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Spatiotemporal Mapping of Agricultural and Meteorological Drought in Wasit Province Based on GIS and Remote Sensing Data

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ABSTRACT

One of the most common natural hazards that can endanger life and property is drought, which can happen under a variety of weather and environmental circumstances. This study aims to monitor the agricultural and metrological drought in the Wasit Province using remote sensing data. Landsat 8 images were used to create the agriculture drought maps based on the NDVI for the years 2013, and 2023. Additionally, SPI-12 was used for the same years to evaluate the meteorological drought. The findings demonstrated that while SPI readings in 2023 were lower, the SPI-12 in 2013 indicated near-normal drought types. Two types of drought have been identified: moderate and slight. The result shows that, for the year 2013 the percentage of moderate drought is 31%, slight drought 64%, and no drought 3.9% from the total area. While, in 2023 the percentage of moderate drought is 47%, slight drought 49%, and no drought 3.2% from the total area. It is noticed that in 2023, the moderate drought class increased by about 16%. Government planners may find this results valuable when developing and managing drought consequences.

Keywords: GIS, drought, NDVI, SPI, remote sensing.

INTRODUCTION

Drought is an expensive, detrimental, and gradual natural occurrence that significantly impacts a region's economy, social activities, and ecosystem [Thenkabail et al., 2004]. A drought is a protracted period of insufficient rainfall that effects on agriculture and water supplies [Nixon et al., 2000; Wilhite and Glantz,1985]. Drought falls into three categories: agricultural, meteorological, and hydrological. The lack of rainfall can define drought as severely impacting the lives of plants and animals [Dracup et al., 1980]. It is anticipated that the drought would get worse, and as a result of the overall climate change scenario, the affected areas may get bigger. In recent decades, nature has seen many anomalies with the environment, which leads to a change in the Earth temperature in increased the land degradation [Dolchinkov, 2024]. Remote sensing technique provide a spatiotemporal up to date in various scale data, that could be very effective in monitoring and analysis the drought risk, and studying the drought impact [Hussein et al., 2023]. Remote sensing considers very effective to understand the drought and manage water supply, especially in arid and semi-arid regions. The vegetation cover, land surface temperatures, and soil moisture content are all important variables in studying the drought, and remote sensing can provide these factors precisely. GIS coupled with remote sensing data could be used to monitoring the drought risk area and enhance the emergency response plane [Arshad et al., 2008; Aziz et al., 2023]. Additionally, it could enhance endeavors aimed at conserving water resources and mitigating drought. Various researchers were evaluated the environmental and economic impact of the drought by mapping the changes in the environment over time period using satellite data. Additionally, the remote sensing considers very helpful in the identification of drought zone, development of mitigation plans, and improving the water resources management. According to Alwan et al. [2019] remote sensing technique can be used to monitor the changes in vegetation, assess groundwater and surface water, and identify the locations that are experiencing drought. Experts and planner can implement strategy to mitigate drought by identifying regions with difficulties related to soil and water through analysis the remote sensing data. For example, Satellite data can be used to monitor vegetation changes and detect areas of desertification, which can help direct efforts to enhance irrigation and water resources.

The meteorological drought could be defining as the evidence and sudden absence of precipitation [Panu and Sharma, 2002]. Khan et al. [2023] examined the stability of extreme precipitation events across Pakistan's regions and gained important knowledge for estimating extreme rainfall at locations where rainfall data are accessible. One of the most often used indicators for characterizing droughts is the SPI. McKee et al. created the SPI index in 1993. Due to its resilience, it was widely utilized to study the droughts since then [Noruzi, 2007]. various timelines are utilized to characterize the meteorological drought using the SPI [Hayes et al., 1999]. The SPI can be used in regions with climatically varied environments. Based on the availability of diverse water resources, the SPI characterizes abnormal wetness or drought at multiple timescales (such as surface and ground water, soil moisture, and reservoir storage). Various vegetation indicators exist, but the NDVI is considered adequate and frequently used to monitor drought and agricultural production [Liu and Huete, 1995; Alwan and Aziz, 2022]. The NDVI can be used to analyze trends in agricultural drought and changes in vegetation [Sruthi and Aslam, 2014].

