MONITORING AGRICULTURAL DROUGHT IN REGIONS OF IRAQ USING REMOTE SENSING TECHNIQUE

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ABSTRACT

The phenomenon of drought is one of the most significant environmental and climatic extreme events; it is more complex in terms of measuring, monitoring, and identifying the possible effects and hazards associated. The remote sensing index, which included the Vegetation Health Index (VHI), was used to describe the geographic and temporal distribution of the springtime agricultural drought. VHI can be calculated based on the Temperature Condition Index (TCI), Vegetation Condition Index (VCI), and Normalized Difference Vegetation Index (NDVI) derived from MODIS Terra satellite data. The outcomes showed that the droughts in the years 2001–2002, 2008–2009 were the most extreme in twenty-two years. The drought years 2001-2002 were followed by the drought-free years 2002/2003,2008/2009. The years 2017-2018 show this phenomenon distributed mostly in the south and southwest bearing. According to the findings, the southwest and western regions are more vulnerable to drought. The results of the drought index VHI indicate that the country is facing non-uniform cycles of drought for all types of droughts. Also, the results showed that there is a negative significance between rainfall and extreme, severe, and moderate drought, even if there was no substantial negative link between rainfall and dryness. It is recommended to adopt the VHI index to monitor the desiccation of vegetation in semi-arid areas with little access to surface meteorological information.

Keywords: vegetation health index, temperature condition index, normalized difference vegetation index, GIS, drought indices

مراقبة الجفاف الزراعي في بعض مناطق العراق باستخدام تقنية الاستشعار عن بعد

فاطمة احمد عبد الله ياسين كاظم التميمي
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المستخلص

يعد الجفاف أحد أهم الأحداث البيئية والمناخية المتطرفة وهو أكثر تعقيدًا من حيث القياس والرصد وتحديد الآثار والمخاطر المحتملة المرتبطة به. تم استخدام مؤشر صحة الغطاء النباتي (VHI) في هذه الدراسة لتقييم الجفاف الزراعي في العراق للفترة 2000–2021. لوصف النمط الجغرافي والزماني للجفاف الزراعي خلال فصل الربيع ، تم حساب VHI باستخدام TCI مؤشر حالة درجة الحرارة ، VCI مؤشر حالة الغطاء النباتي ، و NDVI (مؤشر الغطاء النباتي للاختلاف الطبيعي) المستمدة من بيانات القمر الصناعي MODIS Terra، على التوالي. أشارت النتائج إلى أن مواسم 2001–2002 ، 2008/2009 شهدت أشد حالات الجفاف انتشاراً وشدة خلال اثنين وعشرين عاماً. أعقب سنوات الجفاف 2001–2002 السنوات الخالية من الجفاف 2002/2003 ، 2008/2009. أظهرت الأعوام 2017/2018 انتشار الجفاف في الغالب في اتجاه الجنوب والجنوب الغربي. وكشفت النتائج أن المناطق الجنوبية الغربية والغربية أكثر عرضة للجفاف. تشير نتائج مؤشر الجفاف VHI إلى أن العراق يواجه دورات جفاف غير منتظمة ولجميع اصناف الجفاف. كما أظهرت النتائج وجود علاقة ارتباط معنوية بين الأمطار والجفاف الشديد والشديد والمتوسط. يستخدم مؤشر VHI بشكل شائع ، لذلك يوصى باعتماد هذا المؤشر لرصد جفاف الغطاء النباتي في أماكن أخرى في المناطق شبه القاحلة حيث تكون بيانات الطقس السطحي نادرة.

كلمات مفتاحية: مؤشر صحة الغطاء النباتي، مؤشر حالة درجة الحرارة، مؤشر الفرق المعياري للغطاء النباتي، نظم المعلومات الجغرافية، مؤشرات الجفاف.

