تأثير الجفاف المناخي على الغطاء النباتي والمائي في منطقة الجزيرة بالعراق

The impact of climate drought on the vegetation and water cover of Al- Jazeera region in Iraq

م. د. ليث شاكر احمد عبدالله

Laith Shaker Ahmed Abdullah

وزارة التربية/ المديرية العامة لتربية الانبار/ قسم تربية الفلوجة

Ministry of Education / General Directorate of Education in Anbar / Fallujah Education Department

Dr.laithshaker1982@gmail.com

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المستخلص:

يُعدّ الجفاف المرتبط بالمناخ ظاهرة متكررة في منطقة الجزيرة، لا سيما في الفترة الأخيرة، نظرًا لتأثر هذه المنطقة بشكل مباشر بتقلبات هطول الأمطار المرتبطة بالزراعة البعلية. وينتج هذا الجفاف عادةً عن اختلال التوازن بين التبخر المحتمل وكمية الأمطار، خاصةً في الفترة الأخيرة التي شهدت تغيرات مناخية سريعة تمثلت في ارتفاع درجات الحرارة وانخفاض هطول الأمطار، مما شكّل تهديدًا مباشرًا للمنطقة، لا سيما في الجوانب الزراعية والهيدرولوجية.

يهدف هذا البحث إلى تحليل الغطاء النباتي والمائي من خلال تحديد توزيعهما المكاني ومساحتهما في المناطق الجافة, وقد أظهرت النتائج وجود تباين واضح في الغطاء النباتي والمائي، وأن عام 2005 كان الأكثر جفافًا والأصغر مساحةً مقارنةً بالأعوام الأخرى.

Abstract

Climate-related drought is a recurring phenomenon in the Al-Jazeera region, especially in the recent period, as this region is located directly affected by the fluctuations in the rainfall line associated with rain-fed agriculture. This drought is usually the result of an imbalance between potential evaporation and the amount of rainfall, especially during the recent period, which witnessed rapid climate changes represented by rising temperatures and decreasing rainfall, which posed a direct threat to that region, especially in the agricultural and hydrological aspects.

The research aims to analyze the vegetation and water cover by determining their spatial distribution as well as their area for the dry. The results showed that there is a clear variation in the vegetation cover and water cover and that the year (2005) was the driest year, and the smallest area compared to other years.

Introduction

Climatic drought is one of the most significant extreme climate phenomena that has considerable impacts on ecosystems and economic activities, particularly in arid and semi-arid regions. It is defined as a prolonged decrease in precipitation levels below the long-term average, resulting in reduced water resources, vegetation degradation, and declines in agricultural productivity (Wilhite & Glantz, 1985). Studies have shown that climate change driven by global warming has increased both the frequency and intensity of drought events in recent decades (Dai, 2011).

This type of drought is characterized by its cumulative and slow-onset nature, making it difficult to precisely determine its onset and end. Its manifestations and causes vary across regions depending on climatic and geographical conditions, as well as human influences such as deforestation and poor water management (Mishra & Singh, 2010). According to the Intergovernmental Panel on Climate Change (IPCC, 2021), dry regions are expected to be among the most affected by future droughts unless effective adaptation strategies are implemented.

In this context, modern technologies such as remote sensing and vegetation indices have become essential tools for monitoring and assessing drought, providing high-resolution data over large spatial and temporal scales. These tools help in understanding the long-term environmental impacts of drought (Yengoh et al., 2014). Although there is still some scientific debate about the extent of global drought trends, several studies suggest that changes in rainfall patterns and increased water demand may exacerbate drought conditions in some areas (Sheffield, Wood, & Roderick, 2012).

The last half century witnessed the development and use of various remote sensing devices and the use of many indicators, including the vegetation cover index. The basis for developing this index is that some spectral bands in remote sensing can reveal information about vegetation, including (vegetation structure, vegetation condition, photosynthesis ability, leaf density and distribution, water content in leaves, mineral deficiency), and these spectral bands are sensitive to one or more of the aforementioned factors (Yengoh, G. T et al. 2015).

