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Geospatial Mapping of Drought Risk in Thuan Bac District, Vietnam Using Landsat 8 OLI-TIR Data

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Abstract: ***This study evaluates drought risk in Thuan Bac District, Ninh Thuan Province, Vietnam, between 2018 and 2023 using Landsat 8 OLI-TIR imagery. Geospatial indices including the Temperature Vegetation Dryness Index (TVDI), the Normalized Difference Vegetation Index (NDVI), and surface temperature data were applied to classify drought severity into five categories. The resulting maps were validated with field observations and indicate that over 60% of the district experienced moderate to severe drought during the study period. Areas with minimal or extreme drought conditions accounted for a smaller proportion. This case study illustrates the effectiveness of remote sensing in drought risk assessment and provides vital insights for sustainable land and water resource management in semi-arid regions.***

Keywords: Drought, Remote sensing, Landsat 8, TVDI, Thuan Bac.

1. Introduction

In recent years, the integration of cutting-edge scientific advancements and rapidly evolving technological innovations into the fields of disaster forecasting and management has gained remarkable momentum. This trend has not only reshaped traditional approaches to hazard preparedness but has also attracted substantial attention and investment from a wide range of stakeholders, including national governments, international organizations, research institutions, and humanitarian agencies. The growing interest in these modern methodologies reflects a broader and more profound recognition of the indispensable role that advanced tools, data analytics, and evidence-based strategies play in strengthening our collective capacity to anticipate, monitor, and respond to natural hazards with greater accuracy and efficiency.

Among the most transformative technologies contributing to this shift is satellite remote sensing, which has emerged as a cornerstone in environmental monitoring and disaster risk assessment. By providing timely, high-resolution, and wide-area observations of Earth's surface, satellite systems enable scientists, policymakers, and emergency planners to gain comprehensive insights into dynamic environmental conditions. These insights are crucial for identifying early warning signs, assessing the severity of potential threats, and formulating effective response strategies. Remote sensing technologies are particularly valuable in regions where ground-based data collection is limited or logistically challenging, offering a reliable and scalable alternative for continuous surveillance.

One of the most widely utilized satellite platforms in this domain is Landsat 8, a sophisticated Earth observation system that delivers detailed imagery across multiple spectral bands. These images allow users to analyze surface features, detect subtle changes in land cover, and evaluate environmental stressors such as drought, deforestation, and soil degradation. The extensive spatial coverage and consistent temporal resolution provided by Landsat 8 make it an ideal tool for tracking the progression of drought conditions over time and pinpointing areas that are especially susceptible to water scarcity. This capability is instrumental in guiding the development of targeted mitigation strategies, optimizing resource allocation, and supporting long-term planning for climate adaptation and sustainable land management.

A compelling illustration of the practical importance of satellite-based drought monitoring can be found in Thuan Bac District, situated in Ninh Thuan Province, Vietnam. According to a detailed report released in 2023 by the People's Committee of Ninh Thuan Province, Thuan Bac was officially classified as a Level 4 drought risk zone—the highest level of vulnerability in the national drought risk assessment framework. This designation underscores the severity of water-related challenges facing the district and highlights the urgent need for precise identification and mapping of drought-prone areas. By leveraging remote sensing data and geospatial analysis, local authorities and disaster management agencies are better equipped to implement proactive interventions, including the establishment of early warning systems, the design of sustainable water resource management plans, and the promotion of community-based resilience initiatives.

Ultimately, these efforts are aimed at minimizing the adverse impacts of drought on agricultural productivity, food security, public health, and the overall quality of life for affected populations. As climate variability continues to intensify, the integration of scientific and technological solutions into disaster preparedness will remain a critical priority for building adaptive capacity and safeguarding vulnerable communities around the world.

This study aims to identify drought-prone zones in Thuan Bac District using geospatial analysis of Landsat 8 data, providing a scientific basis for risk mitigation and resource management.

