Spatial and Temporal Analysis to the Major Categories of Drought in Iraq Using GIS and Remote Sensing Technology

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Abstract

Drought impacts are exacerbated in many areas due to increased urban expansion, water demand, population growth, and there are no environmental protection efforts. Drought threatens Iraq's ecology, affecting both the vegetative cover and the economic system. According to the World Bank, climate change has made Iraq one of the world's most drought-stricken countries. The weather in Iraq is extremist, with little rain and high temperatures, which is the most common explanation for the risk of drought. Most prior research in Drought studies in Iraq relied on ground station data and hence were unable to discriminate between geographical and temporal changes in the study region. Overall, GIS and remote sensing technology can play a crucial role in drought monitoring and management, providing a valuable tool for researchers and practitioners working in this field. This study created a spatiotemporal analysis of Iraq using satellite photos and ground stations. This study investigates the environmental and human variables that contribute to drought in the study region. In this study, four major categories of drought are assessed in Iraq: meteorological drought, hydrological drought, agricultural or ecological drought, and socioeconomic drought. Because of drought the agriculture and vegetation that rely on rainfall in Iraq, have been harmed by 56 to 46 percent. The incidence of damage on irrigation agriculture ranges from 46 to 31 percent.

Key words: GIS, remote sensing, meteorological drought, hydrological drought, ecological drought, socioeconomic drought.

التحليل المكاني والزماني لفئات الجفاف الرئيسية في العراق باستخدام تكنولوجيا المعلومات الجغرافية والاستشعار عن بعد

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خلاصة

تتفاقم آثار الجفاف في العديد من المناطق بسبب التوسع الحضري المتزايد والطلب على المياه والنمو السكاني وعدم وجود جهود لحماية البيئة. يهدد الجفاف بيئة العراق، ويؤثر على كل من الغطاء النباتي والنظام الاقتصادي. وفقا للبنك الدولي، فإن تغير المناخ جعل العراق أحد أكثر دول العالم تضررا من الجفاف. الطقس في العراق متطرف، مع قلة الأمطار ودرجات الحرارة المرتفعة، وهو التفسير الأكثر شيوعًا لخطر الجفاف. اعتمدت معظم الأبحاث السابقة في دراسات الجفاف في العراق على بيانات المحطة الأرضية وبالتالي لم تكن قادرة على التمييز بين التغيرات الجغرافية والزمنية في منطقة الدراسة. بشكل عام، يمكن أن تلعب تكنولوجيا نظم المعلومات الجغرافية والاستشعار عن بعد دورًا حاسمًا في مراقبة الجفاف وإدارته، مما يوفر أداة قيمة للباحثين والممارسين العاملين في هذا المجال. خلقت هذه الدراسة تحليل زماني مكاني للعراق باستخدام صور الأقمار الصناعية والمحطات الأرضية. تبحث هذه الدراسة في المتغيرات البيئية والبشرية التي تساهم في الجفاف في منطقة الدراسة. في هذه الدراسة، تم تقييم أربع فئات رئيسية من الجفاف في العراق: الجفاف الجوي، والجفاف الهيدرولوجي، والجفاف الزراعي أو البيئي، والجفاف الاجتماعي والاقتصادي. بسبب الجفاف، تضررت الزراعة والغطاء النباتي الذي يعتمد على هطول الأمطار في العراق بنسبة ٥٦ إلى ٤٦ في المائة. وتتراوح نسبة الأضرار التي تلحق بالزراعة المروية من ٤٦ إلى ٣١ في المائة.

الكلمات المفتاحية: نظم المعلومات الجغرافية، والاستشعار عن بعد، والجفاف المناخي، والجفاف الهيدرولوجي، والجفاف الإيكولوجي والبيئي، والجفاف الاجتماعي والاقتصادي.

1- Introduction

Drought is becoming one of the most dangerous natural disasters due to global climate change, impacting both the natural environment and human existence. There are several types of drought, including meteorological, agricultural, hydrological, and socioeconomic drought (Zhao, L., Lyu, A., Wu, J. et al. 2014). Dryland regions are impacted by droughts, a process that causes land deterioration. Droughts directly affect more than 250 million people, and more than 70% of drylands are now being desertification (Emadodin, I., Reinsch, T., & Taube, F. 2019). Iraq is a country that has been affected by drought in recent years. The country is located in a region that is prone to water scarcity and drought, and its agriculture sector is particularly vulnerable to drought conditions

(FAO, 2021, IPCC, 2021, IPCC, 2014). The drought makes environmental degradation, which is a negative or undesirable modification or damage to the environment. It is the degradation of ecosystems, agriculture, and wildlife extinction. This issue can be caused by both natural and humanity reasons. (Johnson, Donald L., et al. 1997. Xu, Duanyang, et al. 2011).

Based on where in the water cycle the moisture shortage occurs, there are three main types of drought: meteorological drought, hydrological drought, and agricultural or ecological drought (Zhao, Lin, et al., 2014). A meteorological drought when there is insufficient rainy season. Low runoff, streamflow, and reservoir storage are all indicators of a hydrological drought. Plant stress is caused by an agricultural or ecological drought due to evaporation and low soil moisture. on another hand, when demand for an economic good exceeds supply due to a weather-related shortfall in water supply, this is referred to as socioeconomic drought (Abro, Mohammad Ilyas, et al.2022. Zhao, L., Lyu, A., Wu, J. et al. 2014. Maybank, J., et al., 1995).

The use of GIS and remote sensing technology in drought monitoring can be extremely beneficial. GIS can be used to map and analyze drought conditions, whereas remote sensing can provide data on various environmental parameters, such as precipitation, soil moisture, vegetation health, and surface temperature, that can be used to estimate drought severity and impacts (Su, Z., et al., 2017).

Researchers and practitioners can monitor and analyze drought conditions in real time by combining GIS and remote sensing technology, providing valuable information for drought mitigation and response efforts. Early warning systems, drought forecasting, and drought impact assessments are examples of such measures. Furthermore, GIS and remote sensing can be used to identify areas that are particularly vulnerable to drought, allowing drought relief efforts to be directed toward those in greatest need (Belal, Abdel-Aziz, et al., 2014).

A variety of indicators are available for drought assessment and monitoring. In terms of drought detection, each indicator has advantages and disadvantages. Drought indicators incorporate data on annual precipitation, stored soil moisture, and supply of water, but they do not provide enough spatial and temporal information in specific place. Drought indicators derived from satellite-derived surface parameters, on the other hand, have been widely used to study droughts.

