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# Agricultural Drought Assessment in Diyala Governorate Integrating Remote Sensing and GIS Technique

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***Abstract: This study aims to assess the drought levels in Diyala Governorate- Iraq, utilizing Remote Sensing (RS) data and Geographic Information System (GIS) technique. Agricultural droughts were evaluated based on the Normalized Difference Vegetation Index (NDVI) Anomaly for the years 2011, 2014, 2017, and 2021. Landsat images were analysed using ArcGIS 10 software. The results show that 2014 is the worst year during the past 10 years affected by drought. However, the less affected years are 2011 and 2017. During the study period, 2021 year was identified as mild drought conditions.***

***Keywords: Drought; Normalized Difference Vegetation Index (NDVI); Remote Sensing (RS), Geographic Information System (GIS).***

## 1. INTRODUCTION

Drought hazards have had intense effects on human society since their inception. It can cause loss of life and serious damage to human property. The consequences of the climatic changes could be seemingly everywhere, e.g. the temperature is rising, change the precipitation patterns, and melting ice sheets. Despite these profound changes, climate change and its associated risks such as drought are still possible. Thus, drought monitoring is one of the most important tasks that require an early warning system and proactive drought planning (Kulkarni et al., 2020). During the past two decades, satellite-based remote sensing (RS) was providing a high spatiotemporal resolution observation of Earth.

The technique of satellite-based remote sensing (RS) enables us to gather data from space about the Earth's surface, atmosphere, and seas. In this technique, sensors on satellites that collect data at various electromagnetic spectrum wavelengths are used (Ma et al., 2022). These sensors might be active, like radar systems, or passive, like cameras.
The capability of satellite-based remote sensing to deliver high spatiotemporal resolution measurements of the Earth is one of its main benefits. So, it is possible to track changes to the

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Earth's surface through time and at various scales, from local to global, using the information gathered by satellites (Wang et al., 2021).
The frequency at which the satellite gathers data over a specific area is referred to as the temporal resolution of satellite-based remote sensing. While some satellites collect data every day, others could only do so once every few weeks or months. This makes it possible for us to track how the environment changes over time and to research the effects of calamities like droughts, floods, and urbanization that are both natural and caused by humans.
The level of detail in the data that the satellite collects is referred to as the spatial resolution of satellite-based remote sensing. Depending on the type of sensor being utilized, this can range from tens of meters to a few centimeters. To map and track land use, urbanization, and natural resources including forests, water bodies, and agricultural fields, high spatial resolution data can be used (Zakeri and Mariethoz, 2021).

The level of detail in the data that the satellite collects is referred to as the spatial resolution of satellite-based remote sensing. Depending on the type of sensor being utilized, this can range from tens of meters to a few centimeters. To map and track land use, urbanization, and natural resources including forests, water bodies, and agricultural fields, high spatial resolution data can be used. Accordingly, the RS dataset has been increasingly used to monitor the drought (Nanzad et al., 2019). For example, Yoon et al. (2020), Ayehu et al. (2020), and Sultana et al. (2021) developed a number of satellite-derived vegetation indices to monitor drought from local to global scales, and estimate the soil moisture and precipitation.

The available indicators confirm that Diyala has a very severe drought in the summer seasons (IFRC, 2021). One million and 800 thousand people make up the total population of Diyala Governorate are in the cycle of a worsening water crisis. The decline in the flow of water from rivers and streams coming from Iran or Kurdistan besides the lack of rain are all indications of a very severe water crisis. The shortage of rain caused great financial losses for farmers, and a noticeable decrease in the agricultural yield of the province compared to previous years. Thus, many farmers will resort to leaving their areas and migrating towards the city. More importantly, since 2003, the Iraqi side has not established its water rights as a riparian country with the Iranian side, despite the large number of joint committees, which gave Iran a free hand by constructing dams and diverting riverbeds into its territory.