2. Study Area and Data used

2.1 Study Area

Thuan Bac District, situated in the heart of Ninh Thuan Province in south-central Vietnam, has been selected as the focal area for this study due to its distinctive climatic and geographical characteristics. The district is known for its consistently hot and dry weather patterns, which persist throughout the year and contribute to the formation of a semi-arid climate regime. This persistent dryness is largely influenced by the region's topography, which includes low-lying hills and limited vegetation cover, as well as its location within a rain shadow zone that restricts moisture-laden winds from bringing significant rainfall.

As a result of these natural conditions, Thuan Bac is widely recognized as one of the most drought-prone areas in the country. The region frequently experiences prolonged periods of water scarcity, which have serious implications for agriculture, water resource management, and the livelihoods of local communities. The average annual temperature in the district hovers around 27°C, contributing to high rates of evapotranspiration that further exacerbate the effects of limited rainfall. Annual precipitation levels are relatively low, typically ranging between 700 and 800 millimeters, and are unevenly distributed across the seasons, with rainfall concentrated in brief, intense episodes during the monsoon seasons.

These climatic constraints pose significant challenges for sustainable development and disaster preparedness in Thuan Bac. The district's vulnerability to drought has prompted increased attention from researchers, policymakers, and environmental agencies, all of whom recognize the need for targeted interventions. Understanding the spatial and temporal dynamics of drought in this region is essential for designing effective monitoring systems, implementing adaptive agricultural practices, and developing long-term strategies to enhance community resilience in the face of climate variability.

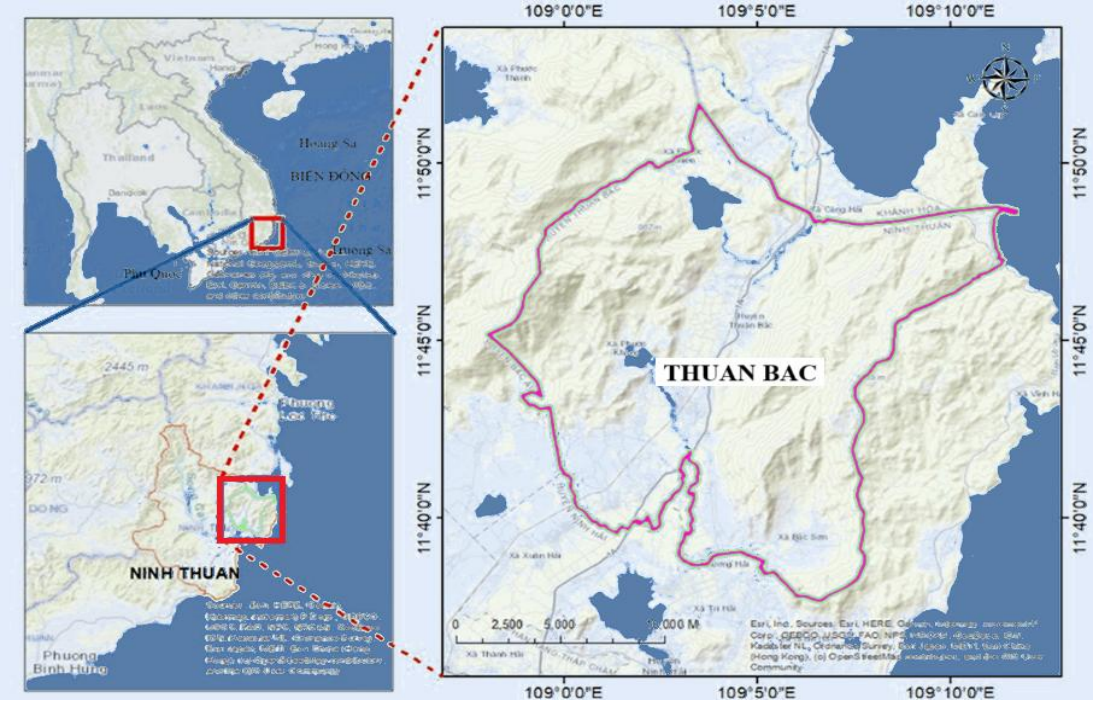


Figure 1: Study area

2.2. Data used

The core dataset employed in this research consists of satellite imagery acquired from the Operational Land Imager and Thermal Infrared Sensor (OLI_TIR) onboard the Landsat 8 satellite. These images were carefully selected for their ability to provide detailed and reliable surface information across multiple spectral bands, which is essential for conducting spatial analysis related to drought conditions. Landsat 8 imagery is particularly well-suited for environmental monitoring due to its moderate spatial resolution, consistent temporal coverage, and accessibility through open data platforms.

