96%	132.75	2.81%	72.89	1.55%
	Extremely wet	0.00	0.00%	2028.03	22.70%	0.00	0.00%	0.00	0.00%
		4715.567997		8934.387422		4716.675121		4715.565232	



Graph 1: Drought area trend from NDVI

Table 2
The LST time series for the years 2009, 2014, 2019 and 2024.

Index Used	Drought Class Severity	2009	Area (%)	2014	Area (%)	2019	Area (%)	2024	Area (%)
LST	Extreme	0.00	0.00%	0.00	0.00%	4712.23	100.00%	4712.23	100.00%
	Severe	6.92	0.15%	177.87	3.77%	0.00	0.00%	0.00	0.00%
	Moderate	130.77	2.77%	2498.83	53.02%	0.00	0.00%	0.00	0.00%
	Mild	784.59	16.64%	2036.36	43.21%	0.00	0.00%	0.00	0.00%
	No Drought	3793.29	80.44%	0.00	0.00%	0.00	0.00%	0.00	0.00%
		4715.567997		4713.065023		4712.234538		4712.2336	

Table 1 illustrates how the NDVI value tends to drop during the observation period. Relying solely on the NDVI as the primary criterion for drought monitoring was insufficient to assess the intensity of the drought on a regional level. For this reason, adding a new parameter is required to increase accuracy. LST was employed as a second parameter in this instance. High LST typically indicates dry soil. According to above table, LST increased dramatically between 2009 and 2024. Dry conditions typically have low NDVI and high LST. Combining both indicators will allow for a more spatial representation of the condition. Then, all datasets were mapped to the vegetation health index (VHI), which is a representation of the temperature condition index (TCI) and vegetation condition index (VCI).

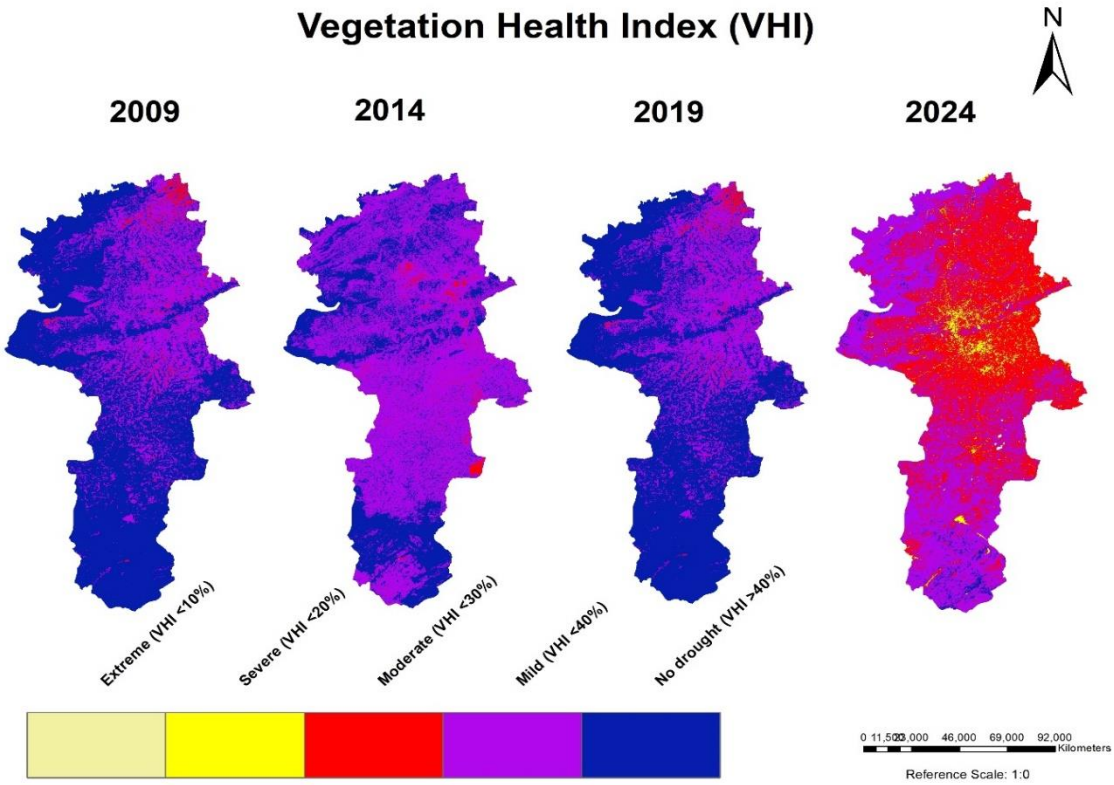
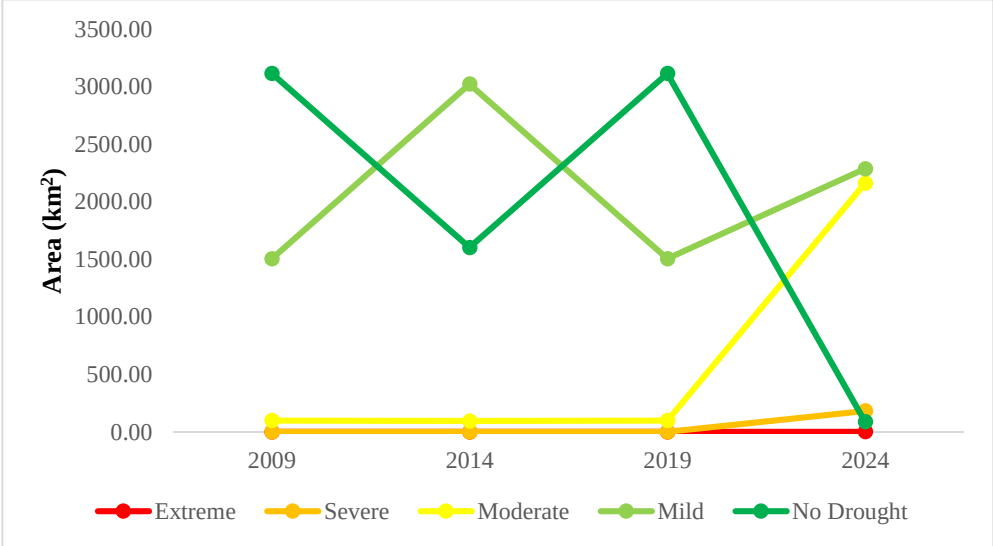