Several areas in Diyala are mostly affected by drought in the summer season such as Mandali and Qazaniya, the Diyala River Basin, and the Hamrin Basin.
Today, Hamrin Lake is the largest water reservoir, has completely dried up as a result of an excessive water release towards the Diyala River. Also, the lack of rain with the absence of a strategic plan has increased the water shortage in Hamrin Lake. Accordingly, the agricultural drought has spread out to the whole of Diyala and became a major threat to the agricultural plan and sources of drinking water.
There is a new environmental disaster on the doorstep, which is represented by a wave of drought caused by the construction of a strategic dam in Wadi Harran on the Iranian side. Qazaniya district has recently issued a warning of a drought disaster by next summer and a major crisis in securing drinking water and irrigation. Accordingly, it is fair to expect that both

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Mandali and Qazaniya will lose water sources completely where 50% of the residents will be deprived of drinking water besides an expected drought of thousands of acres of agricultural land.
The remote sensing data and GIS techniques were intensively used to study the drought phenomenon in Iraq. Fadhil (2011) mapped the drought in Kurdistan region for the years 2007–2008 based on Landsat 7 ETM+ using five indices. The main conclusion of this study is that the soil moisture content is the most effective factor on the vegetative cover. AL-Timimi et al. (2012) investigated the meteorological and agricultural drought levels in Iraq using remote sensing and GIS techniques based on SPI and NDVI anomaly. The drought risk map was obtained by integrating agriculture and meteorological drought risk maps. Abood and Mahmoud (2018) used RS coupled with GIS to monitor the agriculture and meteorological drought in Maysan/Iraq using Landsat 8 temporal images based on NDVI and meteorological data. Jawad et al. (2018) evaluated the drought patterns in Iraq using the remotely-sensed Drought Severity Index and examined the efficiency of DSI for drought monitoring. Al-Quraishi et al. (2020) specified the drought using three spectral indices based on Landsat images, which are NDVI, LST, and NDWI. The study recommended to use a combination of NDVI-SPI indices to provide more reliable results for drought monitoring. Almamalachy et al., 2020 utilised four spectral drought indices; Vegetation Health Index (VHI), Vegetation Drought Index (VDI), Visible and Shortwave Infrared Drought Index (VSDI), Temperature–Vegetation Dryness Index (TVDI) based on MODIS dataset of Terra satellite. The study revealed that the VDI was the most suitable drought index for Iraq.

This study aims to assess the agricultural drought levels in Diyala Governorate- Iraq using RS data and GIS technique based on NDVI Anomaly for the years 2011, 2014, 2017, and 2021. The result could provide valuable information about future dangers with a comprehensive understanding and assess the agricultural drought risk in Diyala governorate, Iraq.

## Study area

Diyala Governorate is one of the eastern governorates in Iraq, which extends to the northeast of Baghdad as far as the Iranian border, and has a capital called Ba'quba. Diyala covers an area of about 17,685 $km^2$ that represents 4% of the total area of Iraq (Aziz et al., 2020). It comprises six districts (Ba'quba, Al-Muqdadiya, Khanaqin, Al-Khalis, Balad Ruz, and Kifri). It has an estimated population of 1,224,358 people, according to the 2003 population census. Diyala River passes through it (Fig. 1), which originates in the Zagros Mountains in western Iran, shaping the Iranian-Iraqi border for more than 30 km (Hamza, 2012).

In the past years, Diyala governorate was exposed to events that dramatically changed the land cover. The dryness of the Tigris River and climatic changes, as well as military developments during the period of the entry of ISIS, led to a significant deterioration of the vegetation and water cover. The recent regional ISIS-created conflict in Iraq has resulted in a humanitarian crisis with the internal displacement of 5 million Iraqis and the destruction of infrastructure and services in the former ISIS-occupied areas the total damages to the agricultural sector are estimated at US$ 2.1 billion. The total damage Diyala governorates estimated at US$ 479 million (World Bank Group, 2018).