In the recent years, because of the global climatic changes, Iraq suffer from irregular rainfall patterns, and increased the temperatures that cause more evaporation, and result in widespread drought, which puts further strain on the availability of water resources. Drought can lead to substantial economic losses, a drop in the growth of the domestic product, crop failure, and an impact on livestock rearing and mortality [Araya and Stroosnijder 2011]. The current study involved the reclassification of drought maps of Wasit into a common scale, taking into account the occurrence of drought, using agricultural and metrological drought indices. The process of creating a drought frequency map included reclassifying each drought index into a binary image for every class of drought severity. Then, these maps are combined and the drought could be classifying to moderate, slight, and no drought events for both agricultural and meteorological droughts at the pixel level. This map could be used to identify adaptation strategies for increasing agricultural productivity in the study area.

The present study uses GIS and remote sensing to map the regional pattern of drought severity in Wasit Province. An analysis of the vegetative stress brought on by less precipitation should also be included in the agricultural drought evaluation. Regarding agricultural policies, planners and regional authorities may find the results helpful.

STUDY AREA

The study area represented in Wasit Province, situated 172 km south of Baghdad, between longitudes 44° 40' – 46° 40' E and latitudes 32° 00' ˏ 33° 50' N, as depicted in Figure 1. Wasit shares borders with the Diyala Province to the Northeast and Dhi Qar to the Southwest. In addition, Iran Mehran City borders it on the East, while Al-Diwaniyah and the Babil Province border it on the West. Situated at the center of the Province, Kut is separated into nearly equal portions by the Tigris River. The Province, which has roughly four square kilometers of agricultural arable area, is regarded as one of the agricultural Provinces. Wasit's nomenclature is based on its location, between Kufa and Basra [Al-Hamawi, 1977]. The environment of the Wasit Province is arid, with only periodic and occasional rainfall. The rainy season ranges from October to April. The study's area faces an extended dry season from May to October due to the disruption of rainfall. The high temperatures that follow cause a great deal of evaporation, which exacerbates dryness and degrades soil [Shahad et al., 2021].

MATERIALS AND METHOD

Dataset

Satellite image

Landsat 8 images play a vital role in monitoring the drought. In this study, Landsat 8 images was used to analysis the drought phenomenon, the image's specification is shown in Table 1.

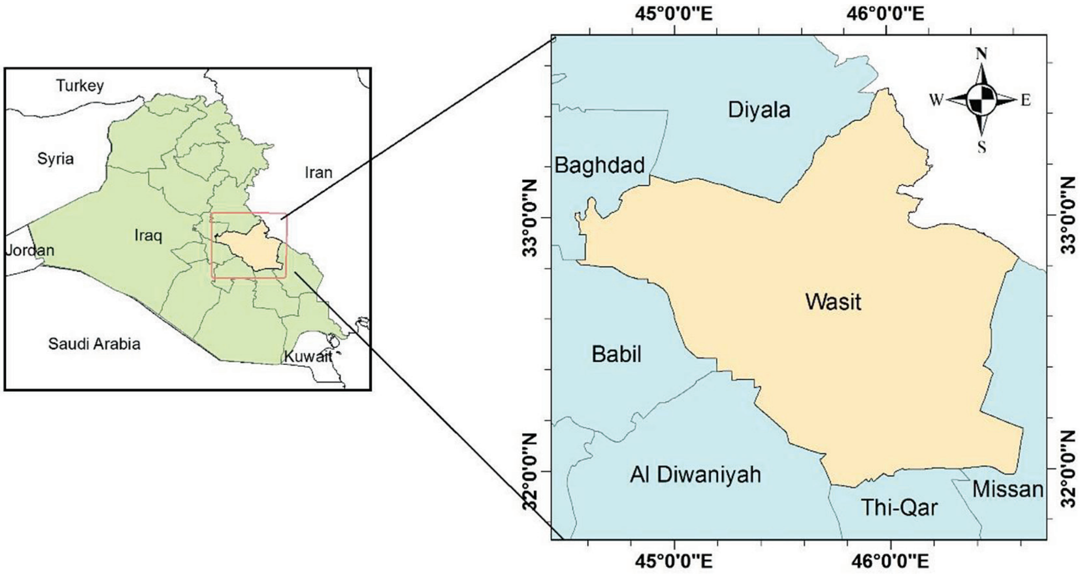

Figure 1. The study area location

Table 1. The specification of Landsat 8 images used in this study

Path/Row	Date	Band	Spatial resolution
167/37	April 2013	Multispectral	30
167/38	April 2013	Multispectral	30
168/37	April 2013	Multispectral	30
168/38	April 2013	Multispectral	30
167/37	April 2023	Multispectral	30
167/38	April 2023	Multispectral	30
168/37	April 2023	Multispectral	30
168/38	April 2023	Multispectral	30

