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Using Geospatial Techniques to Analysis the Impact of Climate Change on Water and Agriculture Resources: Case study Khanaqin District in Diyala, Iraq

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Abstract: The study area was classified into three categories (vegetation cover, water, and others)using four satellite images of the Landsat 8 satellite captured during March for the period 2019-2022 into. The results showed that there is a change in the climatic conditions (temperature and rainfall) for the years of the study. The average temperature increased from 12.29°C to 25.967°C from the year 2019 to 2022. The annual amount of precipitation was decreased from 469.43 mm for the year 2019 to 105.49 mm for the year 2022.this negatively changed affected the water and agricultural resources, as the amount of water storage for Lake Hamrin and Lake Al-Wand together reached to 2,314,584,000 m^3 and 40,404,000 m^3 for the years 2019 and 2022, respectively. This led to decrease in the vegetation area from 1587.29 km^2 to 356.17 for the year 2019 km^2 and 2022, respectively.

Keywords: Climate change, LST, NDVI, NDWI, Vegetation cover.

Introduction

The increase in human activity during the past three decades has led to a steady rise in the atmospheric temperature, depletion of the ozone layer, and the exacerbation of global warming. The rise in the atmospheric temperature may submerge many coastal cities, due to the melting of icebergs, the rise in sea and ocean levels, and the exposure of many regions of the world to very sharp waves of drought due to the low rates of annual precipitation and the irregularity of its distribution (Firas, 2012).

Agriculture is one sector that is not only affected by global warming (for example through atmospheric temperature, precipitation, soil moisture, sea level, and humidity), but also contributes to climate change. Climate change affects the food supply directly due to the dependence of agriculture on the climate. The main issue that many countries, the private sector, institutions, etc. have to face is how to adapt to the future climate changes that are expected to occur. The potential risks due to the effects of climate change must be well managed to ensure the sustainability of agriculture. In particular, in the case of water shortage conditions caused by climate change, yield losses will increase even in areas where dry farming is practiced. However, food production must be provided continuously even under these conditions (Esetlili *et al*., 2018). The report issued by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2012) indicates that climate change may be due to natural internal processes, external influences, or persistent anthropogenic changes in the composition of the atmosphere or land use. Climate change affects food security in Drylands, particularly those in Africa, and high mountain regions of Asia and South America (IPCC, 2019). The importance of detailed studies of climate change has increased with the use of remote sensing techniques and the use of satellite images in monitoring and studying climate variables in detail, in the presence of many environmental problems related to climate, especially in urban areas, resulting from the development in industrialization processes and the high rates of urbanization in Cities of the world (Abdelazem, 2022).

One of the indicators of climate change is the change in vegetation cover, and this has been confirmed by many researchers, Omuto (2011) tracked the impact of vegetation dynamics by modeling the relationship between NDVI and precipitation using regression analysis. The results showed a high correlation between precipitation and NDVI which proved that monitoring the vegetation trend using Remote Sening and Geographic information systems can give an accurate indicator of climate change. Life on Earth depends on carbon, and the carbon cycle is key to producing food and fuel for all living organisms. Therefore, the degradation of vegetation will lead to food insecurity and reduced carbon uptake, threatening human survival (Yelwa & Eniolorunda, 2012). Monitoring vegetation degradation processes is an important component of developing appropriate conservation strategies aimed at managing landscapes for continued human presence (Ferraz et al., 2009). Also, climate change affects water, and this is what Politi *et al.* (2012) found when studying European lakes using remote sensing data and Geographic information systems by distinguishing temporal and spatial trends in water temperature in large European lakes using thermal data of the Advanced Very High-Resolution Radiometer (AVHRR) and concluded that it is possible to use Remote Sensing and Geographic information systems to monitor the course of lake water change with climate change and human impacts. Khalaf (2022), concluded that there is a change in the surface area and surface temperature of Lake Hamrin due to climate change, as he used the NDWI spectral index in his study and found a change from 264,617 km^2 for October 2019 to 140,202 km^2 for September 2020.