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INTRODUCTION

The phenomenon of drought is complex; it has been defined specifically by the remote sensing community as a period of abnormally dry weather, which results in vegetation changes. Although drought is a complicated issue, the remote sensing community has defined it as a time of unusually dry weather that causes changes in the vegetation (8, 17). Drought is a climate phenomenon that occurs repeatedly over a large area and for an extended length of time.,it occurs with irregular temporal and spatial characteristics. It is one of the most frequent natural catastrophes that result in financial losses and has an impact on the agricultural, social, economic, and environmental domains (13, 30). Since the last few decades, numerous types of remote sensing data based on algorithms and remote sensing satellites have been utilized widely to efficiently track drought conditions throughout the world. China's remote sensing analysis of the drought made use of data from the HJ-1 and MASR satellites (40,41), employing MODIS data, as well as in Australia, Iran, India, and the Philippines (10,31), has demonstrated the efficiency of these data in determining national drought. In addition, there are a lot the Temperature of the drought, the TVDI (vegetation dryness index), the VSWI (vegetation water supply index), and the severity index are some of the remote sensing metrics that depend on the NDVI-LST relationship. Dehydration (DSI) and the Natural Plant Supply Water Index (NVSWI) have been proposed and successfully tested. (1, 37). The research issued by the United Nations Mission and Humanitarian Affairs. This Iraqi report, considered in 2009, to help Iraq and the International Astronomical Union office that one of the most important causes of successive drought conditions in Iraq is evident in the low rates of precipitation and the decline in the water discharge rates of Iraq's major rivers. Therefore, it led to a decrease in the level of groundwater, the flow of rivers, and the discharge of springs, deep wells, and shallow wells (19). As opposed to that, within the 10 years between 2003 and 2012, Iraq endured many significant droughts. Lower efficiency is caused by a variety of factors, including high temperatures, insufficient water inflow from upstream nations, and low annual rainfall. Although drought is a complicated issue, the remote sensing community defines it as a time of unusually dry weather that causes changes in the plants (17, 34). Drought is a frequent climatic occurrence that occurs over a wide area for a long period of time with irregular geographical and temporal characteristics. One of the worst natural disasters, it costs money and harms the agricultural, environmental, social, and economic sectors (16, 33). Over the past few decades, to effectively track droughts around the world, a variety of satellite-based remote sensing data and remote sensing algorithms have been used.A drought research using remote sensing was carried out in China using data from the HJ-1 and MASR satellites. Many studies have used MODIS data in Iran, India, and Brazil to verify the usefulness of these data in tracking the national drought (12, 30,40). One remote sensing index that is based on the NDVI-LST relationship is the Vegetation Health Index (VHI), for instance. Vegetation Water Supply Index, Drought Index, Vegetation Dryness Index, and Drought Temperature. The Natural Plant Supply Water Index (NVSWI) and the Dehydration Severity Index (DSI) have been proposed and successfully tested (18,36). The Iraqi report for 2009 issued by the Coordination of Humanitarian Affairs, the United Nations Assistance Mission for Iraq and the International Astronomical According to the union office, the key factors contributing to Iraq's repeated drought occurrences include the country's low precipitation rates and declining river discharge rates. As a result, groundwater levels, river flow, and the release of water sources (springs, deep and shallow wells) all decline (23). On the other hand, within ten years, from 2003 to 2012, Iraq suffered from several severe droughts, which were caused by various reasons, such as low average rainfall, high average temperatures, low water inflow from upstream countries, and low efficiency. Droughts, especially during the past two decades. The decrease in precipitation and its variation in seasons are normal in most countries in North Africa and West Asia.This makes Iraq, among other nations, a place where severe drought control measures should be implemented. In addition, severe drought occurred in 1999 in Erbil and Dohuk, which also experienced moderate drought in 1986-1987, 1989-1991, 1999, and 2008 (14,38) the VCI, or Vegetation Condition Index, was Kogan was the first to do so. (21,22,28) to track NDVI signal evolution over time.Cogan created the To standardize temperature data, TCI (Temperature Condition Index) was created in 1995. Then Kogan created the Plant Health Index (VHI), which combines the VCI and TCI indicators. Using the VCI, TCI, and VHI indices to monitor drought has been the subject of several studies throughout many different parts of the world (20,24,27). This research aims to evaluate the viability of employing information acquired from satellite remote sensor data to identify drought-sensitive vegetation in a semi-arid country such as Iraq.

MATERIALS AND METHODS

Study area : Geographically situated in the subtropical latitudes of the northern hemisphere between the low equator (29.5° to midlatitude 37.5°) and longitudes (38.45° to 48.45° east of the Greenwich Meridian)(25). Iraq is located in Mesopotamia in a large plain, and it has two rivers, the Tigris and the Euphrates (29). See Figure 1. The rainfall shows significant spatial and temporal variability in the annual mean rainfall, with higher values in the northern areas of Iraq and lower values in the southern regions (4). Iraq is divided into three climatic regions according to precipitation criteria: the steppe region, where yearly precipitation is 200-400 mm, the desert region, where annual precipitation is less, and the dry and semi-arid zone, where annual precipitation is more than 400 mm. The research area's typical annual precipitation spatial distribution for 200 mm is between 50 and 100 mm (2,10). The cumulative annual rainfall values from (2017-2021) showed that the largest amount of rainfall was in the north region with (3821) mm and the lowest amount in the west region (665) mm, while the middle region (1848) mm and south region (1828) mm (4,7,11). Surface Air Temperature (SAT) is the main influence on the pressure systems affecting Iraq (3,6). Climate change is leading to an increase in the mean temperature, specifically during the warmest months of the year (6). Drought has become a disaster for many countries, including Iraq in recent years, the country has been facing frequent, irregular, and recurrent droughts for the past 42 years (26). According to the Intergovernmental Panel on Climate Change (IPCC), climate change will lead to an increase in the severity and frequency of droughts in this region. The center of Iraq was the most prone to drought, followed by the west of Iraq, based on some drought indices (35).

Remote sensing data : Two types of remote sensing data were used in the study to assess the agricultural drought in Iraq. The first kind is an eight-day land surface temperature (LST) product with 1 km precision based on (MOD11A2) data. The LST is the term used to describe the radiative skin temperature of the Earth's surface. LST depends on soil moisture, albedo, and vegetated areas. The second type represents the (MOD13Q1) data used to produce the Normalized Difference Vegetation Index (NDVI). The remote sensing data for the period 2000-2021 have been acquired annually for April's Spring season from NASA's website (https://lpdaac.usgs.gov).