Climatic satellite data

The standardized precipitation index (SPI) characterizes climate drought over various time scales. Since it may be used to compare data from areas with radically different climates, it is a crucial indication. The observed precipitation is defined as a uniform deviation from a selected probability distribution that represents the raw precipitation data, and this is how SPI is computed. SPI is closely related to soil moisture in a short period, while SPI can be related to groundwater and reservoir storage in a longer period. In this study, the SPI dataset

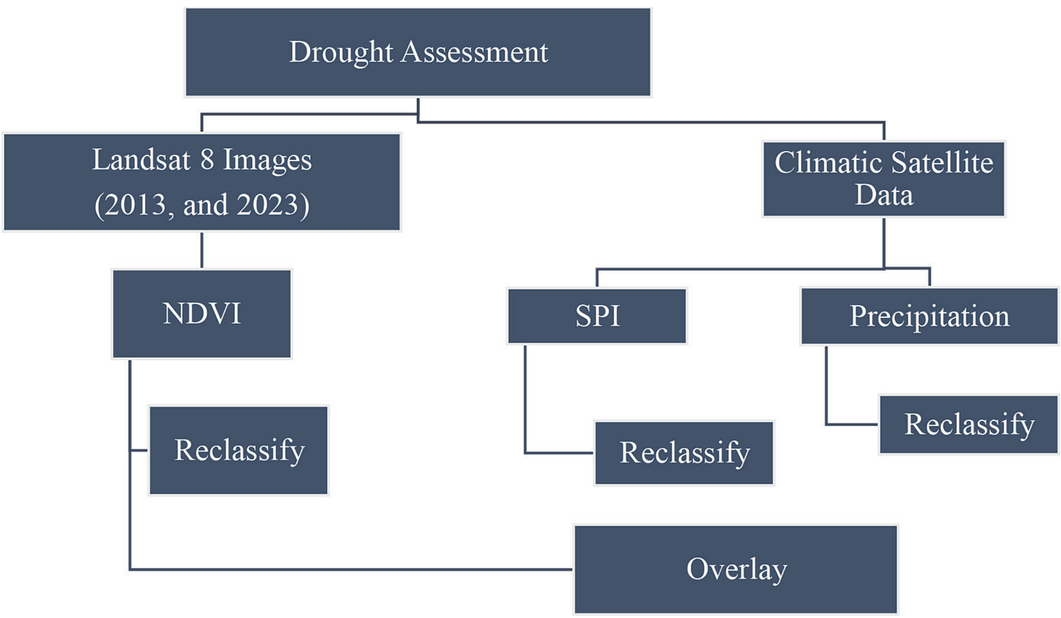

Figure 2. Methodology flowchart

was acquired from the European Drought Observatory (EDO) website. While annual precipitation data was downloaded from the NASA Website, the MEERA Model for 2013 and 2023 with a spatial resolution of 0.5 Degrees was used.

METHODOLOGY

This study aims to map the overall drought based on metrological and agriculture condition, using remote sensing data in Wasit, Iraq. Figure 2 illustrate the steps for this study. The NDVI for 2013 and 2023 was computed using Landsat 8 in order to map the agricultural drought. Furthermore, the annual precipitation was computed in order to track the trend of the metrological drought throughout time. The SPI data was downloaded and interpolated, then all these three layers were combined using overlay process in ArcGIS.

NDVI

NDVI is used to determine the density and health of vegetation, it is calculated by taking the ratio between the reflected values in the red and near-infrared (*NIR*) range and is expressed by the following equation [Khudhur et al., 2023]. Many researchers used *NDVI* to assess agricultural drought. The basic idea behind the *NDVI* is that the green vegetation reflects *NIR*. At the same time, it absorbs a large proportion of red visible radiation (*VIS*) in the electromagnetic spectrum. Thus,

$$NDVI = \frac{NIR-VIS}{NIR+VIS} \quad (1)$$

The value of *NDVI* ranges between -1 and +1. Negative values of *NDVI* indicate water, while values near zero indicate arid areas such as rocks, sand, or snow [Ganie and Nusrath, 2016].