Several studies have been conducted on these indicators, including the study by (Ichii et al. 2002), which analyzed the changes in the northern regions of the middle and high latitudes and showed that increases in the natural vegetation index are associated with rising temperatures, and that the decrease in the natural vegetation index in the southern semi-arid regions is due to low rainfall during the survey period. Also, the study by (Nanzad et al. 2019) mapped the severity of drought and its spatial distribution in Mongolia, based on the anomaly of the normalized vegetation index (NDVI) during the growing season from 2000 to 2016. The results indicated that Mongolia experienced mild to severe drought during the seventeen years, and the most affected years were 2001, 2007, 2002, 2005, 2004, 2009, and 2006, respectively, when 41%-57% of the country was under mild to severe drought conditions. Also, the study by (Gu, Y et al. 2007) shows preliminary results of strong relationships between Normalized Vegetation Index, Normalized Water Index, and Drought Conditions. During the summer over Tall Grass Prairie National Park, the average Normalized Vegetation Index and Normalized Water Index were consistently lower.

The Difference Water Cover Index (NDWI) was first proposed by Mc Feeters (1996) to detect water bodies in any area and indicate wet and dry areas (McFeeters, S. K. 2013). It is a satellite-based remote sensing index that is sensitive to changes in the water content of the area under study. The values of this index range between (-1 and +1) depending on the amount of water present, as high values of this index (blue) indicate the highest water content (JRC European Commission. 2011). Many studies have been conducted on the NDWI, including the study by (Al-Dhizi. 2019), which investigated the impact of drought on vegetation cover in the Parbhani region of Maharashtra, using remote sensing techniques. Analysis of Landsat 8 data for 2015 (drought year) and 2020 (normal year) reveals fluctuations in the Normalized Difference Water Index (NDWI) that are closely linked to rainfall patterns. In 2015, the NDWI indicated severe drought conditions, while in 2020, most areas experienced mild drought.

Data and Methodology

The Al-Jazeera region is geographically located in the northeastern parts of the Arab world in the area between the Tigris and Euphrates, as it occupies the northwestern part of Iraq. The study will depend on the borders of the region within Iraq only, which extends in a northwest-southeast direction in the form of a triangular plateau bordered to the east by the Tigris River, to the southeast by the alluvial plain, to the south and southwest by the Euphrates River, and to the west by the Syrian Iraqi border. The area of the region is (62285.7) km2 of the total area of Iraq, which is (437052) km2 [18]. Thus, the area of the region represents (14.25%) of the total area of Iraq. The region is distributed within three governorates (Ninawa, Salah al-Din, Anbar) with an area of (30.3445, 16.9190, 14.9650) km2 respectively, as shown in Table (1). The region is located astronomically between latitudes (°29 ¯22 =33) and (°52 ¯22 =37) north, and longitudes (°34 ¯01 =41) and (°42 ¯2 =44) east, figure (1). Temporally, data for the years (1987, 1999, 2005, 2017) were adopted, represented by temperatures, rainfall, and evaporation/transpiration, to determine the variation in the dryness of the study area, in addition to selecting some drought years. Satellite images of the study area published on the website of the US Geological Survey were also used. On the link https://earthexplorer.usgs.gov/ (US Geological Survey 2024) figure (2), the satellite images were analyzed during the spring season, as it is the result of the rainy climate season in the study area.

This study focuses on assessing the impact of climate drought on vegetation and water cover in the Al-Jazeera region of Iraq. The scope is geographically confined to the Al-Jazeera Plain, located in northwestern Iraq between the Tigris and Euphrates rivers. Temporally, the study analyzes changes from 1987, 1999, 2005, 2017. The research relies on remote sensing techniques, specifically the analysis of satellite imagery using the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI), to monitor changes in vegetation density and water distribution. The study does not include field-based ecological or hydrological measurements; instead, it depends solely on satellite-derived indices to evaluate environmental changes. Climatic conditions are interpreted primarily through meteorological drought as indicated by remote sensing data, without incorporating socioeconomic factors or local adaptation responses. The study emphasizes spatial and temporal patterns of drought impact, rather than the causes of drought or predictive modeling.

The governorate	Total area of the governorate	Area of the study area from the area of the governorate	Percent %
Ninawa	37.185	30.826	49.5
salah aldiyn	26.685	16.814	27
Al Anbar	138.408	14.645	23.5
Sum.	202.278	62285.7	100

Table (1): The area of the study area and the percentage it constitutes of the area of each governorate (km2)

Source: Using Arc Gis 10.7.