Lal (2009) asserted that the stress caused by drought and climate change are biotic and physical factors that must be addressed to achieve food security in the face of climate change and that the use of Remote Sensing and Geographic information systems is useful for irrigation management and agricultural climate assessment. Cao & Gao (2019) concluded that drought has a great relationship with climate change in their studies in China, especially in all six seasons except for winter and that high temperatures and lack of precipitation are among the most important consequences of climate change. Gebeyehu (2019) noted that agriculture plays a vital role in the economy of every country. It represents a large commercial industry for an economically strong country. The applications of remote sensing technologies are important for crop monitoring, crop condition assessment, and yield estimation for the sustainability of agriculture and natural resources, and are effective tools for water resource evaluation and control.

In the study by Siyal (2018) on the Indus Delta in Pakistan to determine the spatial and temporal change in the vegetation cover of the Indus Delta and the change in water resources due to climate change, a change in forest areas was observed from 103.413 hectares in 1990 to

81.324 hectares in 2017 and an increase in LST as an average of 1.7 during this period. Analysis of satellite images revealed that the water bodies in the entire delta have doubled in the last 28 years from 1.600 square kilometers to 3.000 square kilometers. This study shows that 42.607 hectares of land in the Indus Delta have been degraded due to surface seawater intrusion. Piao *et al.* (2010) emphasized that the possibility of strong negative effects of climate change on food production cannot be ruled out. To reduce the effects of climate change, dams, and irrigation projects should be established to control floods if they occur, as well as water harvesting projects, develop plant species that are resistant to drought, preserve carbon storage in forests, protect vulnerable ecosystems, and ensure agricultural security.

The study aims to know the extent of the impact of change in climatic conditions on the agricultural and water resources of the study area, and to show the extent to which remote sensing techniques and geographic information systems are used along with field data have a positive role in reaching accurate and rapid results that support decision makers in setting Agricultural and water plans to achieve sustainability for these important resources..

Materials & Methods

Study area

The study area was identified in the Khanaqin district, and the phenomena in it were identified through field visits using the global positioning device (GPS). Khanaqin district is located in the northeastern part of Diyala Governorate, located in the eastern central part of Iraq, and it is about 174 km away from Baghdad, the capital of Iraq, its coordinates are between 44o 52′ 36.092 ″ - 45o 47 ′ 33.184″ and 33o 57′ 11.323″ - 35o 05′ 55.992″. The area of the district is divided into three administrative units, which are (Khanaqin Center Subdistrict, Jalawla Subdistrict, and Al-Saadiyah Subdistrict). The area of the district is 3512 km2, which constitutes about 19.85% of the total area of Diyala Governorate, which is 17685 km2 (Al-Hathal & Hassoun, 2022, Fig. 1).