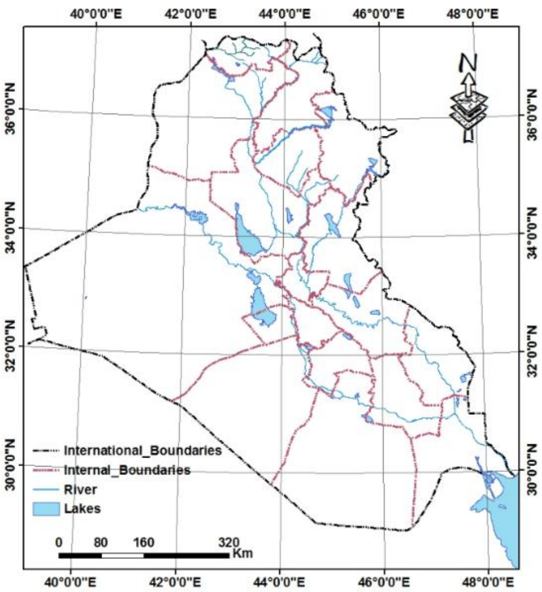

Figure 1. Location map of the study area, Iraq

Approximately 44 raster images were downloaded to cover all of Iraq during the study period of 2000–2021. Sets of April months (Spring season) of the studied period were collected together to calculate the Temperature Condition Index (TCI) and the Vegetation Condition Index (VCI) for each overlapped pixel. The TCI and VCI characterize the thermal and moisture conditions of vegetation, respectively, and were computed using Eqs. (1) and (2):

$$TCI - 100 \times \frac{LST_{Max} - LST_{Pix}}{LST_{Max} - LST_{Min}} \quad (1)$$

$$VCI = 100 \times \frac{NDVI_{pix} - NDVI_{min}}{NDVI_{Max} + NDVI_{min}} \quad (2)$$

where LSTpix, LST max, and LSTmin, for several years, are the monthly composite (8-day average) temperature pixels as well as its highest and lowest temperature pixels, respectively; NDVIpix, NDVImax, and NDVImin are the top, the normalized difference vegetation index pixel of the monthly composite (16-days average), and the lowest normalized difference vegetation index pixels for several years. When there is a moisture deficit and a high temperature, which exacerbates agricultural drought and negatively affects the health of the vegetation, thermal conditions become especially crucial. The VCI and TCI values range from zero (very unfavorable conditions) to one hundred (excellent conditions). Consequently, higher VCI and TCI levels suggest healthy, undisturbed vegetation. The greatest quantity of vegetation grows in years with the best weather, while the least amount (which is typically dry and hot) grows in years with the worst weather. Therefore, the severe climatic occurrences (drought and non-drought conditions) are contained in the NDVIpix and LSTpix absolute maximum and minimum values over the years.

Table 1. Drought severity classes of VHI (18).

Drought Indices Values	Drought Conditions
<10	Extreme drought
10-20	Severe drought
20-30	Moderate drought
30-40	Mild drought
>40	NO drought

The VHI proposed by Kogan (1995, 1997) and Bayarjargal et al. (2006) was obtained from the mathematical relationship (20,21), see Eq. (3):

$$VHI=0.5\ (TCI) + 0.5(VCI) \quad (3)$$

where VHI stands for overall plant health. Due to the lack of sufficient knowledge regarding the contributions of moisture and heat during the vegetation cycle, In this VHI calculation, equal weight has been assumed for both VCI and TCI. (18). Compared to a single drought index indicator, VHI paired with TCI and VCI provides improved drought identification knowledge regarding drought episodes Figure 2). Kogan (2001) then divides VHI into the five categories shown in Table (1) for further research.

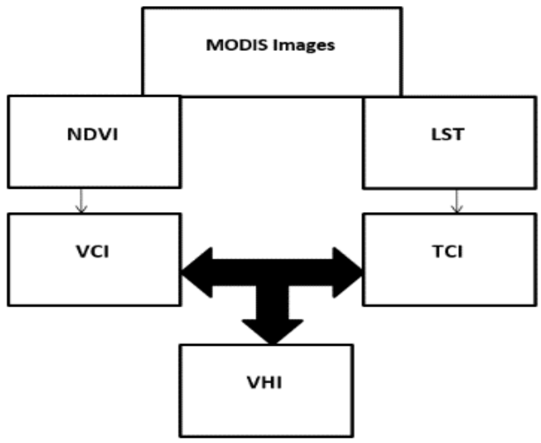

Figure 2. Methodology for mapping VHI in this study.