Figure 2: Displaying the spatial variation of the VHI at the years 2009, 2014, 2019 and 2024.

Table 3
Severity drought for VHI in 2014, 2019 and 2024

Index Used	Drought Class Severity	2009	Area (%)	2014	Area (%)	2019	Area (%)	2024	Area (%)
VHI	Extreme	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.10	0.00%
	Severe	0.00	0.00%	0.04	0.00%	0.00	0.00%	181.73	3.86%
	Moderate	98.23	2.08%	93.79	1.99%	98.23	2.08%	2159.19	45.82%
	Mild	1503.54	31.90%	3020.62	64.07%	1503.54	31.90%	2284.67	48.48%
	No Drought	3112.22	66.02%	1600.40	33.94%	3112.22	66.02%	86.53	1.84%
		4713.992073		4714.858099		4713.992073		4712.230007	



Graph 2: Drought area trend from VHI

According to the data, VHI dropped by more than half between 2009 and 2024, from 3112.22 to 86.53. This graph suggested that the amount of drought, ranging from moderate to severe, has been considerable throughout the research region. The primary cause of the severity, as determined by correlating the VHI with specific LST and NDVI readings, was the increase in LST from 2009 to 2024. Furthermore, from 2009 to 2024, there was a downward trend in NDVI values, indicating a lack of planting activity throughout the most recent dry seasons.

Conclusion

The output of VHI estimations can serve as an early warning system for agricultural drought by tracking its onset. This study attempts to identify the spatio-temporal extent of agricultural drought over Coimbatore using satellite-borne remote sensing data based on vegetation health index (VHI). We found that this index can be successfully used to identify the spatio-temporal extent of agricultural drought. It explains drought severity classes in the research areas through composite analysis of both vegetation health by vegetation condition and temperature condition of vegetation. The results can contribute to monitoring onset of agricultural drought as early warning system.

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