In the context of this study, the use of Landsat 8 OLI_TIR imagery enables the identification of key indicators of drought, such as vegetation stress, soil moisture anomalies, and land surface temperature variations. By analyzing these parameters over time, researchers can detect patterns of environmental degradation and assess the severity and extent of drought across the study area. The satellite data also support the generation of vegetation indices—such as the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST)—which are widely used in drought assessment models.

Moreover, the integration of satellite imagery into the study provides a cost-effective and scalable approach to monitoring drought in regions where ground-based observations are limited or unavailable. This is especially important in semi-arid areas like Thuan Bac District, where traditional meteorological data may be sparse or inconsistent. By leveraging the capabilities of remote sensing technology, the study aims to enhance the accuracy and efficiency of drought

mapping, ultimately contributing to more informed decision-making and better resource management in vulnerable regions.

Table 1: Landsat 8 Imagery Data for the Study Area [1]

No.	Image ID	Acquisition Date	Path	Row	Processing Level / Format	Spatial Resolution
1	LC08_L1TP_123052_20180126_20190413_01_T1.tar	26/01/2018	126	46	L1T/GEOTIFF	30m
2	LC08_L1TP_123052_20230124_20230128_01_T1.tar	24/01/2023	126	46	L1T/GEOTIFF	30m

3. Research Methodology

The Temperature Vegetation Dryness Index (TVDI) is derived from the relationship between surface temperature and soil moisture, serving as an indicator of drought severity. TVDI comprehensively evaluates the interaction and variation between the Normalized Difference Vegetation Index (NDVI) and surface temperature (TS). In conditions of water scarcity, vegetation may initially appear green; however, surface temperature can rise rapidly due to insufficient moisture. The integration of temperature and NDVI provides valuable insights into vegetation health and surface moisture conditions [2–4].

The TVDI values range from [0, 1], where higher TVDI values indicate lower soil moisture and correspondingly higher drought severity, and vice versa. TVDI is determined using the following formula [4]:

$$\text{TVDI} = \frac{T_S - T_{S_{min}}}{a + b * NDVI - T_{S_{min}}} \quad (1)$$

Where:

- T_S represents the surface temperature at the pixel being evaluated,
- $T_{S_{min}}$ is the minimum surface temperature observed within the "wet edge" of the NDVI–TS feature space triangle, and
- $T_{S_{max}}$ is the maximum surface temperature observed for each NDVI interval.

To determine $T_{S_{max}}$, a linear regression model is applied to the maximum surface temperature values corresponding to discrete NDVI intervals. The value of $T_{S_{min}}$ can be taken as the lowest surface temperature observed within the study area.

At the "dry edge," the TVDI value is equal to 1, while at the "wet edge," the TVDI value is 0. Therefore, the key step in constructing the TVDI is the accurate determination of surface temperature (TS) and the "dry edge" line. The dry edge is modeled as a linear approximation, and for each NDVI interval, the corresponding maximum surface temperature pixels are identified to define this boundary.