RESULTS AND DISCUSSION

In the study area to compare spatial patterns of drought for a period of thirteen years, for each month of the growing season, a set of categorized maps indicating the severity of the drought was produced. Each indicator was divided into 5 groups Table (1), ranging from severe dehydration (0 to 10) to no dehydration (40 or more) in this instance. Each indicator's scale runs from 0 to 100; 0 represents the driest conditions, whereas 100 represents the wettest conditions. Figures (3) and (4) illustrate a spatial distribution of VHI indices that were calculated for all years. Data analysis, which corresponds to drought peaks that characterize severe drought, corroborates this observation under drought conditions. For the study period 2000–2021, Figure (3) and (4), shows the spatial distribution of VHI drought situations based on VCI and TCI analysis. In the case of VHI drought, extreme to severe cases was observed mainly at the western parts of the site in 2000, 2001, 2012, 2016, 2018,2019,2020, and 2021. In contrast, the VHI drought was in the middle and southern parts during the years 2005, 2008, 2010, 2013, and 2017. In 2000, 2008, and 2021, drought cases were the most extreme, particularly in 2020. In general, the Northeast seemed to be the only district where mild to no drought conditions were observed. Using 22 years of data from seasons, it can be seen that in 2002, 2003, 2007, 2014, and 2019, no region was at risk of drought. during the wet years 2002, 2003, 2004, 2006, and 2013, the percentage of no drought was 75.5%, 68.1%, 44.6%, 47.8 %, and 39.4% respectively, of the total area, Table (2). During the dry years, 2000, 2008, 2017, and 2019, the extreme drought was 12.1%, 20.8%, 2,4%, and 21.3% respectively of the total area. while the severe drought was 20.3%, 25.4%, 11.5%, and 25.7% respectively, of the total area. From the Table, it can be concluded that the majority of the study area faced VHI drought conditions for the years considered. This region also overlaps with agricultural land cover. The 2017/2018 drought is mainly concentrated in the south and southwest. Based on 22 years of observations by VHI. The presence of the northern regions and most of the central regions has high VHI values, and this indicates that the regions are less dry, and there was a significant decrease in the average rainfall in Iraq in the years 2000, 2008, and 2009, according to the data of the Meteorological Organization. Decreased precipitation and high temperatures played an important role in reducing the regional vegetation in the southwestern and western regions of Iraq.