Some of the most widely used vegetation indices are the Normalized Difference Vegetation Index (NDVI), the vegetation Health Indicator (VHI), the Temperature Condition Index (TCI), the Enhanced Vegetation Index (EVI) and the Vegetation Condition Index (VCI) (Xie, Fei, and Hui Fan, 2021).

:Research questions

1- How can GIS and remote sensing technology be used to improve drought monitoring and early warning systems in Iraq?

2- What are the most effective techniques for using GIS and remote sensing technology to map and analyze the effects of drought on agricultural productivity in Iraq?

3- How has the frequency and severity of meteorological drought changed over time, and what factors are driving these changes in Iraq?

4- How does hydrological drought impact water availability and quality in Iraq, and what strategies can be used to mitigate these impacts?

5- How does ecological drought impact ecosystem health and biodiversity in Iraq, and what management strategies can be used to mitigate these impacts?

6- What are the social and economic impacts of drought on Iraq community, and how can these impacts be mitigated?

Hypothesis:

1- By integrating GIS and remote sensing data on meteorological, hydrological and environmental conditions, it is possible to develop more accurate and effective early warning systems for drought, which can help mitigate its effects on Iraq.

2- If remote sensing and GIS analysis are used properly, they have the potential to significantly improve human growth and environmental sustainability goals.

3- The frequency and severity of meteorological drought has increased in Iraq due to climate change, and is likely to continue to increase in the coming decades, leading to significant impacts on water resources, agriculture, and human societies.

4- Hydrological drought can have significant impacts on water availability and quality, particularly in Iraq that is heavily reliant on surface water resources. Strategies such as water conservation, groundwater recharge, and drought-resistant crops can help to mitigate these impacts and ensure sustainable water management in Iraq.

5- Ecological drought can have significant impacts on ecosystem health and biodiversity, particularly in Iraq with high levels of species endemism and ecological sensitivity. Strategies such as habitat restoration, ecological monitoring, and water conservation can help to mitigate the impacts of ecological drought and promote ecosystem resilience.

6- Socio-economic drought can have significant impacts on vulnerable communities, particularly Iraq that is heavily reliant on agriculture and natural resources. Strategies such as early warning systems, social safety nets, and sustainable agriculture practices can help to mitigate the impacts of socio-economic drought in Iraq.

2- Study area

Iraq is an Arab Asian country that was once known as Mesopotamia. Administratively, Iraq is divided into eighteen governorates and one region known as the Kurdistan Region (see Figure. 1, Table 1). Iraq has a total area of 438,317 km^2. Iraq is situated between latitudes of 29.5 and 37.22 degrees north of the equator, and longitudes of 38.45 and 48.45 degrees east of the Greenwich line, astronomically. Iraq borders the Turkey on the north, the Syrian on the west, the Jordan on the east, Saudi Arabia and Kuwait on the south, and Iran on the east.

Iraq is a rich country in natural resources and natural gas, with large amounts of oil, particularly in the cities of Basra and Kirkuk. This country has only one port on the coast, which is the Persian Gulf port of Basra. The Tigris and Euphrates rivers are the most important in it, with the world's most important civilizations, such as Sumerian, Assyrian, and Babylonian, located on their banks.

The desert climate has an impact on Iraq. In the months of July and August, temperatures can reach 48 degrees Celsius. Furthermore, its summer is distinguished by high temperatures. Between the months of December and April, the country receives rain. The country receives 100-180 millimeters of precipitation per year on average. Iraq's mountain regions receive the most rainfall of any region. The country is divided into three climate zones, which are as follows:

1. The Mediterranean climate: it affects the mountainous areas of Iraq's northeastern region. The coldness and accumulation of snow on the peaks of these mountains are the most distinguishing features of the weather in these areas. The annual rainfall ranges from 400 to more than 1000 mm. Its summer is known as moderation, with temperatures not exceeding 35 degrees Celsius.

Figure (1): Study area.

Resource: https://map.gov.iq/ministry of planning. Iraq.

Table (1) The governorates of Iraq with their area

	Governorate	Population	Area km2	Districts
1	Baghdad	9,465,000	4,555	Karkh, Rusafa, madinat al-Sadr, Adhamiya, Kadhimiya, Abu Ghraib, Tarmiya, cities Husseiniya
2	Mosul	5,034,000	37,323	Baaj, Sinjar, Makhmour, Sheikhan, Hatra, Hamdaniya, Tal Afar, Tel Kaif
3	Basra	3,896,000	19,070	Qurna, Shatt Al-Arab, Al-Faw, Abu Al-Khasib, Al-Zubayr, Medina, Umm Qasr
4	Sulaymaniyah	2,492,000	17,023	Chamchamal, Dukan, Rania, Bashdr, Pishdar, kalar, kifri, Penjween, Chwarta.
5	Dhi Qar	2,459,000	12,900	Shatra, Rifai, suq alshuyukh, Chabaish
6	Babylon	2,364,700	5,119	Mahaweel, Musayyib, Hashemite.
7	Erbil	2,187,700	15,074	Erbil, Koysanjak, Soran, Shaqlawa, Choman, Makhmur, bnaslawa, khabat, Mergasor
8	Anbar	2,091,000	138,501	Anah , Haditha , Hit , Fallujah , wet - Rawah , Amiriya , The Karma , Khalidiya
9	Diyala	1,848,000	17,685	Baquba , Khalis , Muqdadiya , Khanaqin , Baladruz , Kifri
10	Kirkuk	1,715,600	9,679	Daquq , Dibs , Hawija
11	Salahaddin	1,689,000	24,751	Samarra , Shirqat , Baiji , Al- Dur , Balad , Tuz Khurmatu , Dujail
12	Najaf	1,496,000	28,824	Kufa , Manathira , Mashkhab
13	Karbala	1,390,300	5,034	Tuwairej , Ain Al-Tamr, Husseiniya
14	Wasit	1,360,000	17,153	Hay , Essaouira , Badra , Numaniyah , Aziziyah
15	Qadisiyah	1,320,000	8,153	Shamiya , Afak , Hamza, Ghamaas, Al bidir
16	Dohuk	1,258,700	6,553	Amadiyah , Aqrah , Simeel , Zakho

17	Maysan	1,079,644	16,072	Ali algharbi, Almaymuna, Almajar, Qaleat salih, Alkahla
18	Samawa	875,900	51,740	Alrumaytha, Alkhudar, Alwarka', Alsalman
19	Halabja	186,000	3,060	Shahrazour, Penjwen, Sayed Sadiq , Harparaz

Citation: Iraq Population", www.worldometers.info, Retrieved 11-4-2021

2. The Semi-arid/steppe climate: It is a climate that exists between the Mediterranean and desert climates. It has an impact on the country's northern and southern regions. Its effect on areas with ripples is highlighted. The annual precipitation ranges from 200 to 400 mm.
3. Arid/desert climate: this climate affects the sedimentary plain and western plateau regions. It covers 70% of the total land area of the country. It becomes extremely hot; where summer and winter are mild. However, freezing temperatures have been recorded on some winter nights.