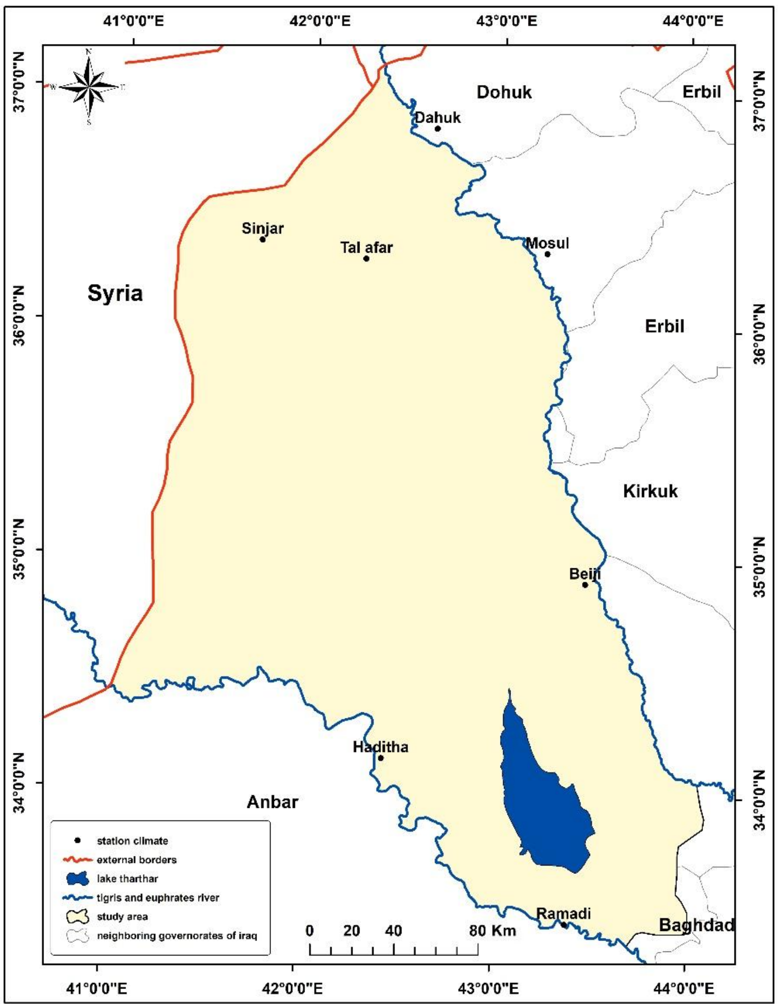

Figure (1): The astronomical and geographical location of the Al-Jazeera region

Source: Based on the General Authority for Survey, the administrative map of Iraq at a scale of 1:1000000, and the Arc Map 10.7 program.

Figure (2): How to download satellite images from the US Geological Survey website

Source: Based on the US Geological Survey website https://earthexplorer.usgs.gov/

The work methods were represented by using climate data represented by temperatures, rainfall, evaporation/transpiration obtained from the Iraqi Ministry of Transport/Iraqi Meteorological Authority and seismic monitoring to determine the drought status and identify dry years to identify the driest dry years.

The drought for the selected years was calculated based on two important indicators, the first of which is the Reconnaissance Drought Index (RDI), which is one of the most important indicators of the World Meteorological Organization for assessing drought and is an ideal indicator for studying the effects of climate instability (Al-Habti, 2017), which was issued and adopted by the World Meteorological Organization (WMO) within the Integrated Drought Management Program (IDMP) (Indices and Indices Guide for Drought Management. 2016). This indicator was calculated using the (Drin C) program, as its calculation is based on two basic variables, which are rainfall (P) and evaporation/transpiration (PET), Figure (3). It is also one of the modern indicators that depends on the sum of the differences between rainfall and evaporation/transpiration. The values and degrees of drought in this factory vary according to their intensity and degree of strength to five degrees ranging from the highest degrees of drought (super-dry) to the lowest (semi-humid), as shown in table (2).