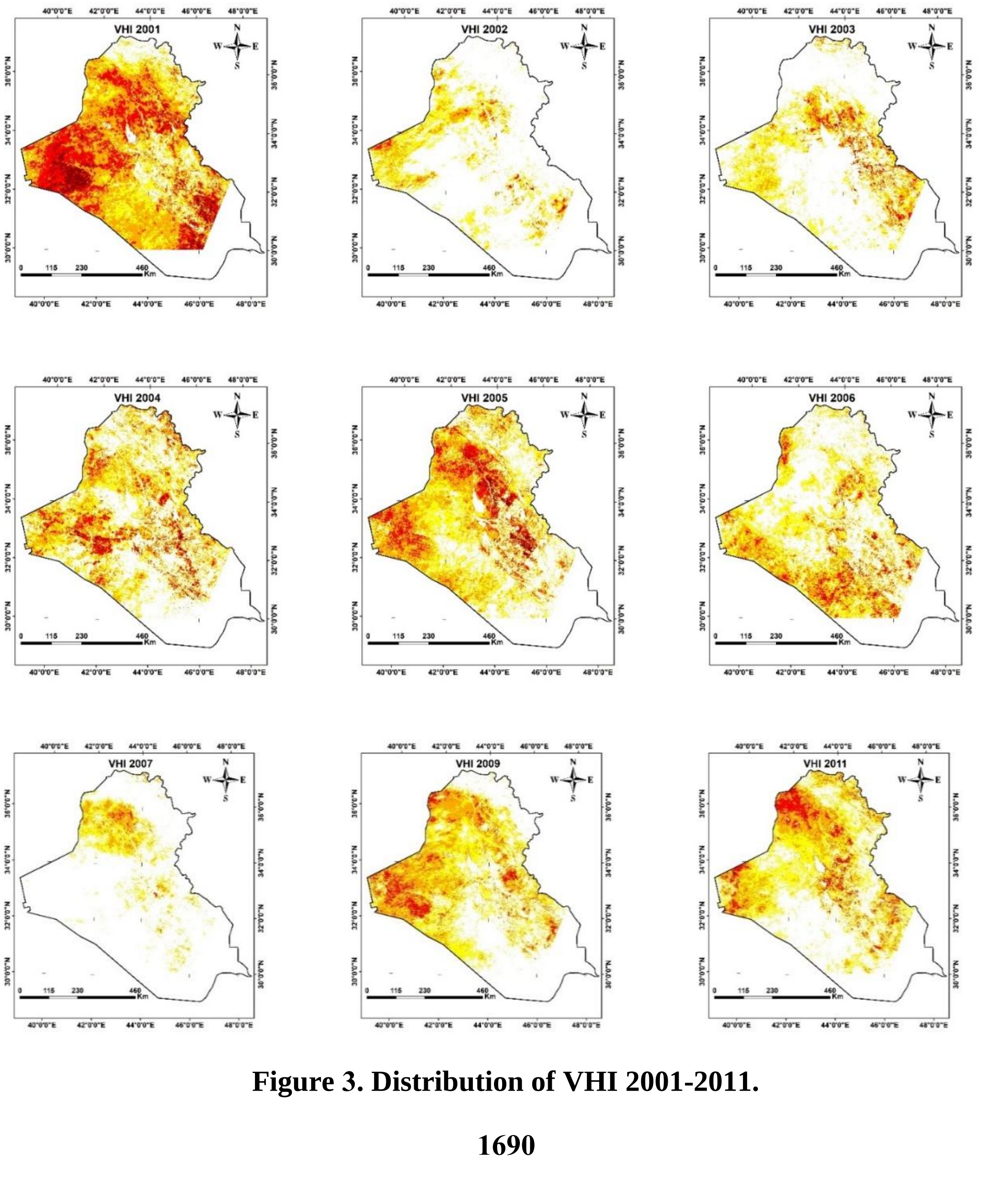

Figure 3. Distribution of VHI 2001-2011.

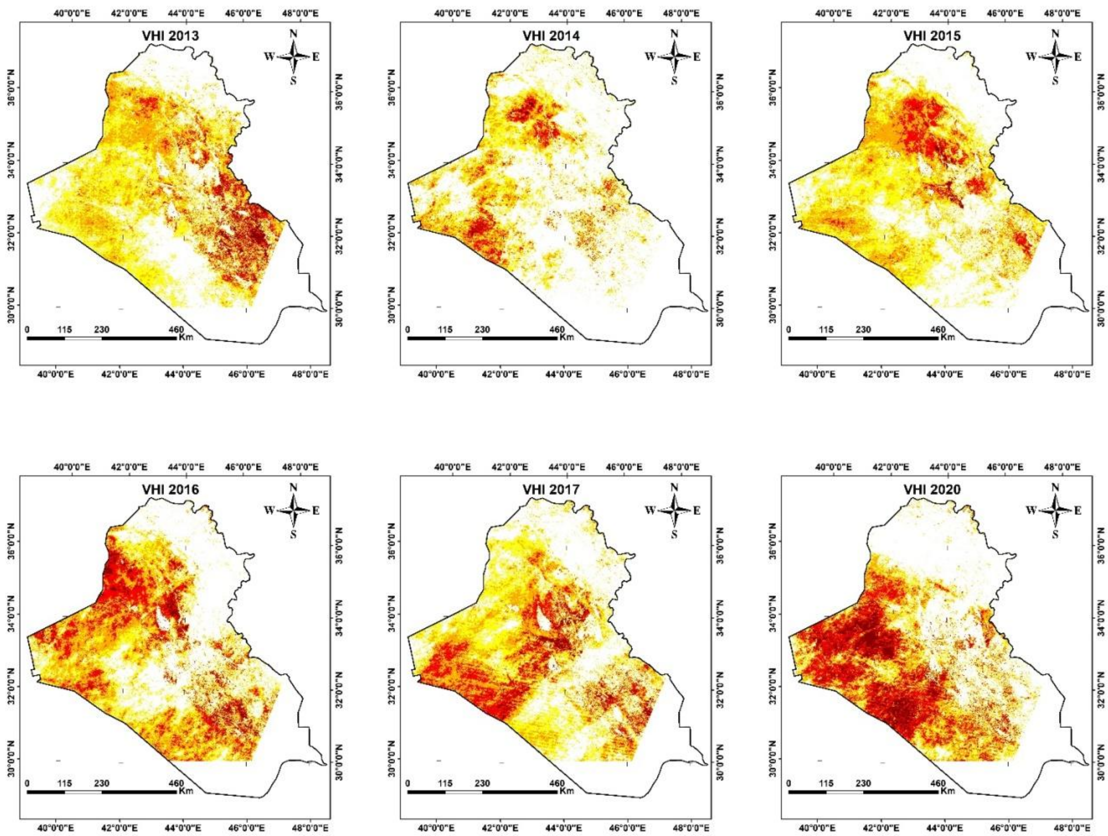

Figure 4. Distribution of VHI 2013-2021.

Table 2. Percentage of drought classes for VHI index.

Years	Extreme%	Severe%	Moderate%	Mild%	No drought%
2000	12.1	20.3	22.1	18.2	27.3
2001	5.1	22.8	37.1	21.2	13.9
2002	0.1	1	6.9	16.6	75.5
2003	0.4	2.7	9.5	19.4	68.1
2004	1.4	7.8	19.4	26.8	44.6
2005	1.9	10.8	25.7	28.3	33.2
2006	0.4	5.1	18.1	28.6	47.8
2007	0	0.5	5.1	10.3	84.1
2008	20.8	25.4	21.3	17.9	14.6
2009	0.2	5.7	24.6	27.7	41.8
2010	4.6	16.1	24	21.2	34
2011	0.3	6.7	20.3	29.5	43.2
2012	0.9	10.1	22.3	25.1	41.6
2013	2.4	6.3	21.1	30.7	39.4
2014	0.6	4.6	12.2	19.1	63.5
2015	0.6	6.1	20.2	29.5	43.6
2016	2.9	13.3	23.5	20.2	40.1
2017	2.4	11.5	21.1	26.5	38.6
2018	4.2	20.4	27.4	20.3	27.7
2019	0	0	0.3	1.1	98.5
2020	8.3	17.2	17.3	13.9	43.3
2021	21.3	25.7	20.3	13.9	18.7