Iraqi society is regarded as one of the young societies. According to the population pyramid of Iraq (see Figure. 2) indicating that people under the age of 15 accounts for 40.5 percent of the total population. The pyramid shows the age group (15-29) in Iraq, and they are the young population according to the national definition of the population in Iraq. They constitute the second group in the number of people, which reached 40.27% of the total population. The working-age population, or those aged between 30 and 44, made up 17.8% of the total population in 2021, down from 11.2% in 2021, according to the most recent official estimates. The people of the age group (15-64) constitute 2.11% of the total population, up from 2.01% in 2021, according to the most recent official (see Figure. 2).

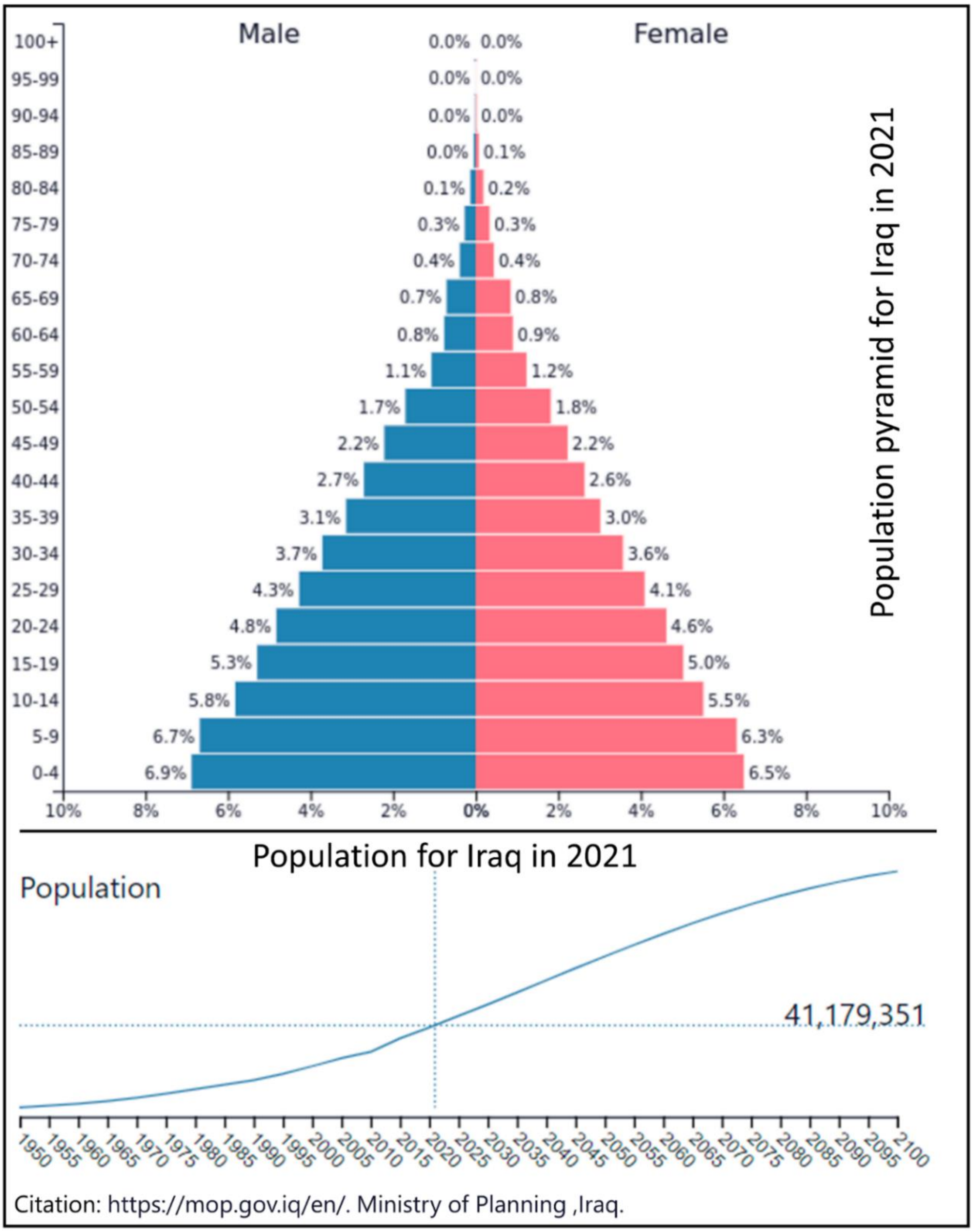

Figure (2): Population distribution by age and sex for Iraq in 2021.

3- Methods and data:

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The inductive approach was used in the study. The analytical approach is based on some Arab and international references. The United Nations, the United States Geological Survey, and the Food and Agriculture Organization all publish international reports. In addition, data from the Iraqi Ministry of Planning and the Central Statistical Organization, as well as data from the Ministry of Environment, are available. The data I use:

i. Moderate Resolution Imaging Spectroradiometer **(MODIS)**

Since the engineering model (EM) was finished in mid-1995, the MODIS instrument has been designed and developed. Two spaceflight units, the Protoflight Model (PFM) and the Flight Model 1 (FM1), have been completed and launched since then. Aqua was launched on May 4, 2002, and before that, Terra was launched on December 18, 1999. The MODIS instruments, which (Santa Barbara Remote Sensing) built to NASA specifications, represent the pinnacle of spaceflight hardware engineering for remote sensing. Monitors 36 spectral bands between 0.4 μm and 14.4 μm (see Figure.3) and Images entire earth every 1-2 days at 1 km resolution.