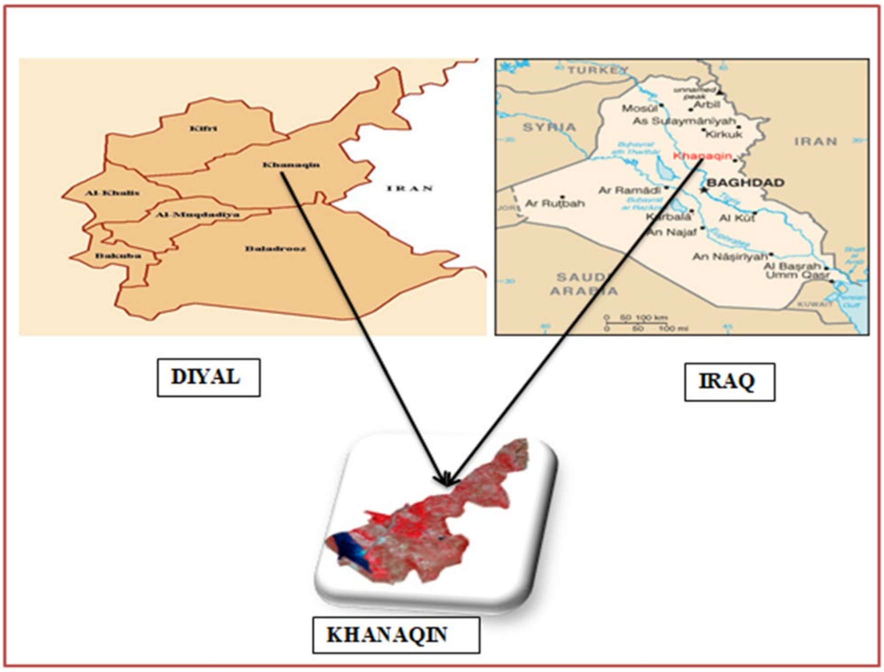

Fig. (1): The area of study in Khanaqin

Satellite imagery processing

In this study, four satellite images of the Landsat 8 satellite were used (Path 168, Row36) for the years 2019, 2020, 2021, and 2022, as shown in table (1). Using the Erdas Imagine 2015 program, the processing and optimization of satellite images were carried out, and to obtain a spatial resolution of 15 m, the bands were grouped with Panchromatic 8, we used ArcGIS 10.4.1 to cut the study area (Fig. 2).

Table (1): Satellite images used in the study.

The satellite	Sensor	Path	Row	Capture date
Landsat 8	OLI_TIRS	168	36	21/03/2019
Landsat 8	OLI_TIRS	168	36	23/03/2020
Landsat 8	OLI_TIRS	168	36	26/03/2021
Landsat 8	OLI_TIRS	168	36	29/03/2022