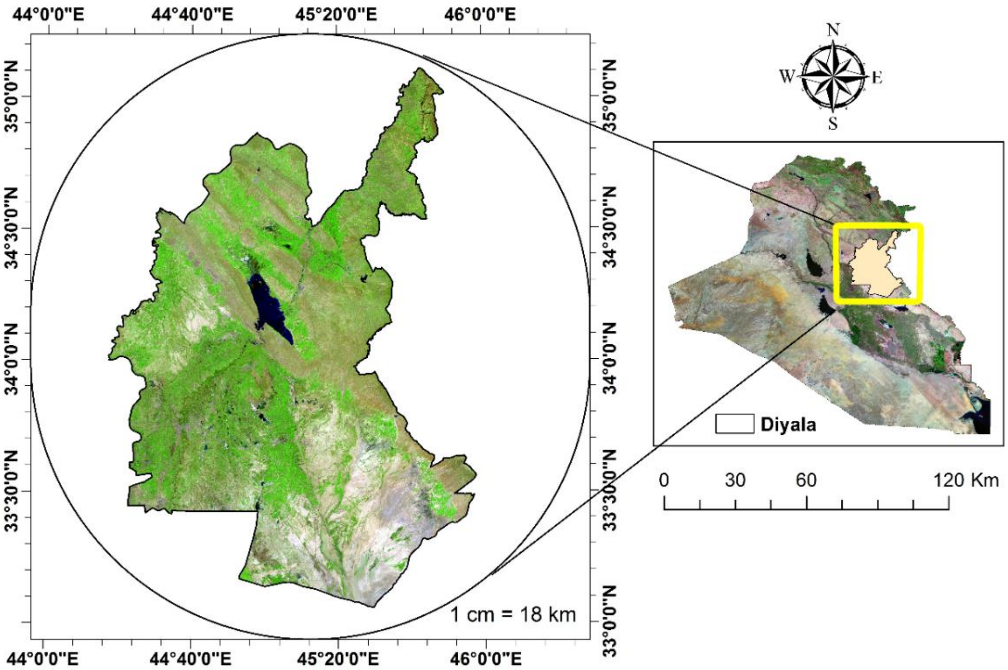


Fig. 1. The location of the study area based on satellite images (Landsat8)

## 2. MATERIAL AND METHODS

Remote sensing data can be used to map drought severity based on NDVI by following these steps (Anderson et al., 2021):

- Determine the time period for which you want to map the drought severity. NDVI data should be available for that period.
- Obtain NDVI data for the time period from a reliable source such as the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data.
- Calculate the NDVI for each time period by using the formula:

$$NDVI = (NIR - Red)/(NIR + Red)$$

Where, NIR is the near-infrared band and Red is the red band of the satellite imagery.

- Calculate the average NDVI for each pixel for the entire time period. This will provide the baseline NDVI value for that pixel.
- Calculate the anomaly NDVI for each time period by subtracting the baseline NDVI from the NDVI for that time period. This will provide a measure of how much the vegetation has changed from the baseline NDVI.
- Compare the anomaly NDVI with the historical data to identify the severity of drought.
- Use a color scheme to visually represent the drought severity. For example, green can be used to indicate areas where vegetation is growing normally, yellow for areas with slight vegetation stress, and red for areas with severe vegetation stress.

 

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- Create a map based on the color scheme to visually represent the drought severity for the selected time period.

**Dataset**

The earth observation data is available; a wide range of data is free of cost (Toth and Jóźków, 2016). LANDSAT 8 images are a useful resource for various agriculture applications to analyse the drought phenomenon. In this study, Landsat images were obtained from USGS, with multispectral bands and spatial resolution of 30 m to calculate NDVI anomaly to study the Spatio-temporal drought events for the period 2011–2021 (Table 1).
Fig. 2 shows the methodology steps used in this study.

Table 1. Image specifications

| Path/Row | Date |
|---|---|
| 168/36 | 3/2011 |
| 168/37 | 3/2011 |
| 168/36 | 3/2013 |
| 168/37 | 3/2013 |
| 168/36 | 3/2017 |
| 168/37 | 3/2017 |
| 168/36 | 3/2021 |
| 168/37 | 3/2021 |