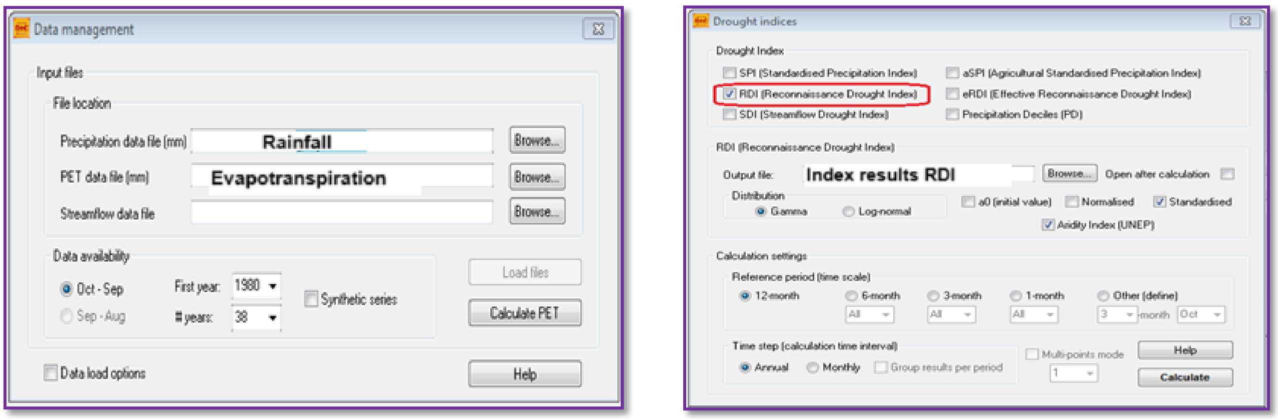

Figure (3): Drin C program interface and RDI drought index

Source: Based on (Drin C 1.7)

Dryness standard	In the Penman Monteith way	In the Harkavy's way
The Hyper Arid	**Less than 0.03**	**Less than 0.05**
The Arid	**0.20-0.03**	**0.20-0.05**
The Sub Arid	**0.50-0.20**	**0.50-0.20**
The Sub Humid	**0.75-0.50**	**65-0.50**
Humid	**More than 0.65**	**More than 0.65**

Table (2): Degrees of drought and humidity according to the Reconnaissance Drought Index (RDI)

Source: G.Tsakirisand H. Vangelis, Establishing a Drought Index Incorporating Evapotranspiration, Lab. of Reclamation Works & Water Resources Management National Technical University of Athens, Iroon Polytechniou, Athens – Greece, 2005.

The Köppen Drought Coefficient was also adopted to ensure that the year is dry or not. This classification was introduced by Wladimir Köppen, a German botanist, who showed the results of his work in 1900. The Köppen classification is one of the most famous climate classifications known (Shalash. 1978). According to the Köppen classification, Iraq's climate is classified into three regions: (Mediterranean climate Csa-warm temperate, steppe climate Bsh-semi-arid, desert climate Bwh-dry), and these regions are characterized by their highly variable rainfall. In general, rainfall fluctuation increases in the desert climate and decreases in the steppe climate and then the Mediterranean climate, considering that the desert climate and steppe climate are basically a deterioration of the Mediterranean climate in terms of temperature and rainfall (Al-Dhizi. 2019). To determine the effective rainfall coefficient in the Al-Jazeera region, the Köppen drought coefficient was used, which depends on the annual average temperature (°C) and the total annual rainfall in (cm).

as well as remote sensing data to extract the amount of change in the vegetation and water cover index for the years studied. The vegetation difference index equation was used according to the following formula:

(1) $\mathbf{NDVI} = (\mathbf{NIR} - \mathbf{R})/(\mathbf{NIR} + \mathbf{R})$ (Sancho, L. G et al. 2016) Equation 1

A model for this index was built based on its own equation, which was formulated as:

(2) $\mathbf{NDVI} = (\mathbf{NIR} - \mathbf{R})/(\mathbf{NIR} + \mathbf{R})$ (Serrano, J et al. 2019) Equation 2

Results and Discussion

First: Climatic characteristics of drought years

The years that were chosen were not randomly, but rather were chosen scientifically, based on which the study was based by identifying consecutive dry years (the driest three years and the fourth is analyzed, or the driest two years and the third is analyzed) and then choosing the last dry year in each of the four study periods. The dry year that was chosen is the driest year and is the result of the previous dry years, which means that desertification manifestations appear clearly, in addition to conducting comparisons between desertification manifestations and the coverage areas of each type to determine the extent of the changes that occurred in them. The years that were chosen (1987, 1999, 2005, 2017) were during the spring season (calculating drought indicators) and conducting a comparison process between those indicators in terms of time and space.