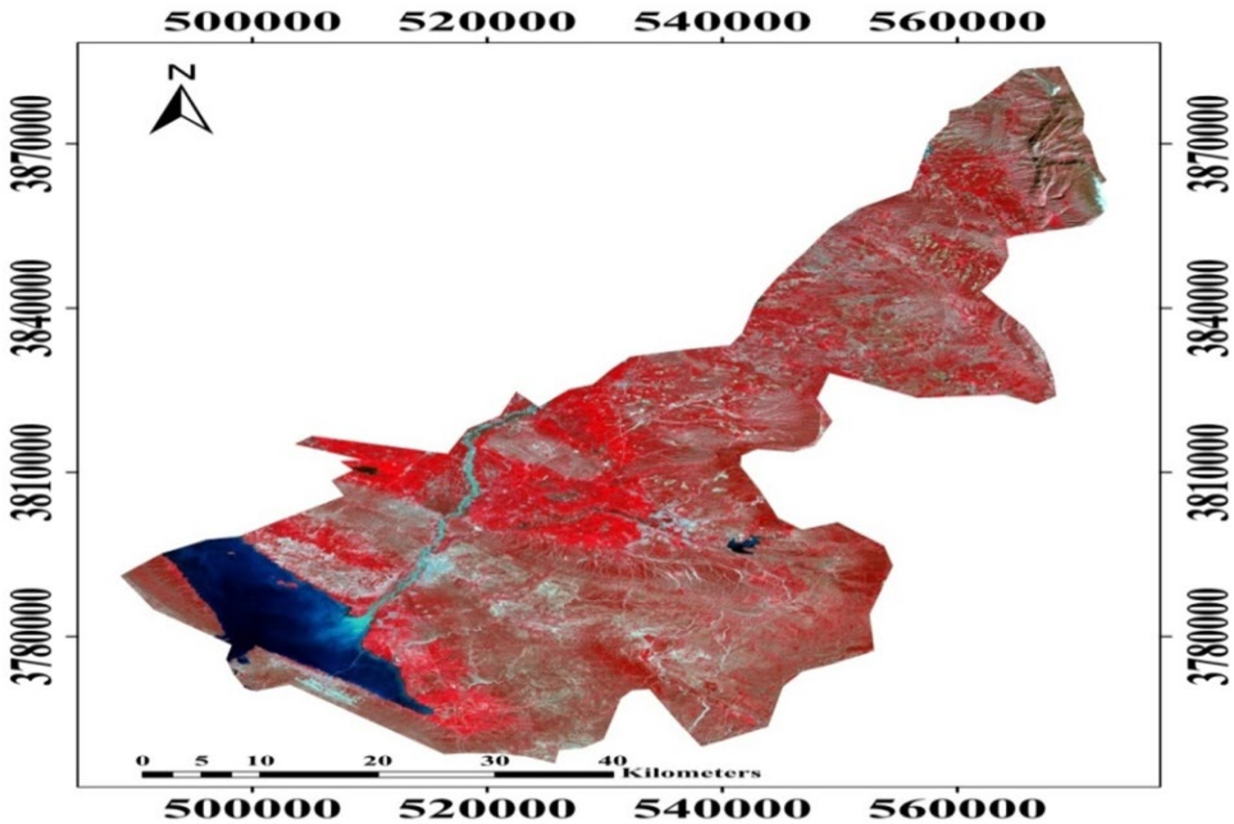

Fig. (2): The studied area in Khanaqin.

The study area was also classified by classification methods (supervised and unsupervised), including a map of the spatial distribution of the categories, namely water, vegetation, and other categories (urban areas, mountains and barren lands ...etc.) for the study years 2019-2022.

Spectral indices used in the study

Normalized Difference Vegetation Index (NDVI)

NDVI is determined from the visible and near-infrared light reflected by vegetation. Healthy green vegetation absorbs most of the visible sunlight which falls over it and reflects a large portion of the near-infrared light. Whereas, unhealthy or sparse vegetation reflects more visible light and less near-infrared light. NDVI was first presented by Kriegler *et al*. (1969), and it is calculated by subtracting the red band from the near-infrared (NIR) band and dividing their difference by the sum of the two bands as given in equation (Higginbottom & Symeonakis, 2014):

NDVI $= (NIR - RED)/(\, NIR + RED)$ ....(1)

Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves give a value close to zero. Water has an NDVI value of less than 0, bare soils between 0 and 0.1, and vegetation over 0.1. The increase in the positive NDVI value means greener vegetation (Guha *et al*., 2019).

Normalized Differences Water Index (NDWI)

NDVI is determined from the visible and near-infrared light reflected by vegetation. Healthy green vegetation absorbs most of the visible sunlight which falls over it and reflects a large portion of the near-infrared light. Whereas, unhealthy or sparse vegetation reflects more visible light and less near-infrared light. NDVI was first presented by Kriegler *et al*. (1969), and it is calculated by subtracting the red band from the near-infrared (NIR) band and dividing their difference by the sum of the two bands as given in equation (Higginbottom & Symeonakis, 2014):

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Normalized Differences Water Index (NDWI)

The spectral reflectivity of water is high in the green wavelength 0.52-0.60 µm and very little in the near-infrared wavelength range 0.76-0.90 µm. The high reflectivity of the plant and soil in the infrared wavelength range makes the NDWI values positive for Water areas that are therefore illuminated and have positive values in NDWI when green and built areas appear dark and dark with negative or zero values (2). The equation is (Silva *et al*., 2020)

$NDWI = (GREEN - NIR)/(GREEN + NIR)$ … .(2).

Using Erdas Imagine V.15 and ArcMap 10.4.1, the NDWI and NDVI maps of the study area were compiled and then categorized.

Calculation of LST from satellite images

At first, the Geometric and Radiometric remedy and Enhancement measures for the satellite data utilized in the examination were performed utilizing the Erdas Imagine 2015 program, depending on the two thermal bands B10 and B11 from each satellite image. The surface temperature of the khanaqin water was calculated during the study period as follows:

1- The numerical values of DN of each pixel in the image for the two thermal bands were converted to the values of DN to radiance using the following equation (Higginbottom & Symeonakis, 2014):

“$L\lambda = ML \times Qcal + AL$ ” .... (3)

where Lλ= is radiative reflection (m2 × sr × m), ML = is Standardization factor specific to each package, Qcal = The numeric value of the pixel, AL = Correction factor

2- The temperature was calculated at the satellite TOA (Top of Atmospheric brightness highest temperature) Utilizing the following equation (Sobrino *et al.,* 2004):