The annual temporal pattern of rainfall and classes of VHI can be analyzed Figures (5-9) shows clear that during the years with heavy rainfall, The values for the intense drought were low (2002, 2003, 2006, and 2019). A negative correlation exists between the rainfall values and the extreme drought, as shown in Figures (10-14), where a polynomial line fit (order 2) ok, now for the data. The findings demonstrated a strong link. r = 0.87 between rainfall and extreme drought %. Also, it can be noted that the severe drought recorded the lowest value in 2002 and 2019 and the highest value in 2008 and 2021. The results have shown that there is a negative correlation between rainfall and Severe drought r = 0.8 polynomial line fits. In the case of Moderate and mild drought as shown in figures (5) and (6), it is seen there is no correlation between rainfall and other droughts (r = 0.4 Moderate draughts), (r = 0.36 mild drought). So, it can be clear that all types of droughts are the opposite of rainfall, that is, the more precipitation increases, the area of droughts decreases. The findings demonstrate a strong association (r = 0.6) between rainfall and the absence of drought classes. We notice in the years when there is a large amount of rain, we notice that the area in which there is no greater drought and the pattern is similar to the pattern of rain falling, that is, the more rain falls, the soil is moister, so it meets the plants' need for water, so the vegetation cover increases.

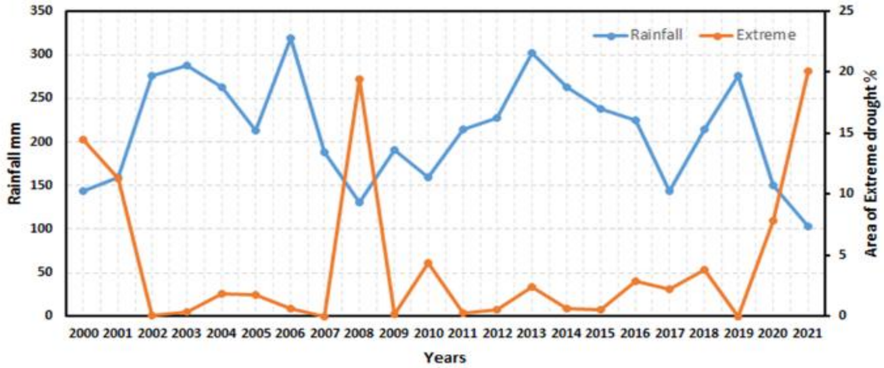

Figure 5. Clarifying the relationship between rainfall and extreme drought.

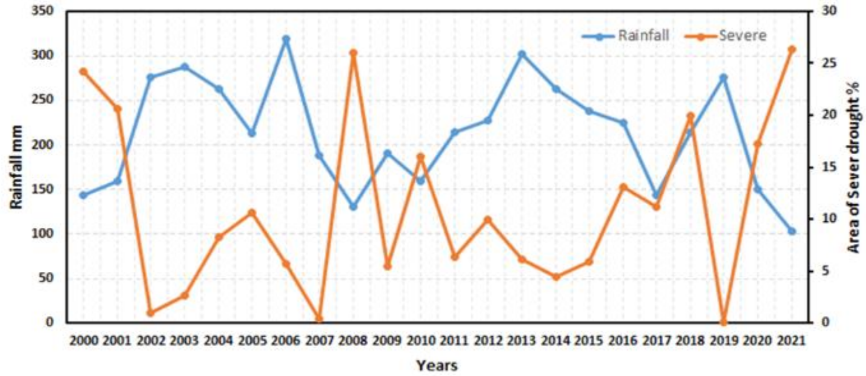

Figure 6. Clarifying the relationship between rainfall and Severe drought.

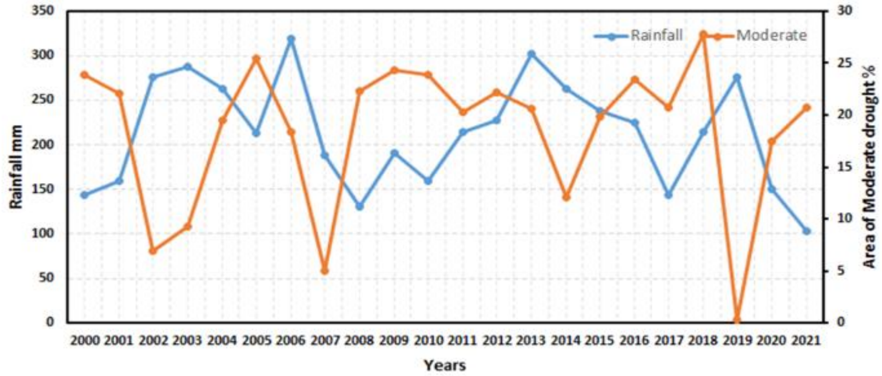

Figure 7. Clarifying the relationship between rainfall and moderate drought.