Table (3) describes the climatic characteristics of the drought years in the study area and classifies them according to rainfall, temperature, and evaporation/transpiration, in addition to calculating the drought indicators for each year by adopting two climatic indicators, namely the Reconnaissance Drought Index (RDI) and the Köppen Drought Coefficient. It was found that all the years that were identified were dry and varied in their degree of dryness according to their geographical location, in addition to the temperature, rainfall, and evaporation/transpiration for each of them. In the stations located north of the study area (Dohuk, Mosul, Sinjar), their degree of dryness was less than the stations located south of it (Baiji, Ramadi, Haditha) due to their geographical location and their location in higher latitudes, in addition to being affected by colder air masses than those affecting the south of the study area, as well as their higher elevation above sea level, which led to them having a lower temperature, higher rainfall, and a lower amount of evaporation/transpiration, which led to them being less dry compared to the rest of the other stations.

Station	Years	Sum Rain (m)	Average temp. c°	Sum Evapotranspiration (m)	RDI	Köppen
Dohuk	1987	256.4	20.4	1597.1	The Sub Arid	Bsh
	1999	129.7	22.7	1712.6	arid	Bwh
	2005	312.7	20.9	1615.6	The Sub Arid	Bsh
	2017	332	20.7	1552.1	The Sub Arid	Bsh
Average/Annual Total		369.7	20.4	1612	-	-
Mosul	1987	254.7	20	1421.8	arid	Bsh
	1999	139.5	21.4	1521.4	arid	Bwh
	2005	357	20.6	1381.9	The Sub Arid	Bsh
	2017	291.2	20.7	1205.5	The Sub Arid	Bsh
Average/Annual Total		353.1	20.4	1348.5	-	-
Sinjar	1987	236	20.4	1915.4	arid	Bsh
	1999	342.2	22.2	1910.9	arid	Bsh
	2005	309.3	21.6	1803	arid	Bsh
	2017	384.5	21.8	1512.1	The Sub Arid	Bsh
Average/Annual Total		362.5	20.9	1747.4	-	-
Talafar	1987	288.7	20.9	1514.1	arid	Bsh
	1999	151.7	21.9	2047.4	arid	Bwh
	2005	295.4	21.7	1876.1	arid	Bsh
	2017	302.1	22.1	1318.3	arid	Bsh
Average/Annual Total		308.6	21.1	1700.1	-	-
Biji	1987	94.4	22.4	1632.1	arid	Bwh
	1999	211.1	24	1801.9	arid	Bwh
	2005	252.5	22.7	1293.3	The Sub Arid	Bwh
	2017	171.5	23.5	1442.8	arid	Bwh
Average/Annual Total		192.4	22.8	1599.6	-	-
Ramadi	1987	40.6	21.6	1807.4	The Hyper Arid	Bwh
	1999	165.3	23	1790.5	arid	Bwh
	2005	109	22.6	1866.3	arid	Bwh
	2017	125.8	22.6	1564.6	arid	Bwh

Average/Annual Total		108.1	22.2	1721.8	-	-
Haditha	1987	95.7	21.5	2259.5	arid	Bwh
	1999	41.4	22.7	2154.7	The Hyper Arid	Bwh
	2005	82.2	22	1834.6	arid	Bwh
	2017	113.1	22.3	1452.7	arid	Bwh
Average/Annual Total		130.2	21.3	1954.3	-	-

Table (3): Climatic characteristics of the selected dry years in the study area

Source: Ministry of Transport, Iraqi Meteorological and Seismic Authority, Climate Department, unpublished data.

Second: Analysis of the Normalized Difference Vegetation Index (NDVI)

Vegetation cover is one of the clear and important indicators and indications, as vegetation cover reflects rain, as it shrinks during dry years and its areas decrease, while its areas increase in wet years because of the abundance of rain. Therefore, vegetation cover in the Al-Jazeera region will be analyzed during dry years and the extent of the increase or decrease of those areas will be determined according to the amount of rain and its spatial distribution.