SPI

For quantifying drought, the SPI is a commonly used statistic. As the globally standard index for meteorological drought, the SPI was suggested by the Lincoln Declaration on drought [Hayes et al., 2011]. The SPI mainly addresses the severity of the precipitation shortfall or meteorological drought. The lack of precipitation can fundamentally describe drought; this is possibly the most basic of all metrics. However, due to the significant variations in precipitation climatology across temporal and geographical scales, evaluating the extent of the precipitation shortfall can be challenging [NOAA, 2010]. The *SPI* typical values presented in Table 2. The Equation to obtain *SPI* value is [Gulmez, 2010]:

$$SPI = (Xi\text{-}Xi \text{ mean})/\sigma \quad (2)$$

where: *Xi* – mean is the average precipitation, *Xi* represent the precipitation, Σ is the standard deviation.

Table 2. SPI values classification [NAD, 2011]

Drought type	Value of SPI
Extremely wet	≥ 2.00
Very wet	1.50 to 1.99
Moderately wet	1.00 to 1.49
Near normal	-0.99 to 0.99
Moderately dry	-1.00 to -1.49

Precipitation

The annual time average map for 2013 and 2023 was downloaded from the NASA website from the (M2TMNXFLX) model. The data NetCDF from and converted to raster by interpolation based on SPI method.

Overlay process

The final step to mapping the drought is to combine the three thematic layers (namely, NDVI, precipitation, and SPI) using the weighted overlay method in ArcGIS software after reclassified it to a uniform scale.

RESULTS AND DISCUSSION

NDVI

In this study, NDVI values for 2013 and 2023 were computed using Landsat 8 images using Arc GIS 10.5 to monitor the health of vegetation. NDVI maps for the study years. To evaluate the change brought on by the drought, a temporal analysis of these images was conducted. AS shown in Figure 3, in terms of NDVI, the brown color indicates unhealthy and drought areas, while green color indicates healthy and wet vegetation areas. In 2013, the NDVI values ranged between 0.6 to -0.2, as shown in Figure 3. Most of the Wasit faced moderate drought of different intensities in various parts, the distribution of poor vegetation performance is

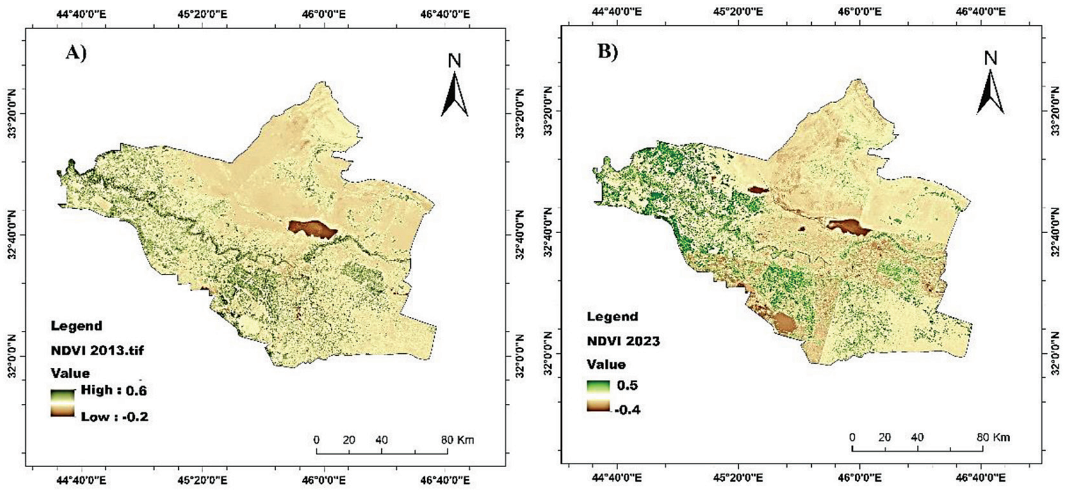

Figure 3. The NDVI values for the years ((a) 2013, (b) 2023)

indicated by the NDVI values. In 2023, the values of NDVI reduce and ranged between 0.5 and -0.4. Extreme dry conditions were observed in Wasit, where the value of NDVI remains less than 0.2, spatially in the Northwestern part.

Annual precipitation spatial patterns

The Annual Precipitation was used to assess the change in precipitation for 2013 and 2023, as shown in Figure 4. The annual Precipitation values 2013 ranged between 0.97 and 0.39 mm/month. While for 2023, it ranged between 1.6–0.3 mm/month.