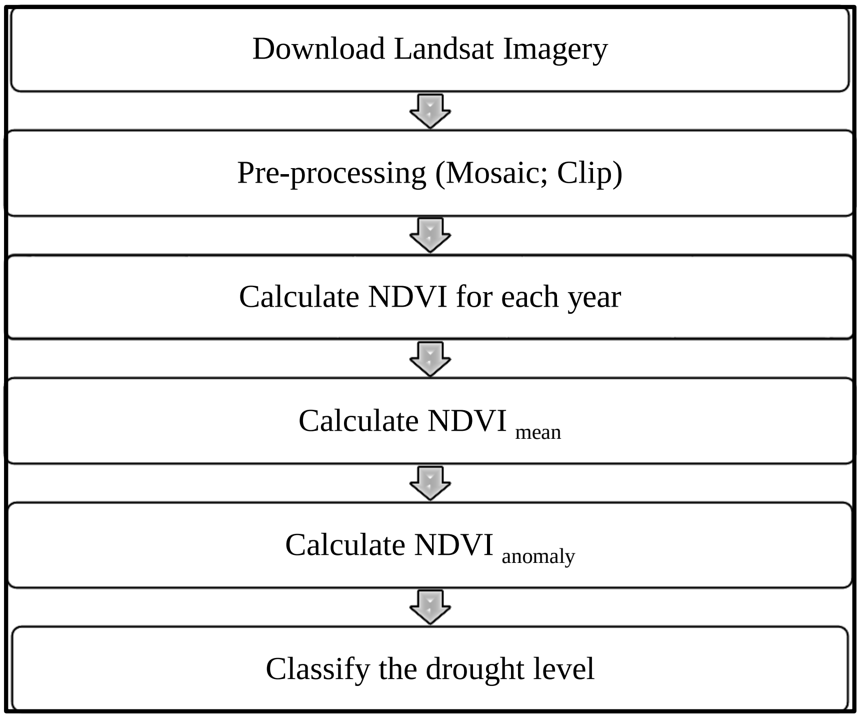


Fig. 2. The methodology flowchart of this study

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**Calculate the NDVI anomaly**

NDVI anomaly can be considered as one of the most common NDVI based approaches to detect and map the drought with its long-term mean for a pixel at a given time (Anyamba and Tucker, 2012). In the NDVI anomaly, the positive pixel value represents normal conditions. Whereas, the negative pixel value refers to severe drought conditions (Nanzad et al., 2019). After computing NDVI of March of each selected four years during the past 10 years, the mean (NDVI) of the four years is computed as follows

$$NDVI_{mean} = \sum_{i=1}^{n} \frac{NDVI\ i}{n} \quad (1)$$

*n* is the number of years (2011, 2014, 2017, and 2021).
The NDVI anomaly could be computed using the following equation (Anyamba et al., 2001) as represented in Eq. 2

$$NDVI\ _{anomaly\ i} = \frac{NDVI_i - NDVI_{mean}}{NDVI_{mean}} \quad (2)$$

NDVI *anomaly i* is the NDVI anomaly for March during *i* year.
Finally, the classification process used to assess the level of drought severity was adopted based on the NDVI anomaly classification scheme shown in Table 2.

Table 2. Drought classification scheme (Vaani and Porchelvan, 2017)

| **Level of Drought** | **NDVI anomaly values (%)** |
|---|---|
| Normal (Non-drought) | Above 0 |
| Mild | 0_-10 |
| Moderate | -10 _-25 |
| Severe | -25_-50 |
| Very severe | Below -50 |

## 3. RESULTS AND DISCUSSION

The drought severity was mapped utilizing RS data based on NDVI anomaly for the period from 2011 to 2021. The first step produces the NDVI maps for the four selected years during the study period as shown in Fig. 3. Then, the drought map for each year was generated as shown in Fig. 4, which demonstrates the drought severity levels. The results show that the drought severity is ranged from normal to severe drought. In produced drought maps, the navy colors refer to a positive NDVI anomaly, referring to normal condition; and, cyan, green, orange, brown colors expression negative NDVI anomalies, refer to the mild, moderate, severe, and very severe drought conditions, respectively. The worst year affected by drought during the last 10 years was 2014. However, the less affected years were the 2011 and 2017 years where the study area was identified as normal (no drought). During the study period, 2021 year was identified as mild drought conditions.
These results are in agreement with the FAO report which listed that “Iraq alone has lost about 40 percent of its agricultural production since the Islamic State of Iraq and the Levant (ISIL)

 

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took control of some of the most important agricultural areas of the country in 2014. This has resulted in severe damage to agricultural facilities in the retaken areas, including damage to food storage and crop processing structures, as well as significant losses of farm machinery, equipment, and tools". Also, a large number of farmers have reported a significant decrease in water supply in 2014 due to the poor state of irrigation infrastructure. This greatly affected their rural livelihood and led to a decrease in their agricultural production (Iraq, F.A.O., 2018). Jaafar and Woertz (2016) indicated that the production was able to capitalize on improved rainfalls in 2015 after a drought in 2014. This in turn commensurate with the findings of this study that signifies no agriculture drought in 2017.