$$T_{S_{max}} = a + b * NDVI \quad (2)$$

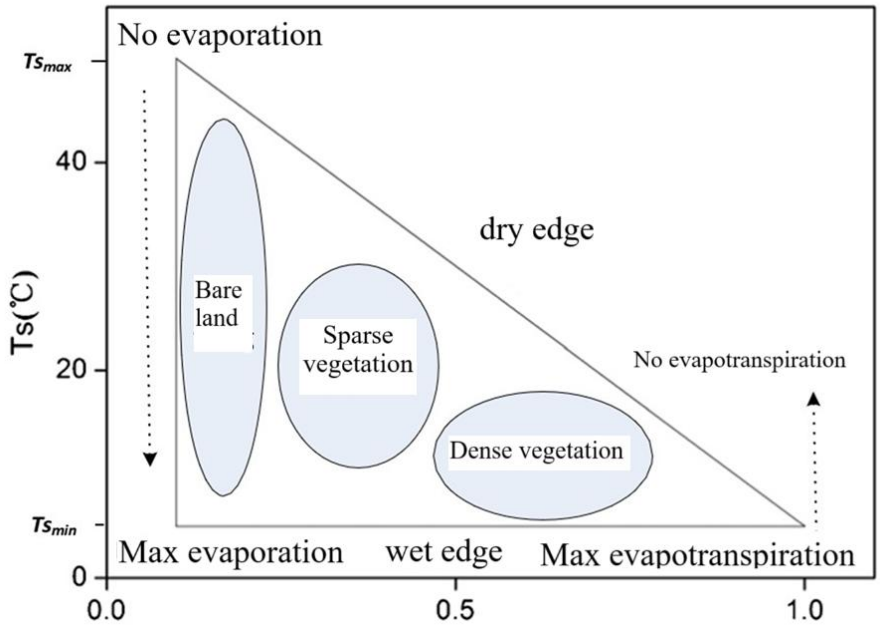
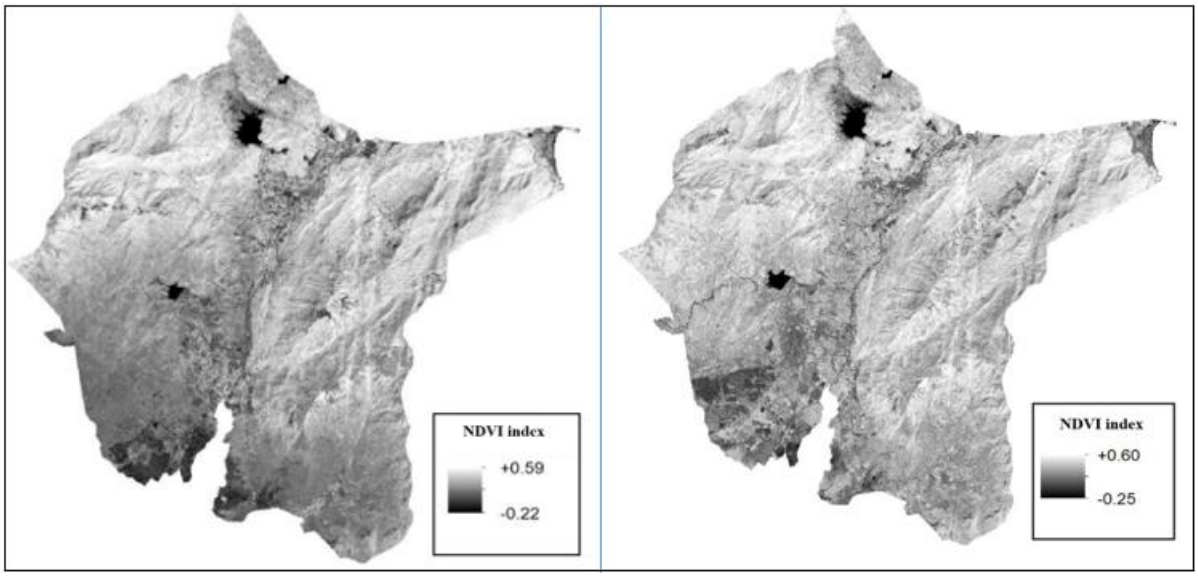


Figure 2: Correlation Graph Between Vegetation Index (NDVI) and Surface Temperature (TS) [4]

4. Results and Discussion

To determine the NDVI, Land Surface Temperature (LST), and TVDI indices, this study employed ArcGIS Desktop version 10.7.

Experimental results indicate that the NDVI values derived from Landsat 8 imagery for the study area range from approximately -0.2 to +0.6.