“$TB = (K2 \,/\, (Ln\, (K1/\, L\lambda + 1))$ ” ..... (4)

Where: TB = The temperature on the satellite, K1 = Conversion factor constant (Thermal band number), K2 = Transformation factor steady (thermal band number). Then the temperature values were converted from the Absolute temperature to the Celsius temperature using the following relationship (Higginbottom & Symeonakis, 2014)

$$C° = K - 273.15 \quad .... (5)$$

3-The percentage of vegetation cover is calculated according to the following equation (Sobrino *et al.,* 2004):

$$Pv = square\ ((NDVI - NDVImin)/(NDVImax - NDVI\ min)) \quad .... (6)$$

Where: NDVImin It is the lowest value of 0.2 NDVI for soil-exposed pixels and NDVImax It is the highest value of NDVI 0.5 for a healthy vegetable pixel, Pv = The percentage of vegetation cover

4- The surface temperature was calculated using the following equation (Higginbottom & Symeonakis, 2014):

$$LST = TB / (1 + (L \times TB/P) \times Ln(e)) \quad .....(7)$$

Where LST = Land Surface Temperature, P= (14380) Fixed value, e = 0.004 × Pv + 0.986, The emission correction factor is constant.

5- The above calculations were made for bands 10 and 11 of each image, and then the average was taken from them, and thus the surface temperature of khanaqin was extracted (Sun *et al*., 2010; Sichangi & Makokha, 2017).

Methodology

The methodology shown in the fig. (3) was used.

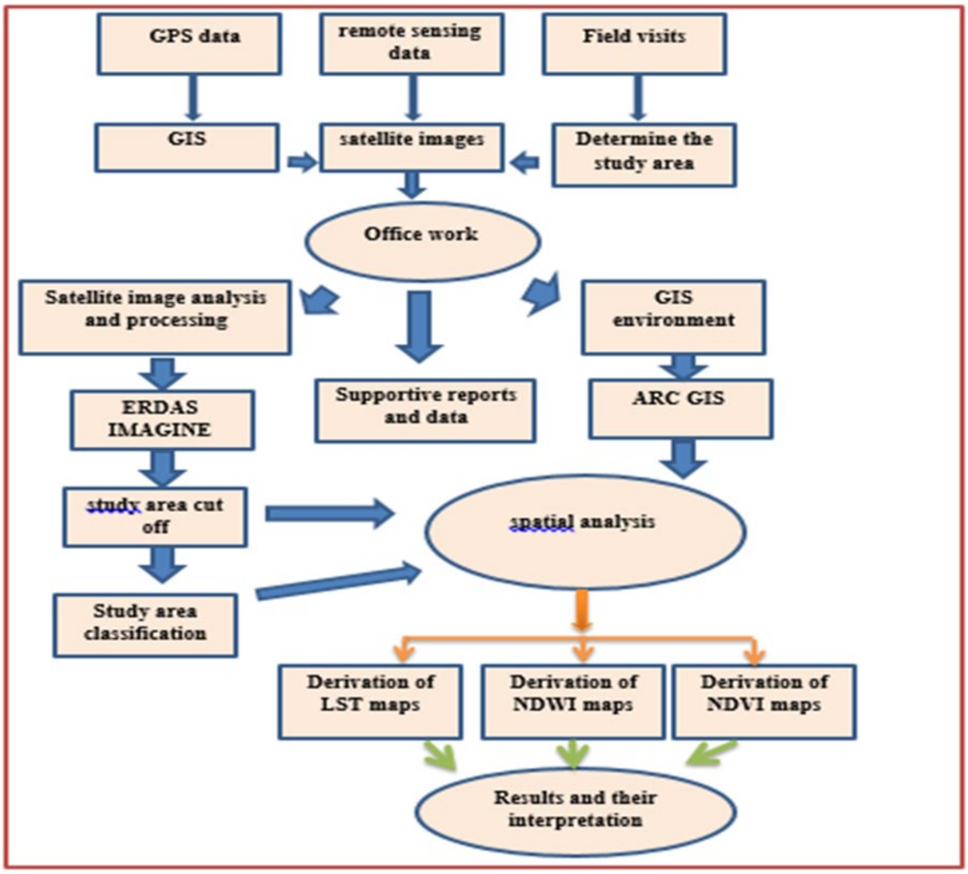

Fig. (3): Flow chart of the methodology.