The vegetation cover in the Al-Jazeera region was classified into three categories: the first is dense vegetation, which appears on the maps in dark green; the second is medium vegetation, which is represented in light green; and the third category is barren lands devoid of vegetation, which is represented on the maps in light yellow.

It is noted through the analysis of Table (4) and Figure (4) that the dense vegetation cover type is concentrated in the far north of the study area, as it recorded an area of (2697.8) km2 at a rate of (4.3) in the year (1987), which is the rainiest and least hot year, which means that it is the least dry. Then, that area decreased very significantly in the year (1999), which is the smallest area among all the years studied, as it reached (1005.1) km2 at a rate of (1.6) %. Then, it rose again during the year (2005) with an area of (2785.1) km2 at a rate of (4.4) %, and it increased significantly during the year (2017), which is the highest area, reaching (5996.8) km2 at a rate of (9.6) %. The reason for these decreases is due to the small amount of rainwater and its insufficiency for plant growth or the irregularity of its distribution in the study area and the decline in its areas for the same years in which the cover deteriorated Vegetarian.

Years	1987	Persnt	1999	Persnt	2005	Persnt	2017	Persnt

Cover type		%		%		%		%
Dense vegetation cover	2697.8	4.3	1005.1	1.6	2785.1	4.4	5996.8	9.6
Medium vegetation cover	4520.9	7.3	4222.2	6.8	3100.3	5.0	1810.7	2.9
Non vegetation cover	55067.0	88.4	57058.4	91.6	56400.3	90.6	54478.2	87.5
Sum.	62285.7	%100	62285.7	%100	62285.7	%100	62285.7	%100

Table (4): Areas and percentages of vegetation cover in the study area

Source: Based on satellite visual analysis (Landsat, 5, 8) and Arc Gis 10.7 program.