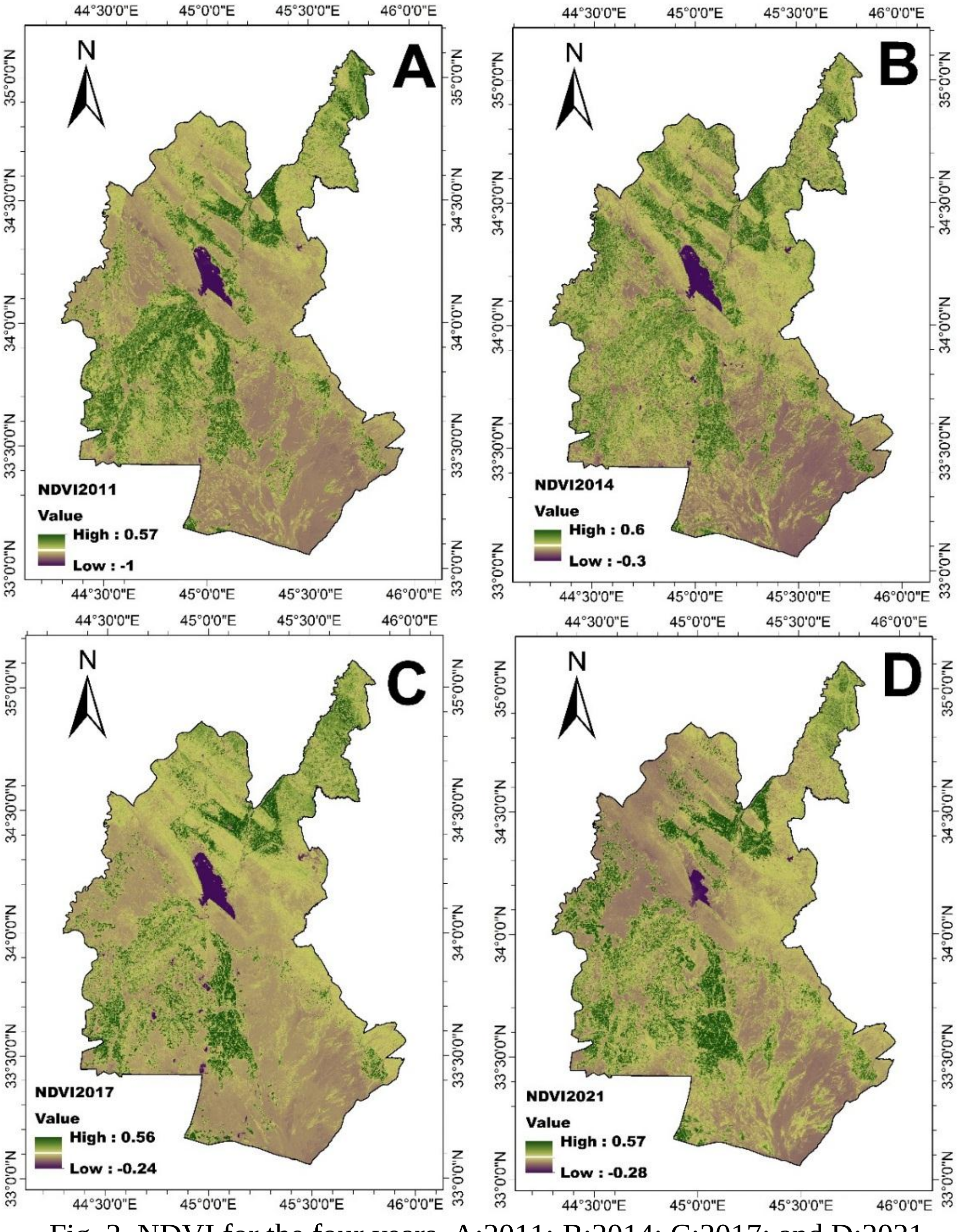

Fig. 3. NDVI for the four years, A:2011; B:2014; C:2017; and D:2021

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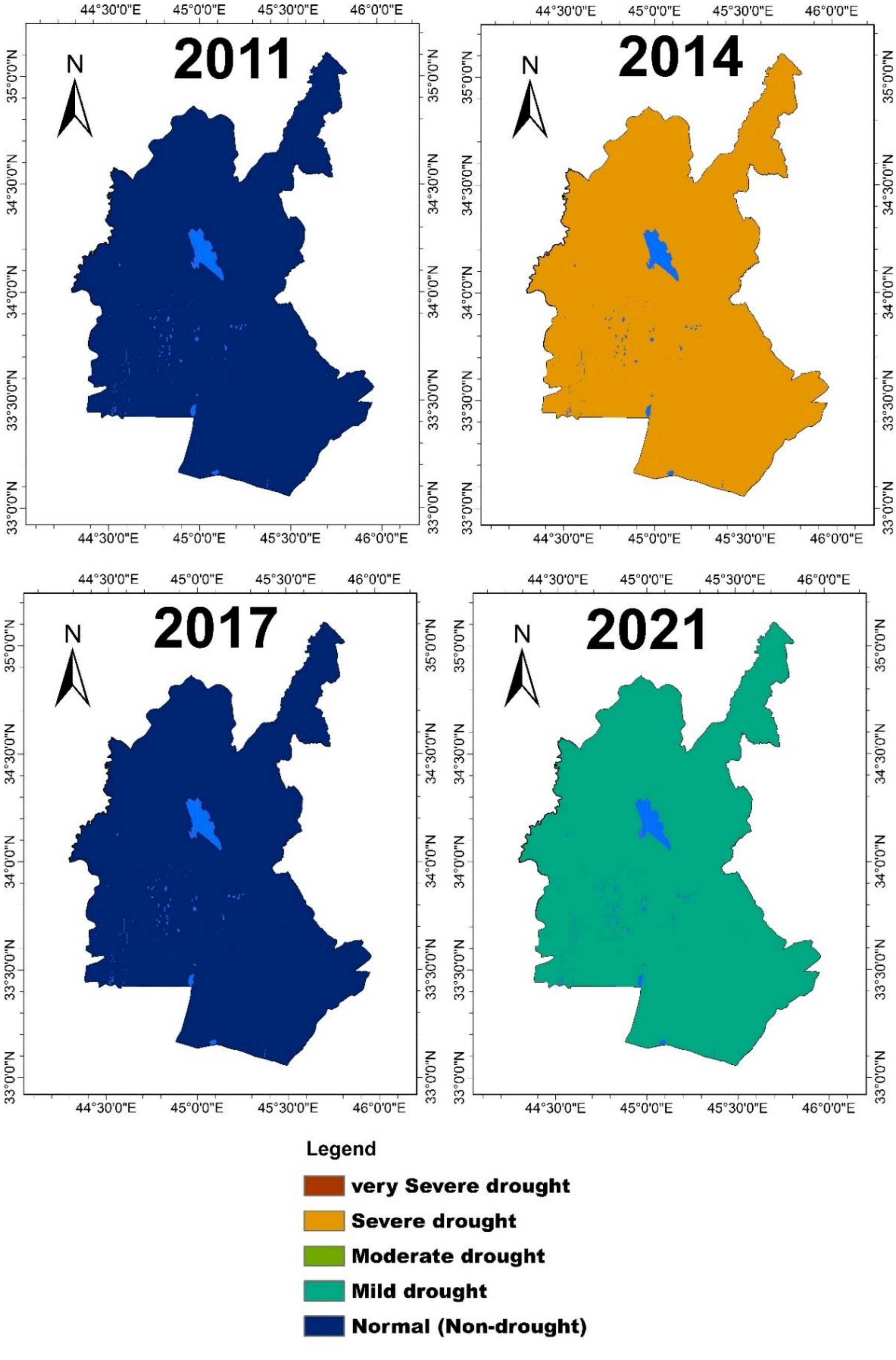


Fig. 4. The drought severity levels in Diyala for four years

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## 4. CONCLUSIONS

This study aims to employ RS data to monitor the drought severity during the period 2011–2021 in Diyala, Iraq. NDVI anomaly has been considered to identify the drought severity conditions. The results showed that the worst year affected by drought during the ten years was 2014. Whereas, the less affected years were 2011 and 2017 of normal drought. During the study period, 2021 year was identified as mild drought conditions. This study can provide valuable information for the emergency managers, regional planners, and policymakers at different levels of government to assess the drought risk map in Diyala governorate/Iraq.

**Funding**
This study has not been funded

**Conflict of Interest**
There is no any conflict of interest

**Highlights**
1. An assessment of the drought levels in Diyala Governorate- Iraq is conducted.
2. Remote Sensing data and Geographic Information System techniques were used.
3. Landsat images were analysed using ArcGIS 10 software.
4. Compared to 2011, 2017, and 2021, 2014 has been recognised as the worst year affected by drought.
5. 2011 and 2017 are the less affected years affected by drought.

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