Results & Discussions

Classification of the study area

To classify the study area, the unsupervised classification method was used first to identify the ground covers in general, and then the supervised classification method was used, depending on the training samples (45 samples), because this method is more accurate than the first method. The classification results showed three categories, which are water, vegetation cover, and other categories (urban areas, mountains, arid lands, etc.) (Fig. 4 and table 2).

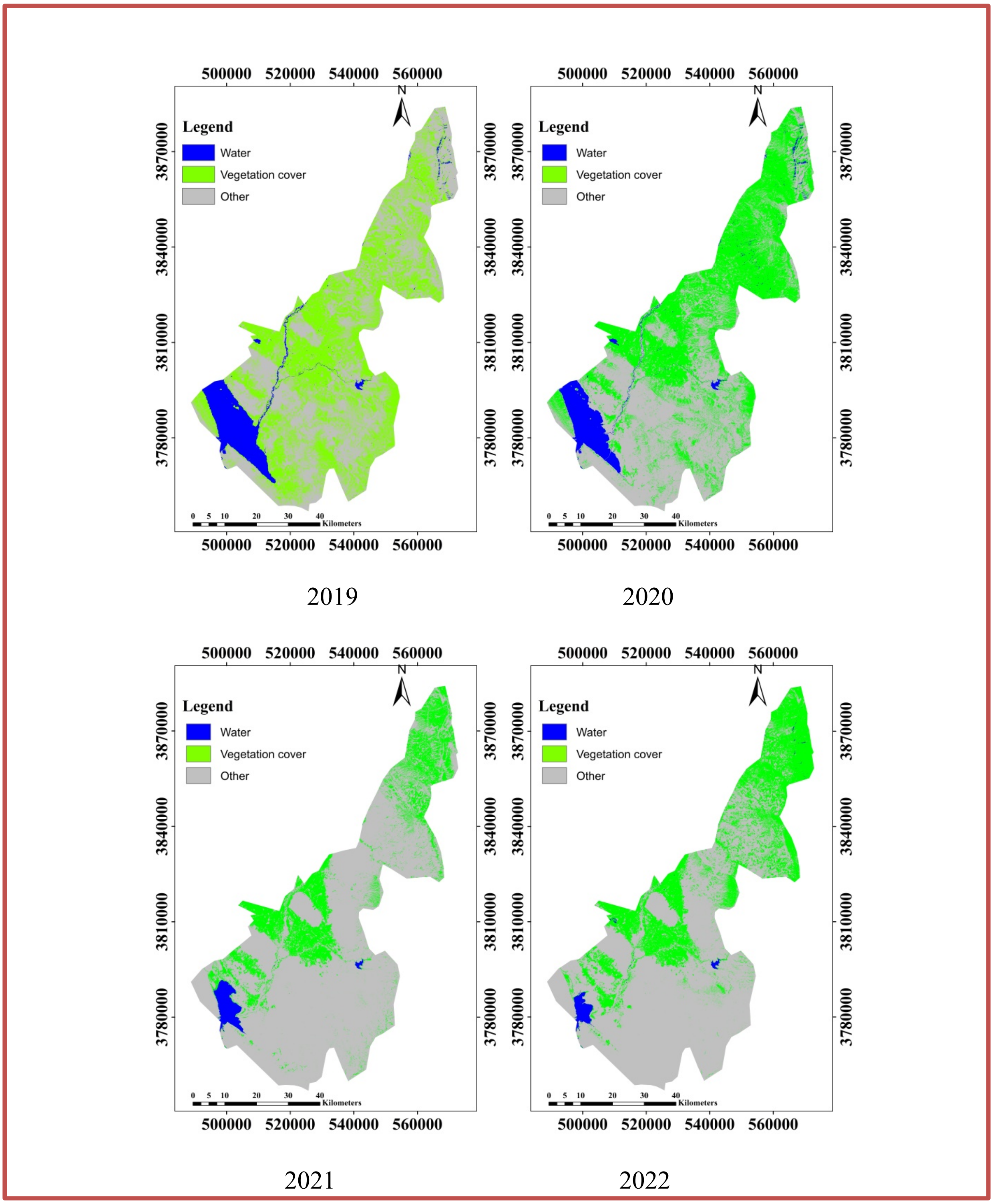

Fig. (4): The spatial distribution of land covers for the study area in Khanaqin.

Table (2): Land coverings of the study area in Khanaqin for each category and area according to the classification map prepared by the satellite images.

Categories	2019		2020		2021		2022	
	Area km^2	Percentage %	Area km^2	Percentage %	Area km^2	Percentage %	Area km^2	Percentage %
Water	146.96	4.18	86.63	2.47	83.03	2.36	70.00	1.99
Vegetation cover	1587.29	45.20	1598.25	45.51	791.62	22.54	356.17	10.14
Other	1777.75	50.62	1827.12	52.03	2637.35	75.10	3085.83	87.87
Total	3512.00	100.00	3512.00	100.00	3512.00	100.00	3512.00	100.00

To indicate the accuracy of the classification, used the Kappa statistical scale based on 45 ground control points, so the overall accuracy of the classification map was 0.88, 0.84, 0.86, and 0.88 for the classification map for years, 2019, 2020, 2021, and 2022, respectively. This accuracy is acceptable and good for adopting the classification map (Khalaf & Al-Alaf, 2021, Table 3).

Table (3): The Kappa statistical value for the classified images.

Categories	2019	2020	2021	2022
Water	0.78	0.76	0.77	0.79
Vegetation cover	0.91	0.85	0.92	0.93
Other	0.95	0.91	0.89	0.92
Accuracy %	0.88	0.84	0.86	0.88