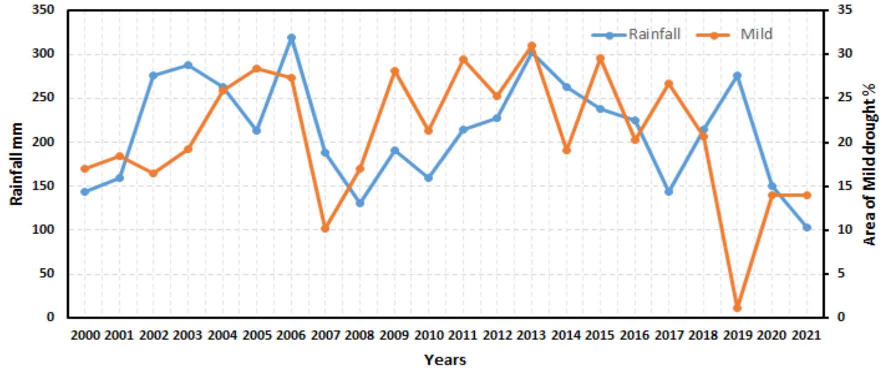

Figure 8. Clarifying the relationship between rainfall and mild drought.

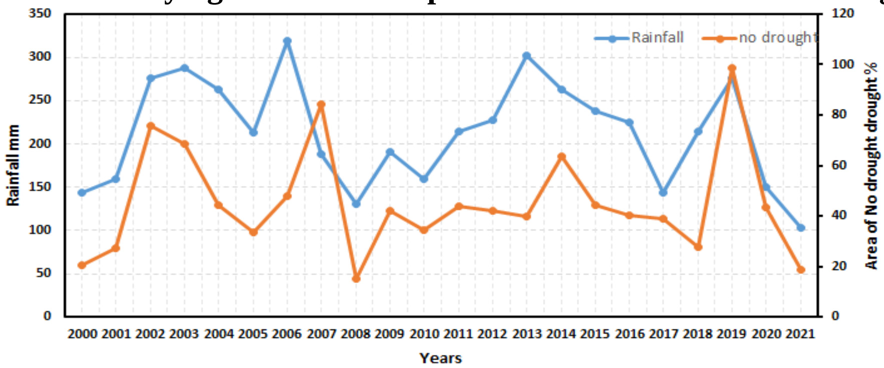

Figure 9. Clarifying the relationship between rainfall and No drought

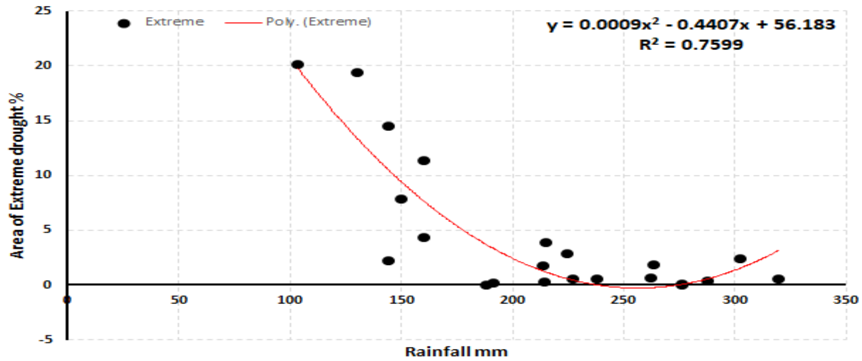

Figure 10. Clarifying the relationship between rainfall and extreme drought.

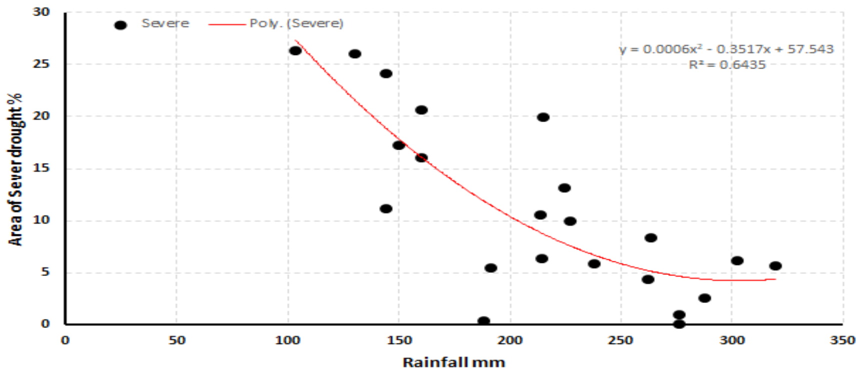

Figure 11. Clarifying the relationship between rainfall and severe drought.