MODIS products that are relevant are: MOD11 - Surface temperature and emissivity; MOD43 - Albedo; MOD15 - Leaf Area Index (LAI); MOD13 – NDVI; Mod07 - Atmospheric stability, temperature, and vapor pressure at 20 vertical levels; MOD03 - Latitude, longitude, ground elevation, solar zenith angle, satellite zenith angle, and azimuth angle (MODIS Components, 2021).

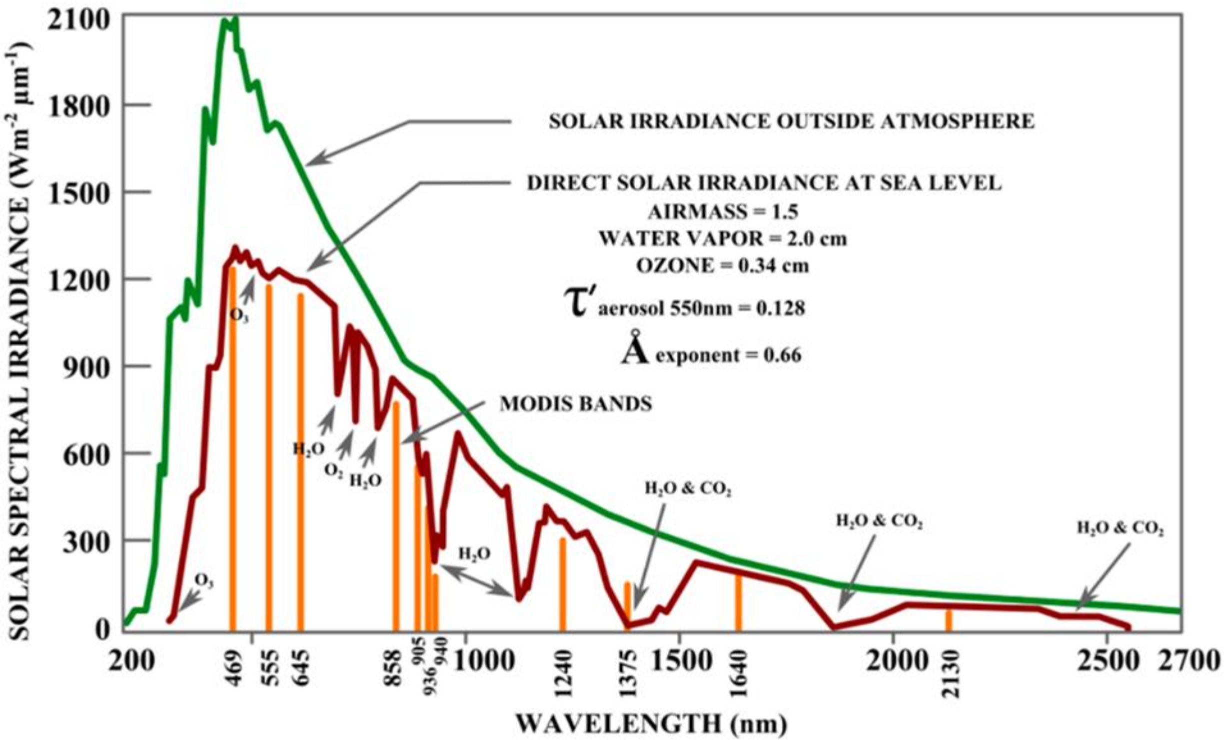
POWER Data Access Viewer v2.0.0 ***(DAV)****.ii*

I downloaded free climate data from 1981 to 2020 from DAV. I got temperature, precipitation, humidity, wind, and many other data from 1981-2020 for Iraq. DAV is Web Mapping Application includes cloud related parameters, meteorological, and geospatially enabled solar that can be used to evaluate and develop renewable energy systems (https://CRAN.R-project.org/package=nasapower).

iii. Normalized Difference Vegetation Index (NDVI)

We should observe the distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants to determine the density of green on a patch of land. It helps to differentiate vegetation from other types of land cover (Eastman, J. Ronald, et al.2013).

Figure (3): Solar irradiance spectrum and MODIS bands.



Citation: MODIS Imagery, https://modis.gsfc.nasa.gov/

The NDVI is calculated using the following formula: NDVI = (NIR-Red) / (NIR+Red), where NIR is near-infrared light and Red is visible red light (Pettorelli, N.2013).

4- EVI: The Enhanced Vegetation Index (EVI) was designed to correct NDVI results for atmospheric influences as well as soil background signals, particularly in dense canopy areas. Healthy vegetation has a value range of 0.2 to 0.8. and EVI has a value range of -1 to 1 (Waring, R. H., et al.2006).

Formula of EVI: EVI = 2.5 * ((NIR – Red) / ((NIR) + (C1 * Red) – (C2 * Blue) + L)) where NIR/red/blue are atmospherically corrected and partially atmosphere corrected (Rayleigh and ozone absorption) surface reflectances, L is the canopy background adjustment that addresses non-linear, differential NIR and red radiant transfer through a canopy, and C1, C2 are the coefficients of the aerosol resistance term, which uses the blue band to correct for aerosol influences in the red band. The MODIS-EVI algorithm employs the following coefficients: L=1, C1 = 6, C2 = 7.5, and G (gain factor) = 2.5. (Waring, R. H., et al. 2006).

5- The Vegetation Health Indicator (VHI): Drought of Iraq was studied using the Vegetation Health Indicator (VHI), a remote sensing index. VHI= a*VCI + (1- a)*TCI, where an is the coefficient that determines the contribution of the two indices. VHI is a measure for vegetative health or a combined estimate of moisture and temperature. VHI can be calculated using both the NDVI and Land Temperature Surface (LST) (Masitoh, F., Rusydi, A. N. 2019).