It can be observed from table (2) and fig. (4) that there is a decrease in the vegetation cover area for the year 2022 compared to 2019, when it was 1587.29 km^2 and 356.17 km^2, respectively, and in general due to climate change on the one hand and urban sprawl on the other hand, and this is consistent with the findings of (Mahal *et al.,* 2022). The changes that occur to natural resources such as vegetation cover and water resources are one of the most important components of global environmental change (Ali & Muhaimeed, 2016) and this impact is negatively reflected on the biodiversity of the Earth (Mariye *et al.,* 2022).

Also note that there is an increase for the year 2020 compared to the year 2021 (1598.25 and 1587.29) km^2, an increase of 10.96 km^2, as a result of the increase in agricultural areas due to the increase in the amounts of rain for the year 2019, which led to store more amounts of water in dams and water reservoirs, especially Hamrin dam and Al-Wand dam located within the area study in Khanaqin, which are considered a basic and important source of drinking water and other uses, especially agricultural ones, in Khanaqin district and other districts within Diyala Governorate, and this led to the development of agricultural plans by the Departments of Agriculture and Water Resources with areas larger than 2019 as a result of the better availability of water shares, as in table (4), as we note in table (4) that there is a big difference between the years 2019 and 2022, as the areas cultivated with the wheat crop amounted to 4870.50 hectares and 4003 hectares, respectively, and also the areas of orchards and vegetables were 1072.75 hectares and 979 hectares for the years 2019 and 2022, respectively, due to the lack of water resources and the shortage in the water level and storage in Hamrin and Alwand dams, as shown in table (5).

Table (4): Areas cultivated with wheat and others (orchards, vegetables, etc.) in Khanaqin district and for the years of study.