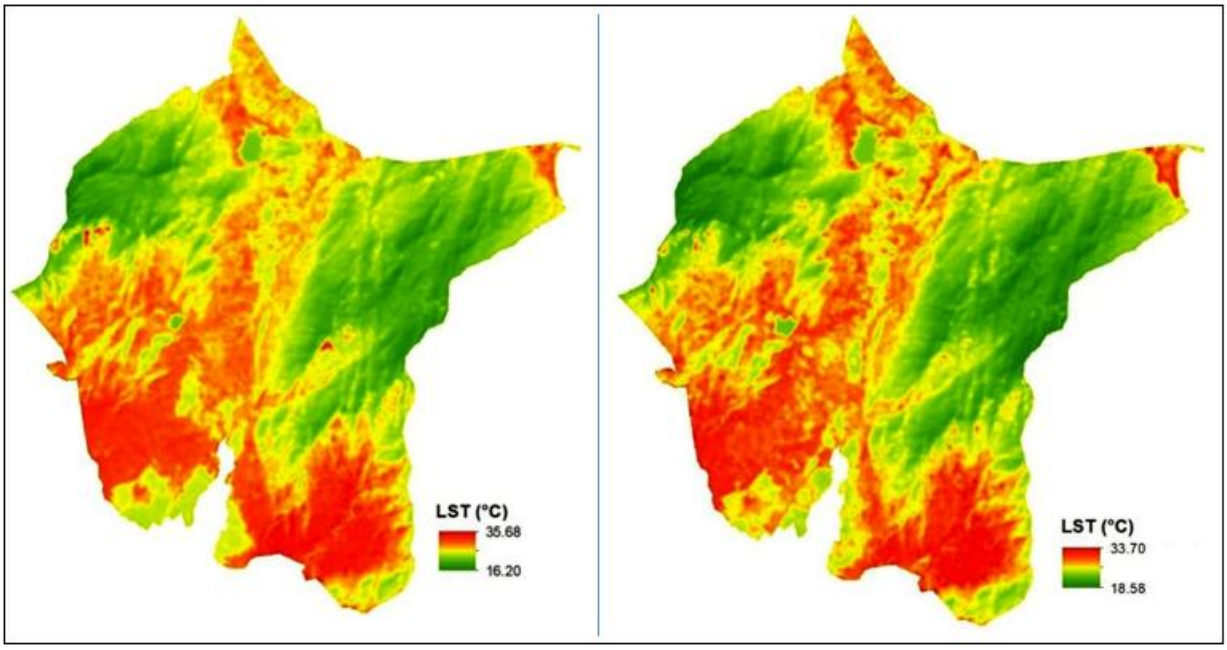


2018 **2023**

Figure 3: NDVI Values in the Study Area

The surface temperature results for Thuan Bac District (Ninh Thuan Province) are presented in Figure 4. Analysis of the data indicates that areas with high surface temperatures are primarily distributed in regions lacking vegetation cover.

To compute ($T_{S_{max}}$) within the LST/NDVI feature space, the NDVI values were divided into 20 intervals. For each interval, the maximum surface temperature was identified. A scatter plot of surface temperature as a function of NDVI was constructed for each satellite image.



2018 **2023**

Figure 4: Surface Temperature (TS) Determination Results in the Study Area

The results obtained from the analysis of surface temperature data specifically pertaining to Thuan Bac District, which is located within Ninh Thuan Province, are comprehensively illustrated and visually represented in Figure 4.. Analysis of the data indicates that areas with high surface temperatures are primarily distributed in regions lacking vegetation cover.

To compute ($T_{S_{max}}$) within the LST/NDVI feature space, the NDVI values were divided into 20 intervals. For each interval, the maximum surface temperature was identified. A scatter plot of surface temperature as a function of NDVI was constructed for each satellite image.

To calculate TVDI using Equation (1), the minimum surface temperature value ($T_{S_{min}}$) was taken from the lowest observed temperature in the study area. The parameters a and b of the "dry edge" for each image were determined using a least squares regression applied to the maximum temperature values corresponding to the NDVI intervals.