Consequently, the VCI is computed from the EVI time series using the reflectance data in the visible and NIR bands, and the TCI is computed from brightness temperature data from the MODIS thermal infrared spectral band), (Aitekeyeva, Nurgul, et al. 2020). The VHI, TCI, and VCI can be expressed as follows:

$$\mathrm{VHI} = 0.5 \times \mathrm{TCI} + 0.5 \times \mathrm{VCI} \quad (1)$$

$$(2)\mathrm{TCI} = \frac{(LSTmax - LST)}{(LSTmax - LSTmin)}$$

$$(3)\mathrm{VCI} = \frac{(EVI - EVImin)}{(EVImax - EVImin)}$$

$$(4)\mathrm{EVI} = \frac{2.5 \times (NIR - Red)}{(NIR + 6 \times Red - 7.5 \times Blue + 1)}$$

where Red, NIR, and Blue are the reflectivity of the surface; EVI and LST are download of MODIS products; LSTmin and LSTmax are the minimum and maximum the LST values; and EVImin and EVImax are the minimum and maximum the EVI values, respectively. The VHI was divided into five classes based on the threshold values presented in the following table, which were determined by taking into account the high association between VHI 40 and crop stress, which has previously been utilized and proven in prior drought research (Table 2).

Table (2): Classes of drought for the vegetation health index (VHI), (Aitekeyeva, Nurgul, et al. 2020).

Severity Class	**Value**
Extreme drought	<10
Severe drought	10–20

Moderate drought	20–30
Mild drought	30–40
No drought	>40

4. **Results**

Drought can be categorized into different types based on its causes, duration, severity, and impacts. These categories are not mutually exclusive, and a drought event can fall into more than one category. Understanding the different categories of drought can help policymakers, water managers, and communities to develop effective strategies to mitigate its impacts.

According to recent studies, drought has reached 39% of Iraq's area, with the remaining 54% under threat (FAO, 2021). Iraq has been plagued by droughts on a regular basis since 2001, the Food and Agriculture Organization (FAO) of the United Nations reporting that the country was hit hard by drought conditions in 2011 (as seen in figure 4) and once more in 2018–2019. A significant impact on the nation's food security has been caused by these droughts, which have significantly decreased crop yields, particularly in the wheat and barley sectors.

Climate change mitigation and transnational water management will be difficult due to national and regional political uncertainties. In figures 4, show the spatial and temporal environment degradation in Iraq. The agricultural areas that were harmed by 10 to 38 percent (the vegetation health index (VHI)) are those where agriculture and vegetation rely on rainfall, or what is known as rainfed agriculture in Iraq. The incidence of damage in places that rely on irrigation agriculture on the banks of the Tigris and Euphrates rivers ranges from 38 percent (the vegetation health index (VHI)) (as seen in figure 4). That means climate change, human activity, and water management all play a role in the drought in Iraq.

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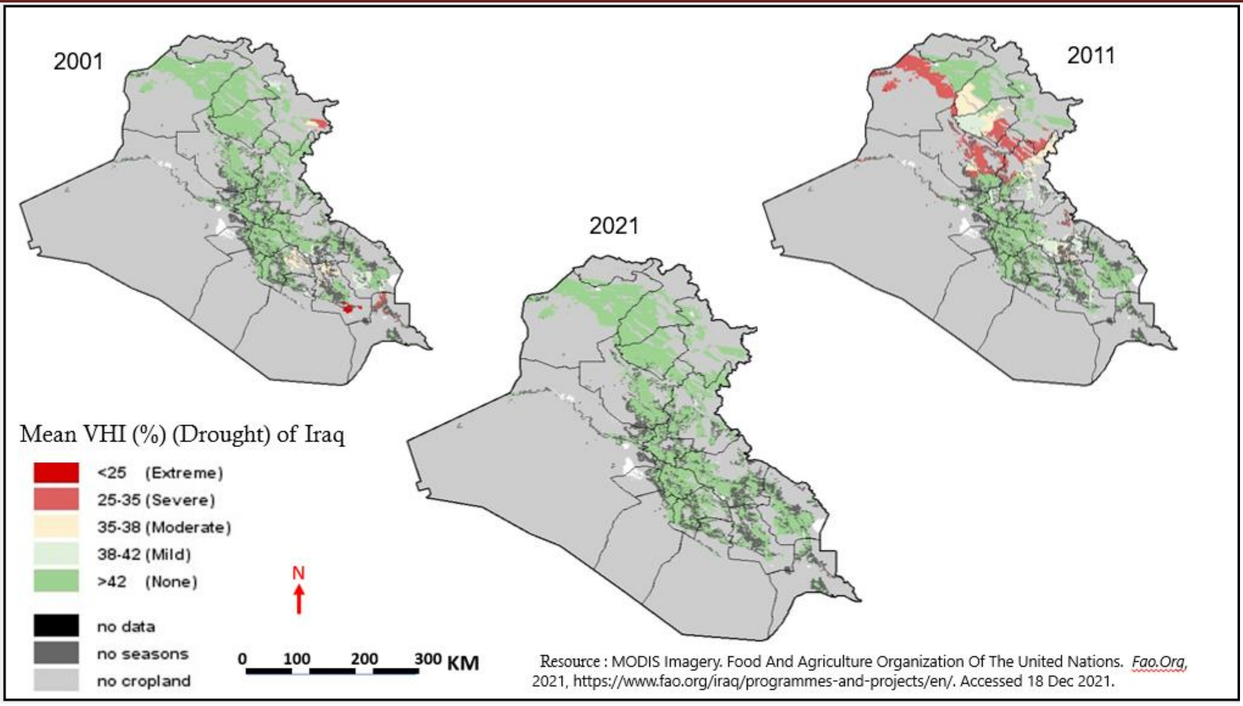


Figure (4): The yearly drought of cropland in Iraq for (2001, 2011, 2021).

The following are the major categories of drought in Iraq:

1- Meteorological Drought: This type of drought occurs when there is a prolonged period of abnormally low precipitation, leading to a deficiency in water supply. Meteorological droughts are usually seasonal and can occur in any region (Heim, R. R. Jr. 2002). Iraq's environmental, economic, political, and security issues are being exacerbated as a result of climate change. Iraq's agricultural has been weakened by rising temperatures, declining precipitation, desertification, severe droughts, salinization, and the growing frequency of dust storms (Hassan, K., Born, C; Nordqvist, P. 2018). Furthermore, climate change, such as rising temperatures, less precipitation, and increased water scarcity, will almost certainly have long-term consequences for Iraq's state. In this study, I focus on rising temperatures as well as declining precipitation as follows:

1.1- **Rising temperatures:** Iraq's winters are also brief and cold, and summers are long, hot, and dry. The hottest months of the year are June, July, and August. the coldest months of the year December, January, and February. In Iraq, average temperatures range from 29 degrees Celsius in July and August to below 4.4 degrees Celsius in January and February (see: Table 3 and Figure 5). Central Iraq's July temperatures exceed making it one of the world's fastest-warming locations. It presents a dismal picture of global climate change in the future (world bank. 2019), (see Figures 5, 6 and table (3)).