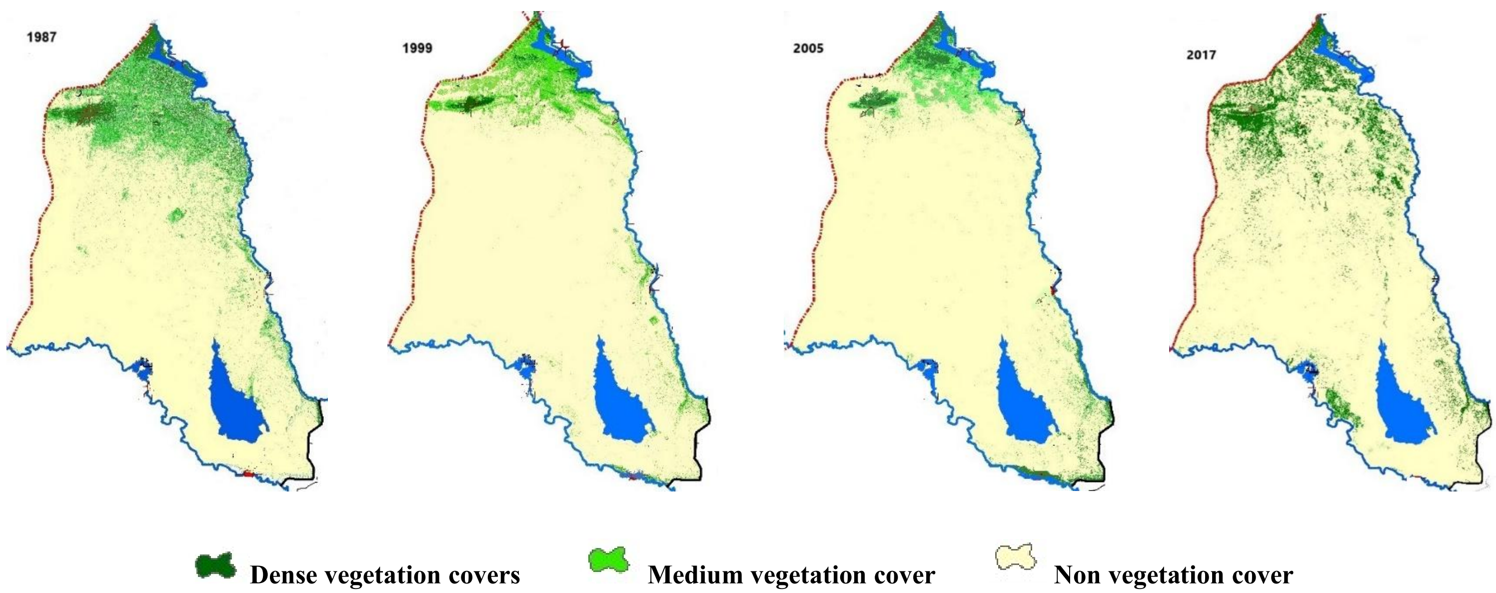

Figure (4): Vegetation cover index (NDWI) in the study area during the dry years of the study

Source: Based on satellite visual analysis (Landsat, 5, 8) and Arc Gis 10.7 program.

As for the second category, which is the medium vegetation category, which is spread near river courses in the study area, it is noted that during the year (1987) it recorded an area of (4520.9) km2, at a rate of (7.3)%, and decreased during the other years to record during the year (1999) an area of (4222.2) km2, at a rate of (6.8)%, while in the year (2005) it recorded an area of (3100.3) km2, at a rate of (5)%, and those areas declined very significantly in the year (2017) to reach (1810.7) km2, at a rate of (2.9 %).

Barren lands devoid of vegetation cover also recorded varying areas ranging between (57085.4 and 54478.2) km2, at a rate of (91.6 and 87.5) % as the highest and lowest area and percentage for the years (1999 and 2017), respectively.

From the above, it can be concluded that the vegetation cover in the study area is in continuous decline because of the decrease in rainfall as well as the rise in temperatures, which led to what is known as drought, which was directly reflected in the shrinkage of the vegetation cover areas, and this was very clear.

Third: Analysis of the Normalized Difference Water Index (NDWI)

The water surface index shows the area of water cover in the study area through its increase or decrease during the selected years studied. The areas of water cover vary in its different categories in the Al-Jazeera region according to the amount of rainfall as well as temperatures, as their increase leads to an increase in evaporation/transpiration processes, which leads to the drying up of water sources and soil first, then plants second.

It is clear from the analysis of Table (5) and figure (5) that we find that the first category, which included shallow water bodies represented by water ponds and seasonal rivers during the spring, recorded varying areas, the highest of which was in the first year, where it covered an area of (472.9) km2, at a rate of (0.8)%, which is the highest area during the study years. Then, that area declined in the following years, as it recorded a close percentage during the years (1999, 2005, 2017), reaching (200.9, 225.1, 197.3) km2, at a rate of (0.3, 0.4, 0.3) %, respectively.

As for the deep water cover represented by Lake Tharthar and the Tigris and Euphrates rivers, its area in the first year (1987) reached about (2505.9) km2 at a rate of (4)%, and that area decreased during the following three years in a very clear way to record (1764.2, 1649, 1752.8) km2 at rates of (2.8, 2.7, 2.8)% for the years (1999, 2005, 2017) respectively.

The lands without water cover (dry) also recorded varying areas, but in general they tended to increase during the study years. The year (1987) recorded the lowest area of (59306.9) km2, at a rate of (95.2) %, then it rose to its highest rate in the last two years (2005, 2017) to reach (60366.6, 60335.6) km2, at similar rates (96.6) %. This increase came at the expense of a clear decrease in the areas of deep and shallow water cover.

Years / Cover type	1987	Persnt %	1999	Persnt %	2005	Persnt %	2017	Persnt %
Shallow water cover	472.9	0.8	200.9	0.4	225.1	0.4	197.3	0.3
Deep water cover	2505.9	4.0	1764.2	2.8	1694.0	2.7	1752.8	2.8
Non water cover	59306.9	95.2	60320.6	96.8	60366.6	96.9	60335.6	96.9
Sum.	62285.7	%100	62285.7	%100	62285.7	%100	62285.7	%100

Table (5): Areas and percentages of water cover in the study area

Source: Based on satellite visual analysis (Landsat, 5, 8) and Arc Gis 10.7 program.