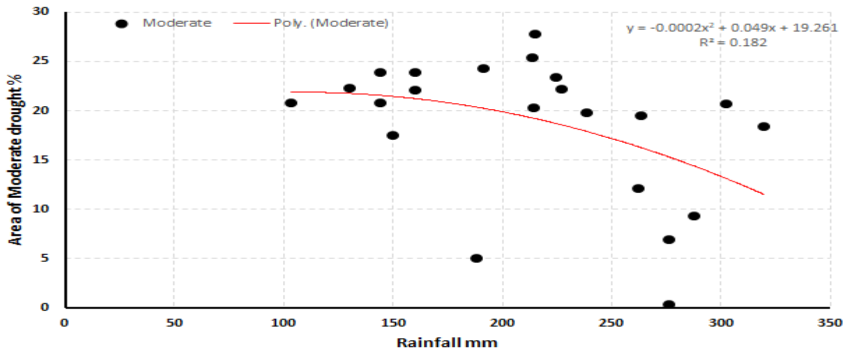

Figure 12. Clarifying the relationship between rainfall and moderate drought.

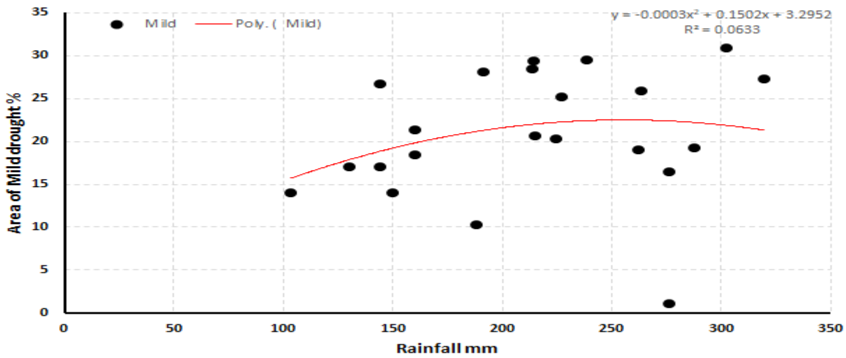

Figure 13. Clarifying the relationship between rainfall and mild drought.

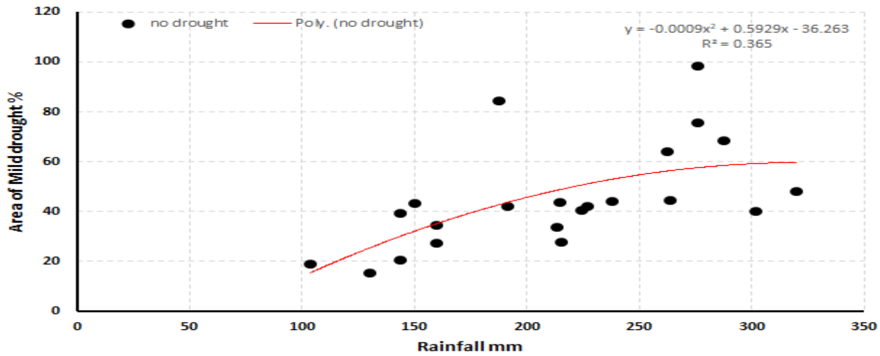

Figure 14. Clarifying the relationship between rainfall and no drought.

Figure (15), shows the relationship between rainfall and the mean of VHI in Iraq. It notes that the relationship between the VHI index and rainfall is positively related, with a correlation coefficient of 0.73.

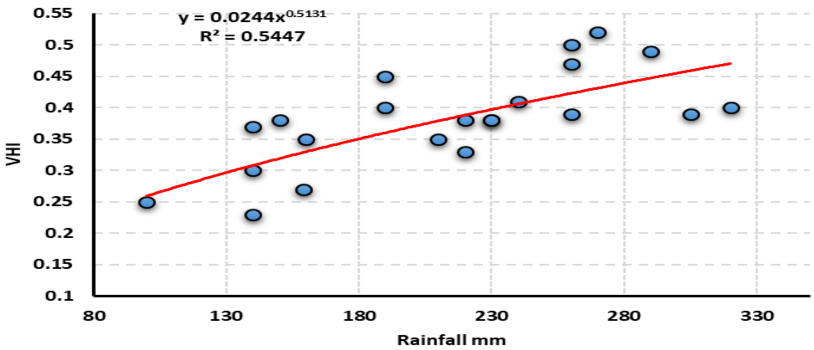

Figure 15. The relationship between the rainfall and the mean of the VHI index.

CONCLUSION

Using MODIS imagery based on NDVI and LST imagery, annual drought patterns have been plotted for Iraq spanning the years 2000–2021. Using a total of three drought indices (VCI, TCI, and VHI), the distribution of extreme and severe drought in the region was calculated. To research drought, Remote sensing is a practical technique, especially in big, inaccessible areas. The technique used is an affordable strategy, a repeatable process, and an effective substitute for field measurements for research and monitoring of the drought on a nationwide scale. 2008 saw the worst drought ever in Iraq. The results of the drought index VHI indicate that the country is facing non-uniform cycles of drought for all types of droughts. Also, the results showed that there is a negative correlation between rainfall and extreme, severe, and moderate drought; the absence of a drought has a substantial positive correlation with rainfall. It is simpler to identify the areas and districts in Iraq that are most susceptible to severe and extreme drought according to the methodology used in this study. This data is crucial for rangeland planning and future planting, and it can be used to guide policymakers in implementing the right mitigation strategies for upcoming drought episodes. With the proper adjustments, the suggested processes could be applied to additional Middle Eastern nations.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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