Even though temperatures in neighboring countries are similar, they are the highest in Iraq. Because the infrastructure has been destroyed and is no longer capable of absorbing all of the climate extremism. Iraq is one of the most vulnerable countries to climate change.

Table (3): Annual Climatic data for Iraq (2011-2021). (Temperature °C (Average Maximum and Minimum) and Precipitation cm).

The month	Average Maximum Temperature °C	Average Minimum Temperature °C	Precipitation cm
January	14	5	18
February	15	6	15
March	17	11	9
April	21	14	5.1
May	23	17	1.7
June	26	20	0.25
July	28	22	0
August	29	23	0
September	28	22	0.5
October	26	17	4
November	20	10	12
December	16	7	17
Annual rate	22	15	82.55

Resource: General Authority for Meteorology and Seismic Monitoring Iraq, 2021.

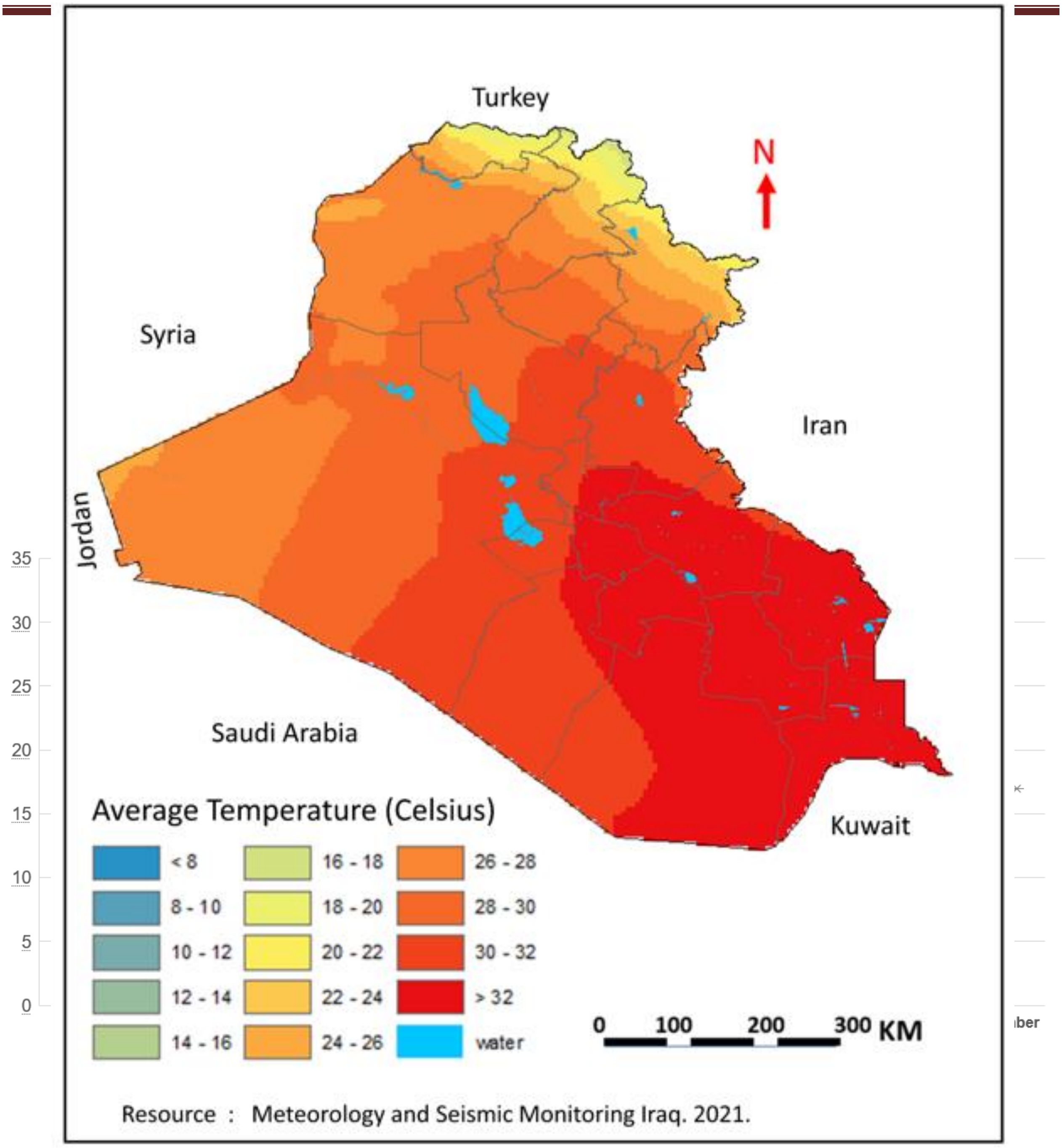


Figure (5): Annual Climatic data for Iraq (2011-2021)

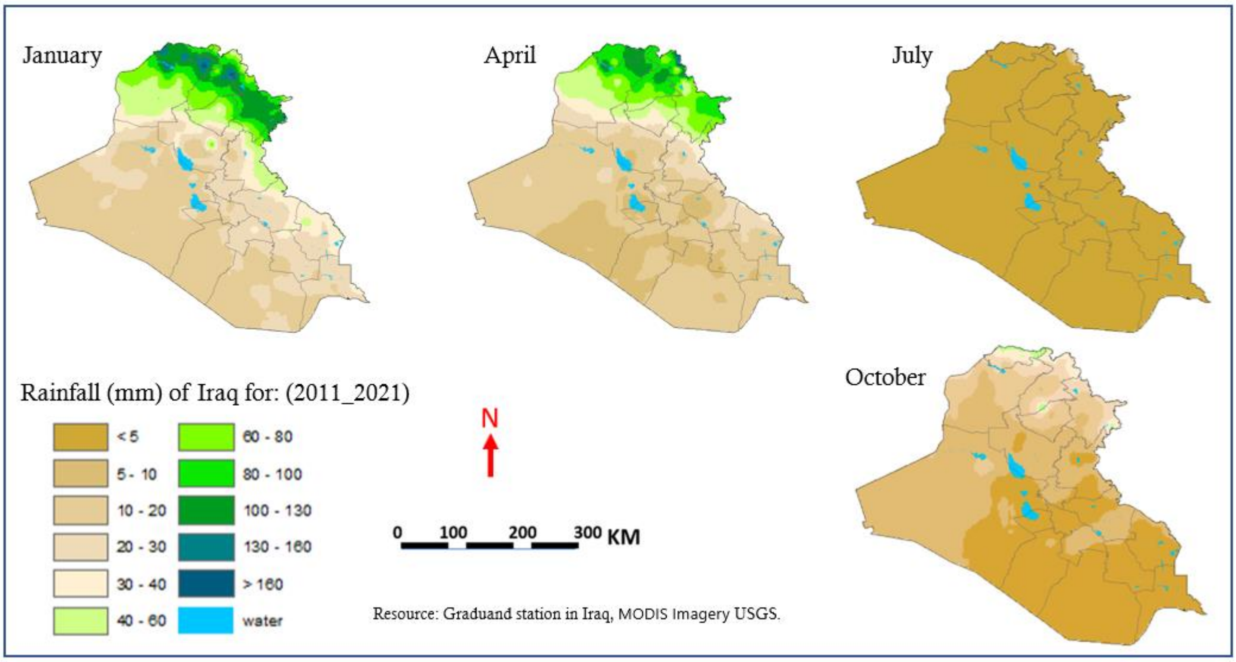
Citation: Table (3).