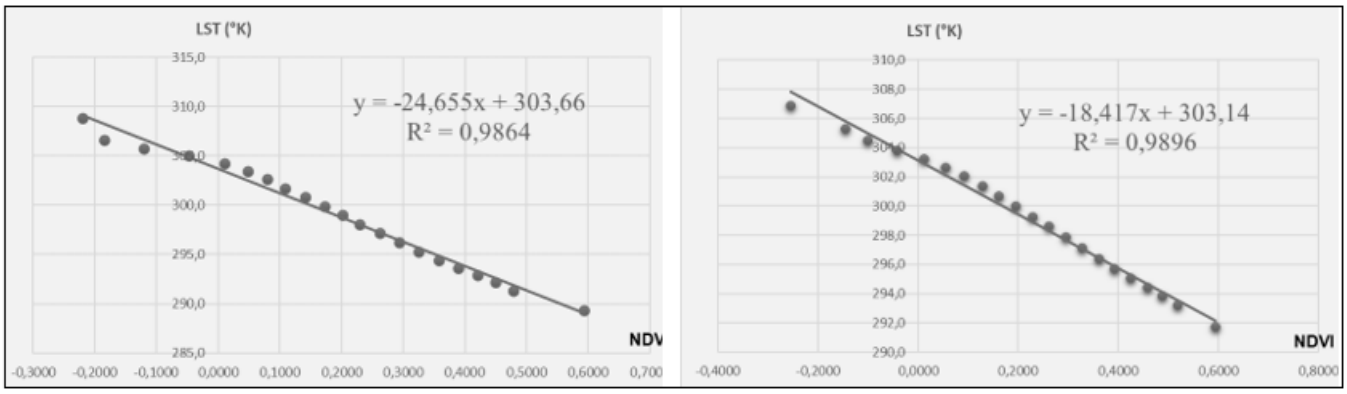
Figure 5 presents the dry edge regression lines for Thuan Bac District in 2018 and 2023, with the respective parameters a and b identified. With these parameters held constant, the

TVDI value for each pixel in the Landsat images from 2018 and 2023 was calculated as follows:

$T_{S_{max}}$ (2018) = -24.655 x NDVI + 303.66 (K)

$T_{S_{max}}$ (2023) = -18.417 x NDVI + 303.14 (K)

The coefficient of determination (R^2) for the years 2018 and 2023 were 0.9864 and 0.9896, respectively, indicating a high level of reliability in the regression model.



2018 **2023**

Figure 5: Dry Edge Values Determined by Linear Regression

The TVDI index ranges from 0 to 1. To generate a map assessing surface drought severity, the calculated TVDI values were processed using ArcGIS software, which assigns color codes to each region based on value intervals [5]. The drought severity zoning maps for Thuan Bac District in 2018 and 2023, at a scale of 1:100,000, based on TVDI values, are presented in Figure 6. Following the calculations and statistical analysis, the areas classified as experiencing moderate drought were approximately 126 km² in 2018 and 128 km² in 2023. Mild drought zones covered 91 km² in 2018 and 91 km² in 2023. Severe drought areas accounted for 72 km² in 2018 and 70 km² in 2023. The remaining areas, categorized as either non-drought or extreme drought, occupied smaller portions: approximately 18 km² and 9.9 km² in 2018, and 20 km² and 7 km² in 2023, respectively (Table 2).

Analysis of the results indicates that the majority of Thuan Bac District's area experienced moderate to severe drought, comprising over 60% of the total region. Areas projected to have no or low drought risk accounted for more than 30% of the district. Zones with extreme drought conditions were relatively limited, occupying only 2–3% of the total area.

The findings also highlight the critical role of vegetation cover in mitigating drought risk. In regions that have been reforested or newly afforested, surface temperatures tend to be lower, resulting in reduced drought severity. Conversely, residential areas with sparse vegetation exhibit higher surface temperatures, which correspond to increased drought intensity.