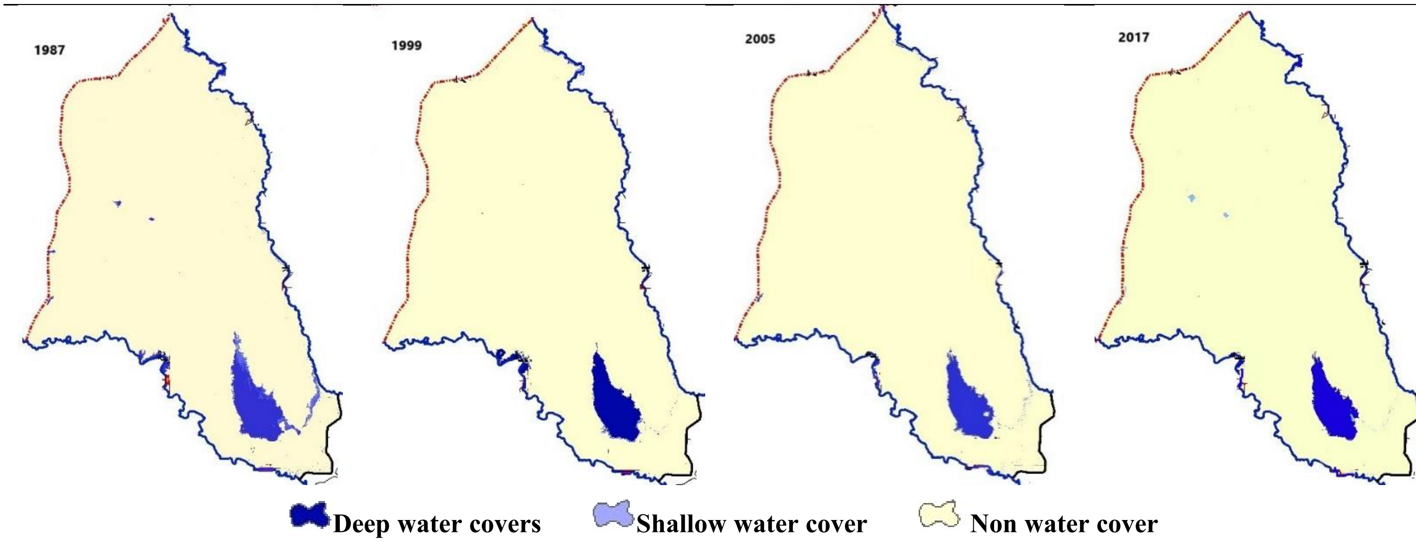

Figure (5): Water cover index (NDWI) in the study area during the dry years of the study

Source: Based on satellite visual analysis (Landsat, 5, 8) and Arc Gis 10.7 program.

Conclusion

The climate drought indicators using remote sensing technology in the study area recorded a clear variation in the difference in vegetation index during the study years. The dense vegetation cover (NDVI) type recorded an area percentage of (4.3, 1.6, 4.5, 9.6) % respectively, while the medium-density vegetation cover decreased in areas to (7.3, 6.8, 5, 2.9) % respectively. The barren lands devoid of vegetation cover recorded an area percentage of (88.4, 91.6, 90.6, 87.5) % respectively. The reason for the decrease in areas and their decline is due to the decrease in the amount of rainfall in addition to the rise in temperatures in the study area, which led to an increase in the amount of evaporation/transpiration. This is evidence that the region is clearly affected by climate change, which has been directly reflected in the vegetation cover in it.

The analysis of the difference water cover index (NDWI) showed that the shallow water cover category represented by water ponds and seasonal valleys limited to a specific season recorded an area percentage of (0.8, 0.3, 0.4, 0.3)% during the four consecutive years of the study, while the deep water cover category represented by Tharthar Lake and the Tigris and Euphrates Rivers decreased in area by (4, 2.8, 2.7, 2.8)% respectively, while the area of lands free of water cover recorded a general trend towards increasing by (95.2, 96.8, 96.9, 96.9)% respectively. From this, we conclude that the water cover in the Al-Jazeera region is constantly decreasing, which poses a threat to agriculture, agricultural lands and vegetation cover in general.

Declarations

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Data availability: Data will be made available upon request.

Competing interests; The authors competing interests.

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