Figure (6): Iraq Average Temperature (Celsius) 2011-2021.

1.2- **Declining precipitation.**

Between November and April, and December and March, nearly 90 percent of the annual rainfall falls. Rain is uncommon in the remaining months, particularly those with high temperatures, such as June, July, and August (as shown in Figure 5, 7). Except for the north and north-east, data from stations in the foothills of the mountains, the plains of the south, and the south-west of the mountains indicate that the average annual precipitation for that region ranges between 1500- and 2000-mm (IOMS,2021). Precipitation is more abundant in the mountains, possibly up to 2,600 mm per year in some places, but the terrain prevents extensive cultivation. Agriculture is limited to unirrigated land, primarily in mountain valleys, foothills, and steppes that receive 700 millimeters of rain or more per year (IOMS,2021). Even in this region, only one crop can be grown per year, and increased rainfall frequently causes crop failure.

Figure (7): Spatial distribution of seasonal precipitation in Iraq for: (2011_2021)



2- Socio-economic Drought: Socio-economic drought occurs when water demand exceeds the available water supply, leading to social and economic impacts. This type of drought can affect industries, power generation, tourism, and other economic activities that depend on water (Wilhite, D. A., 2000). One of the major issues that the globe, as well as Iraq, faces is the continuing increase in population (see Figure. 2, Table 1). The problem of rapid population increase is the root cause of all other problems, and this rapid population expansion is ascribed to environmental developments in a variety of disciplines. Massive growth that is out of proportion to available natural resources leads to the collapse of agriculture, resulting in a downturn and challenges in controlling economic and social development. Population expansion will certainly have an impact on environmental damage due to the constant strain on basic services and the horizontal increase in natural resource exploitation (Bartlett, Albert A,1994). Iraq had a real problem creating the governments that was reflected in the socioeconomic reality of the country after Saddam the regressive dictator's rule, the occupation after 2003, and the failed and corrupt governments after 2012. Iraq's socio-economic drought is being exacerbated by two major human-caused issues:

1- Iraq’s political and governmental achievements:

The following are examples of government performance issues in Iraq, as well as their impact to environmental degradation (World Bank,2019):

a- The difficulties of policies and legislation, exemplified by a high volume of imports at the expense of domestic products and a lack of investment in the agricultural sector, particularly infrastructure projects.

b- Use of rudimentary agricultural technologies and the lack of rivalry between local food commodities and their imported counterparts.

2- Wars: Iraq is remarkable in the number of wars that have ravaged it, and this has had a noticeable impact on the environment. These wars were:

- Iraq & Iran War (1980–1988)
- Gulf War (1990–1991)
- Iraq War (2003–2011)
- War in Iraq (2013–2017)

The Iraq wars have had an impact on the environment in:

1- Oil, sulfur, soot, and acid rain rained down from as far as 1,900 kilometers (1,200 miles), poisoning the animals and vegetation, contaminating the water, and choking the people. Nearly half a billion tons of carbon dioxide were emitted by burning oil fields (Dixon, M., & Fitz-Gibbon, S. 2011).

2- Wars have an impact on the environment because the weapons and military equipment employed in hostilities leave environmental legacies. Land mines, cluster munitions, and other explosive remains of war can restrict access to agricultural land and damage soils and water supplies with metals and harmful energetic elements, limiting access to agricultural land (CEOBS, 2020).

3- Hydrological Drought: Hydrological drought is a deficiency of water in rivers, lakes, and groundwater. This type of drought is caused by a prolonged period of low precipitation, reduced runoff, and increased evaporation (Vicente-Serrano, Sergio M., et al. 2012). Because of a shortage of rainfall, a meteorological drought occurs. Low precipitation, streamflow, and water storage are all factors that contribute to a hydrological drought. Climate change, while not the only cause of water shortage, causes less rain for agriculture and deterioration of the quality of freshwater reserves due to the inflow of saline water from the Gulf into freshwater aquifers and higher pollutant concentrations. Iraq's water security is predicated on the Tigris–Euphrates Rivers system, which are deteriorating. The 2020-2021 rainy season in Iraq was very dry in the last 40 years, resulting in a 29% and 73% decline in water flow in the Tigris Unsustainable resource construction projects (such as and Euphrates, respectively. hydroelectricity, dams, and water diversion systems among river basins) have a direct impact on Iraq's hydrological systems. Additionally, excessive decrease and improper use of water from natural sources in traditional agriculture in Iraq have led to the destruction of various streams and wetlands.

Turkey, Iran, Syria, and Iraq all share the Euphrates-Tigris Basin. Unilateral irrigation plans that affect river flows, dam construction, and political disputes between countries have strained relations in the basin. Disputes have made it impossible for the three countries to successfully co-manage the basin's rivers. Despite increasing cooperative efforts in the 2000s, no official agreement on basin water management has been reached (climate-diplomacy.org, 2021).