SPI and drought

Identifying and monitoring different types of dryness conditions at different time scales is one of the main benefits of using the SPI. The spatial pattern of the study period was displayed by analyzing the SPI-12 data values. Figure 5 illustrates the computed SPI values after interpolated using the Spline method to determine the drought zone. Between 2013 and 2023, the SPI values in the Northeastern region of Wasit decreased to less than -1.4, indicating a moderate drought. While the northeast was most vulnerable to drought risk during the research period, SPI was utilized to identify the medium-term trend in precipitation.

Drought assessment

This study used SPI, annually prepetition, and NDVI to evaluate drought. All the criteria layers should be reclassification and ranking. Each layer is given a rank between 1 and 5, with 5 being the peak value for each parameter rank. Lastly, the

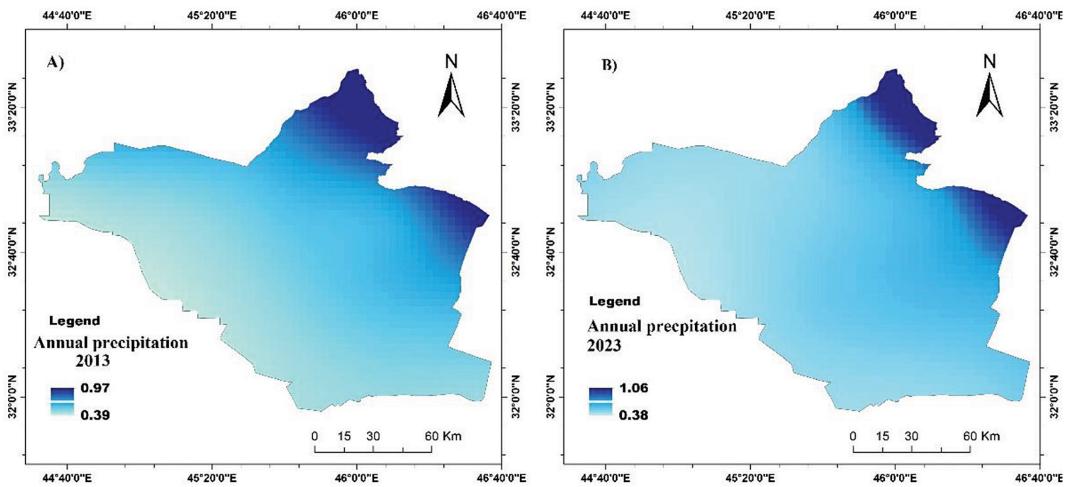

Figure 4. The annual precipitation values for the years ((a) 2013, (b) 2023)