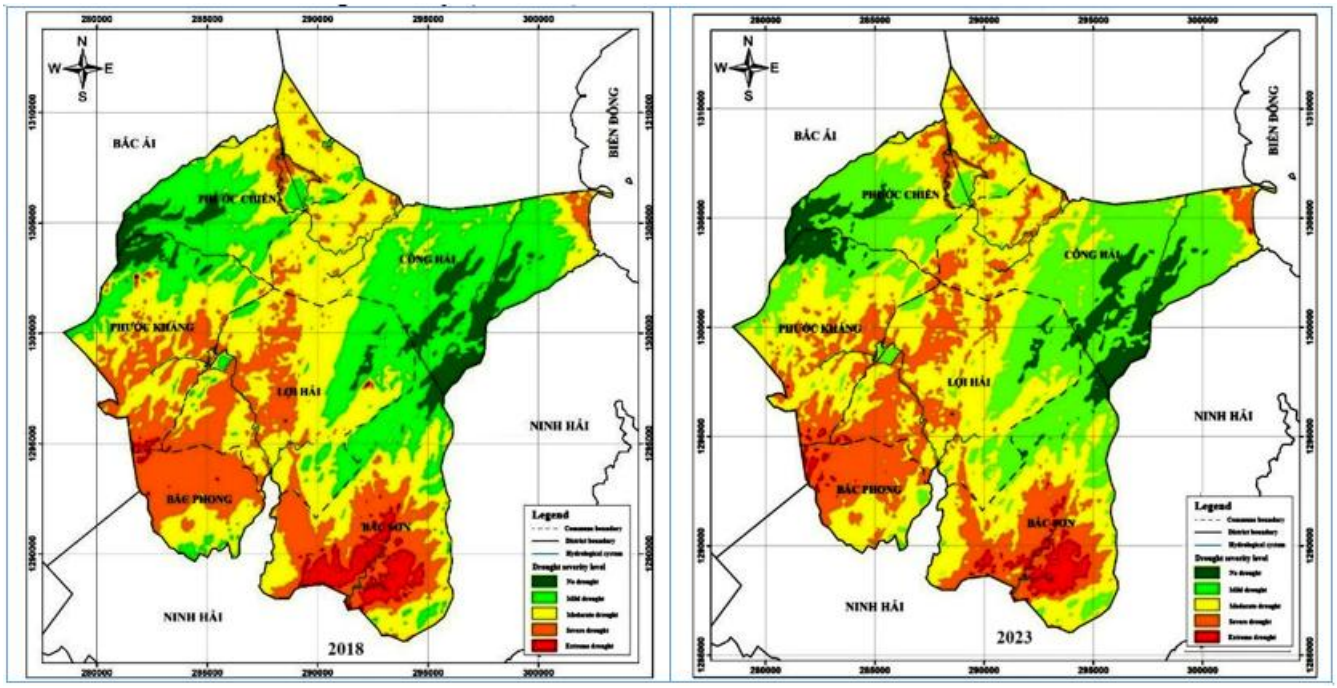


Figure 6: Drought severity classification map of Thuan Bac district, Ninh Thuan province

Table 2: Relative drought zoning in Thuan Bac district

Year / Drought Level	2018		2023	
	Area			
	(km²)	*(%)*	*(km²)*	*(%)*
No Drought	18.9819	5.98	20.7639	6.54
Mild Drought	91.1134	28.38	91.2141	28.73
Moderate Drought	126.6273	39.88	128.0511	40.33
Severe Drought	71.8218	22.62	72.4304	22.18
Extreme Drought	9.9594	3.14	7.0443	2.22

The study conducted a comprehensive collection of data related to drought conditions in Thuan Bac District, focusing specifically on the situation as it stood in the year 2018. This effort aimed to establish a clear understanding of the spatial extent and severity of drought across the district during that time. By analyzing environmental indicators and referencing official sources, the research was able to provide a detailed snapshot of drought impacts on local land use and natural resources.

In particular, the findings cited from reference [6] offer valuable insights into the distribution and intensity of drought within the district. These findings are systematically presented in Table 3, which outlines the extent of drought-affected areas in 2015. The table serves as a key component of the study, helping to visualize the severity of drought across different communes and providing a foundation for further analysis related to drought risk management, agricultural planning, and environmental monitoring in Thuan Bac District.