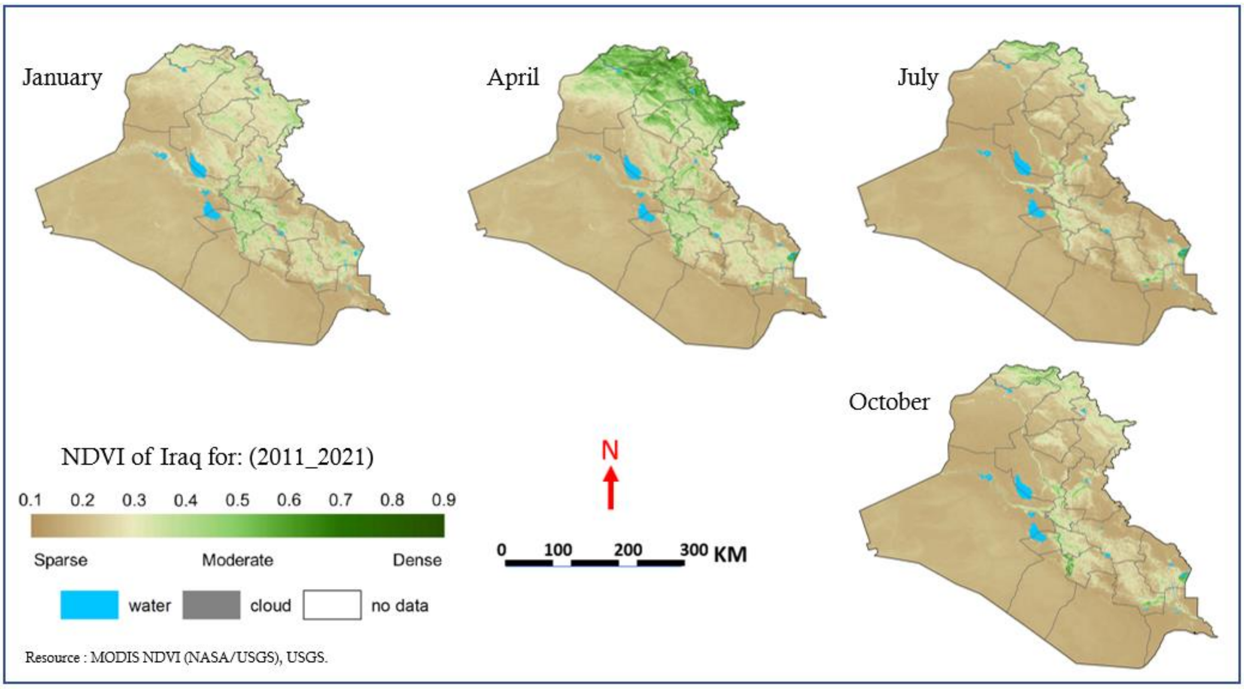
4- Agricultural Drought: Agricultural drought happens when the moisture content in the soil is insufficient to support crop growth, resulting in lower crop yields, and loss of agricultural production. This type of drought can lead to food shortages and can have significant economic impacts on rural communities (Kogan, F. N. 1997). Because of evaporation and low soil moisture, plants are affected during an ecological or agricultural drought.

The agricultural drought of Iraq is caused by a combination of natural and human factors, including retreating water, climate shifts, and bad land management. The degradation of Iraq's habitat is the result of agricultural drought in a semi-arid climate zone.

There is a spatial correlation between precipitation and vegetation cover (as shown in Figures 7 and 8 and table (3)). We can see an increase in vegetation cover in the northeastern regions of Iraq, which receive a lot of rain, as well as around riverbanks that rely on rain and snow in the Tigris and Euphrates basins. On the other hand, in the arid areas, as in the western and northern regions, we see a decrease in vegetation cover. As a result, we discover that droughts have a significant impact on the regional and temporal distribution of vegetation cover. This indicates that drought, as a manifestation of climatic extremism in Iraq, plays a significant influence on ecological degradation.

The drought is severe and prolonged, with higher-than-average temperatures, fluctuating rainfall. All of this resulted in the annihilation of agricultural crops and the drying up of vast swaths of land. Temperatures gradually rise as vegetation declines. In figures 5 and 6, show the spatial and temporal temperature distribution in Iraq, and figure 8 shows the spatial and temporal vegetation distribution in Iraq which has an extremely high correlation. You can see that vegetation grows at the same season of the year when temperatures are low or moderate, which is normally be in Iraq's northeastern regions. On the other hand, in locations with high temperatures throughout the year, such as the south-southwest, we find that vegetation cover declines. Finally, we discover that temperatures have a significant impact on the regional and temporal distribution of vegetation cover. This indicates that the agricultural drought in Iraq has a devastating impact, especially with high temperatures, solar radiation and decreased annual precipitation contribute significantly to environmental degradation.

Figure (7): Iraq average monthly maximum NDVI for: (2011-2021)



5- conclusion

Finally, GIS and remote sensing technology can be used to improve water management and conservation in drought-prone regions. By combining data on water resources, land use, and environmental conditions with GIS analysis and remote sensing data, it is possible to identify areas where water management and conservation efforts are most needed, and to develop more effective water management strategies to mitigate the impacts of drought in Iraq.

The Iraqi government has implemented a number of measures in response to the current drought conditions to lessen the effects of the drought and enhance water management. The promotion of drought-resistant crop varieties and the use of drip irrigation systems are two examples of actions that can be taken to increase the efficiency of water use in agriculture.

In addition, the government has implemented measures to improve water conservation and reduce water waste, such as limiting the extraction of groundwater and building new water storage facilities. Despite these initiatives, drought still poses a serious problem for Iraq, especially in light of climate change and rising water demand. Therefore, continuing investment in water management and drought mitigation strategies will be essential to guarantee the nation's food security and economic growth in the years to come.

The study conclusions are summarized as follows:

1- Environmental degradation is a symptom of global processes that endanger the globe, such as desertification and drought caused by global warming and climate change.

2- Exacerbation of the salinity and water scarcity problem as a result of neighboring countries' policy, particularly Turkey's, of constructing massive dams in contravention of international law.

3- By combining data on soil moisture, vegetation health, and other environmental factors with satellite imagery and GIS analysis, it is possible to accurately assess the impacts of drought on crop yields and identify areas that are particularly vulnerable to drought-related losses in agricultural productivity.

4- The socio-economic drought is the result of current and prior regime practices such as draining marshes and water bodies, chopping down millions of palm trees, and burning oil wells in the south.

5- Iraq's rising population expansion has put a strain on natural resources and the environment and exacerbation of the socio-economic drought.

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