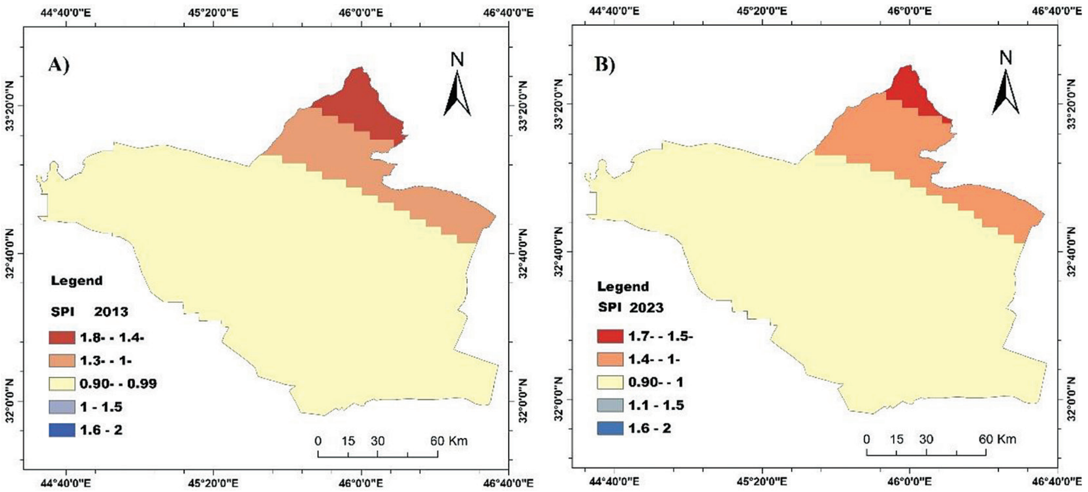

Figure 5. SPI value over the years (a) 2013 and (b) 2023

overlay method is used to integrate these layers, and the drought map for 2013 and 2023 is produced. The NDVI trend indicated a decrease in precipitation in the crop-dominated central and northwest regions of Wasit. The distribution of vegetation was mapped, and it varies spatially. The western part of the study area, which is at a lower elevation, showed good rainfall distribution and amount. On the other hand, compared to the southern part of the area, there is less vegetation coverage. This suggests that additional environmental factors are present and have an impact on the growth, development, and condition of vegetation. Other regional elements that affect vegetation include soil properties, patterns of land use and cover, and stress levels from prior years. This result shows that rainfall amount and NDVI value were not correlated in the same study area. This is likely due to the presence of other variables that affect vegetation growth and development, such as soil, temperature, and topography. Therefore, there are other factors besides rainfall, which is a significant variable climate that affects vegetation growth and development as indicated by the NDVI, that affects vegetation growth and development of vegetation. As shown in Figure 6, the final map divides the study area into three classes: no drought, slight drought, and moderate drought. Table 3 illustrates the area and percentage for each class. For the year 2013 the percentage of moderate drought is 31%, slight drought 64%, and no drought 3.9% from the total area. While, in 2023 the percentage of moderate drought is 47%, slight drought 49%, and no drought 3.2% from the total area. It is noticed that in 2023, the moderate drought class increased by about 16%.

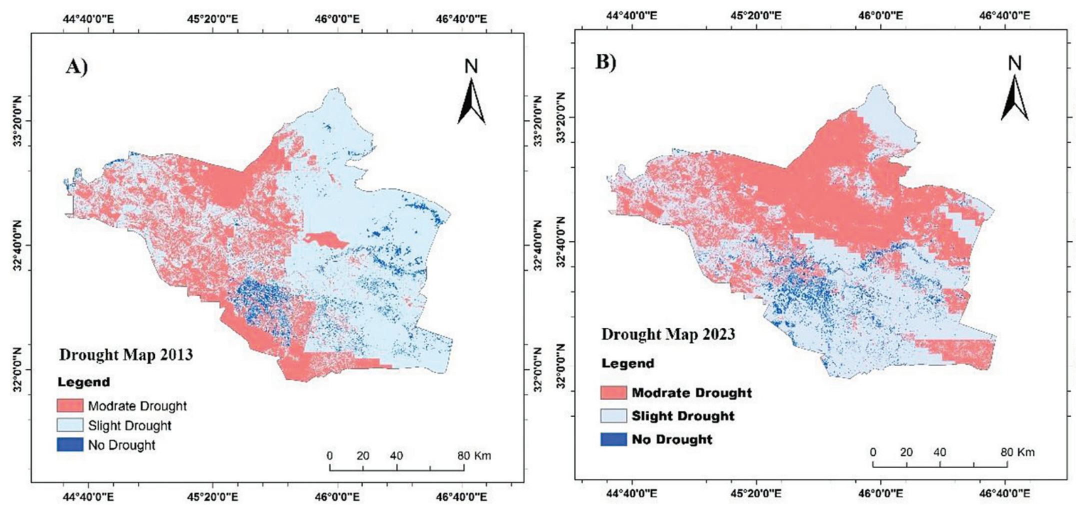

Figure 6. Drought assessment map for the years (a) 2013 and (b) 2023

Table 3. The area and percent for the drought classes for the study area

Class	2013		2023	
	Area (Km^2)	Percentage	Area (Km^2)	Percentage
Moderate drought	5645.7	31.8%	8433.1	47.5%
Slight drought	11415.69	64.3%	35998.54	49.3%
No drought	11415.7	3.9%	8752.6	3.2%

CONCLUSIONS

This study aims to map the drought using GIS and climatic remote sensing data for in Waist Province, Iraq. The SPI was used to analysis the metrological drought. While the NDVI used to map the agriculture drought. The findings indicate that the most common drought location was the Northern part of Wasit Province, which lie in a rainfall deficiency zone with poor vegetation cover. The result shows that, for the year 2013 the percentage of moderate drought is 31%, slight drought 64%, and no drought 3.9% from the total area. While, in 2023 the percentage of moderate drought is 47%, slight drought 49%, and no drought 3.2% from the total area. It is noticed that in 2023, the moderate drought class increased by about 16%. These results could be used in estimation the overall drought condition in the study area and could be useful for developing plans for drought management. This result could enhance decision-making and organize management plans to deal with the risk.

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