Table 3 presents a detailed overview of the drought-affected area in Thuan Bac District for the year 2018, indicating that approximately 91 square kilometers of land were impacted by drought conditions. This figure represents a substantial portion of the district's total area and highlights the widespread nature of the drought during that period. When this is compared to the area specifically classified as experiencing severe and extreme drought measured at 81.7 square kilometers, it becomes evident that the majority of the drought-affected land was subject to high-intensity conditions.

Table 3: Drought Area in Thuan Bac District in 2015

Region	Drought-Affected Area				
	Natural Area (km^2)	Drought-Affected Area (km^2)	Percentage Affected (%)	Severely Drought-Affected Area (km^2)	Percentage Severely Affected (%)
Thuan Bac	318.609	91	28.6	7	2.2

The comparison between the total drought-affected area and the subset experiencing severe and extreme drought suggests that the methodology used to estimate drought severity, despite being based on multi-temporal satellite data, produced results that are both consistent and credible. This reinforces the reliability of remote sensing and spatial analysis techniques in capturing environmental stressors with a high degree of accuracy. Furthermore, the close alignment between the two figures supports the validity of the classification criteria and strengthens the case for using such data in future drought monitoring and early warning systems.

These findings are particularly important for local authorities and planners, as they provide a scientific basis for prioritizing areas most in need of intervention. By identifying zones with the highest levels of drought severity, decision-makers can allocate resources more effectively, implement targeted mitigation strategies, and enhance community resilience against future climate-related challenges.

5. Conclusion

The research results indicate that from 2018 to 2023, a large portion of Thuan Bac District in Ninh Thuan Province was affected by drought, with over 60% of the area experiencing moderate to severe conditions. These droughts significantly impacted agriculture, water resources, and local livelihoods, emphasizing the region's vulnerability to climate stress and the need for ongoing monitoring and adaptive strategies.

Among the communes, Bac Son had the largest area under severe to extreme drought 29.7 km² in 2018 and 24.1 km² in 2023 showing some spatial variation over time. Bac Phong Commune had the highest proportion of land affected, with over 95% of its area classified as severe or extreme drought, indicating high exposure and risk. In contrast, Cong Hai Commune experienced the lowest drought severity, with only 38.7% of its area affected, possibly due to more favorable local conditions.

The main outcome of the study is a drought severity zoning map of Thuan Bac District at a 1:100,000 scale. This map is a valuable tool for visualizing drought distribution and supports disaster preparedness, response planning, and long-term mitigation efforts. It helps guide decisions to reduce the environmental and socio-economic impacts of drought on local communities.

The findings of this study are critical for informing drought response strategies and promoting climate resilience in one of Vietnam's most drought-affected districts. They also contribute to the broader application of remote sensing tools in environmental hazard monitoring.

References

[1] http://glovis.usgs.gov, acccessed 10/2/2025.
[2] Le Sam, Nguyen Dinh Vuong, The selection of a research formula of drought index and applying to calculate droughty requency in Ninh Thuan province. The Southern institute of water resources research – Proceeding of 2008, 2008.
[3] Eskinder Gidey, O.D., Reuben Sebego, Eagilwe Segosebe & Amanuel Zenebe, Analysis of the long-term agricultural drought onset, cessation, duration, frequency, severity and spatial extent using Vegetation Health Index (VHI) in Raya and its environs, Northern Ethiopia. Environmental Systems Research volume 7, Article number: 13. 2018.

[4] Rasmussen K., S.I., Anderson J., A simple interpretation of the surface temperature/vegetation index space for assessment of the surface moisture status. . Remote Sensing of Environment, 79, pp. 213–224, 2002.
[5] Trinh Le Hung, Application of landsat thermal infrared data to study soil moisture using temperature vegetation dryness index. Vietnam journal of earth sciences, 36(3), 262 – 270. , 2014.
[6] Bui Quang Huy, Tran Trung Kien, An Quang Hung, Vu Huu Long, Nguyen Vu Giang, Application of Multi-Temporal Satellite Imagery for Rapid Assessment of Drought Severity in the Central Highlands and South Central Provinces,Technical Report, Institute of Space Technology, 2016