Agricultural division	Saadia	Jalawla	Khanaqin	Total
2019 / Hectare Wheat	202.75	2578.00	2089.75	4870.50
other	224.00	125.00	723.75	1072.75
2020 /Hectare -Wheat	99.75	3279.25	1734.75	5122.75
other	232.25	180.50	695.00	1107.75
2021 / Hectare-Wheat	120.75	2270.00	1850.00	4240.75
other	229.00	206.25	765.00	1200.25
2022 / Hectare-Wheat	12.50	2502.50	1488.00	4003.00
other	220.25	75.00	683.75	979.00
chi-square (χ^2)- Tabular value	3.84			
Measure value	750.3			

* Directorate of Agriculture in Diyala Governorate.

Table (5): Storage and water levels in the Hamrin and Alwand dams.

Dam name	Hamrin	Alwand	Total
Level/m^3	103.60	215.29	
Capacity/m^3	2.274.800.000	39.784.000	2.314.584.000
Level/m^3	99.88	215.18	
Capacity/m^3	1.293.500.000	39.046.000	1.332.546.000
Level/m^3	94/46	213.96	
Capacity/m^3	4.558.000	31.862.000	36.420.000
Level/m^3	91.26	215.08	
Capacity/m^3	1.984.000	38.420.000	40.404.000
chi-square (χ^2)- Tabular value	3.84		
Measure value	142.504		

*Directorate of Water Resources in Diyala Governorate.

The chi-square (χ^2) statistical scale was used to find out the significant differences in the amount of wheat crop for the study years 2019 and 2022, in table (4), as the statistical measure gave a value of 750.3, and this value is higher than the tabular value (3.84), which indicates there are significant differences in the values of wheat yield between study years, also in table (5), the calculated chi-square value was 142.504 for the storage capacity of Lake Hamrin and Alwand, which is greater than the tabular value (3.84) for study years 2019 and 2022, which indicates the existence of significant differences.

Table (5) it is noted that there is a decrease in the level and quantity of water stored in Lake Hamrin for the years of study, as the level reached 103.60 m for the year 2019 and 91.26 m for the year 2022. The storage was 2.274.800.000 m^3 for the year 2019, while it was 1.984.000 m^3 for the year 2022. Also in the Alwand Dam, there decrease, as the level and storage in 2021 reached 13.96 m3 and 31,862,000 m^3, respectively, while in the year 2022, the level and storage were 205.08 m and 38.420.000 m^3, there is an increase and the reason is the increase in the discharge coming from neighboring countries (e.g. Iran) in the year 2022 compared to the year 2022, as the incoming discharge was 7 $m^3.sec^{-1}$ and 10 $m^3.sec^{-1}$ for the years 2021 and 2022, respectively. Note that the annual amount of precipitation in the study area was 469.34, 348.05, 189.84, and 105.49 mm for the years 2019, 2020, 2021, and 2022, respectively, meaning there is a clear decrease in the amount of rain, which negatively affected water resources and therefore agricultural resources.

Spectral indices

To find out the amount of change in vegetation cover (agricultural resources) and water resources, NDVI and NDWI spectral indices were used (Figs. 5 and 6).

The decrease from 2019 to 2022 in values is due to the deterioration of the vegetation cover associated with the lack of water resources, as well as the urban sprawl represented by the removal of green spaces and their transformation into urban areas, and this explains the increase in the areas of other items at the expense of the areas of vegetation cover, it was also observed that the NDWI index values decreased from 2019 to 2022 due to the lack of annual rainfall and the lack of water coming from neighboring countries, which negatively affected water storage and thus agricultural resources.. The use of spectral indices was useful for classifying land covers and detecting changes in them, as it is considered an easy and fast method (Khalaf & Al-Jibouri, 2020).

Land surface temperature

Land surface temperature distribution maps for the study area were prepared from the satellite data used in the study (Fig. 7).

The average surface temperature for the years 2019, 2020, 2021, and 2022, according to the dates of taking the satellite images, was 12.029, 16.440, 23.908 and 25.967 degrees Celsius, respectively. It is clear that there is an increase in temperatures as a result of the change in climatic factors, as with climate change that changes precipitation patterns and temperatures all over the world due to the lack of vegetation cover and its deterioration; the role of vegetation is not hidden from us in improving the environment, softening the atmosphere, and preserving the ecological balance in general (Liu *et al.,* 2022).

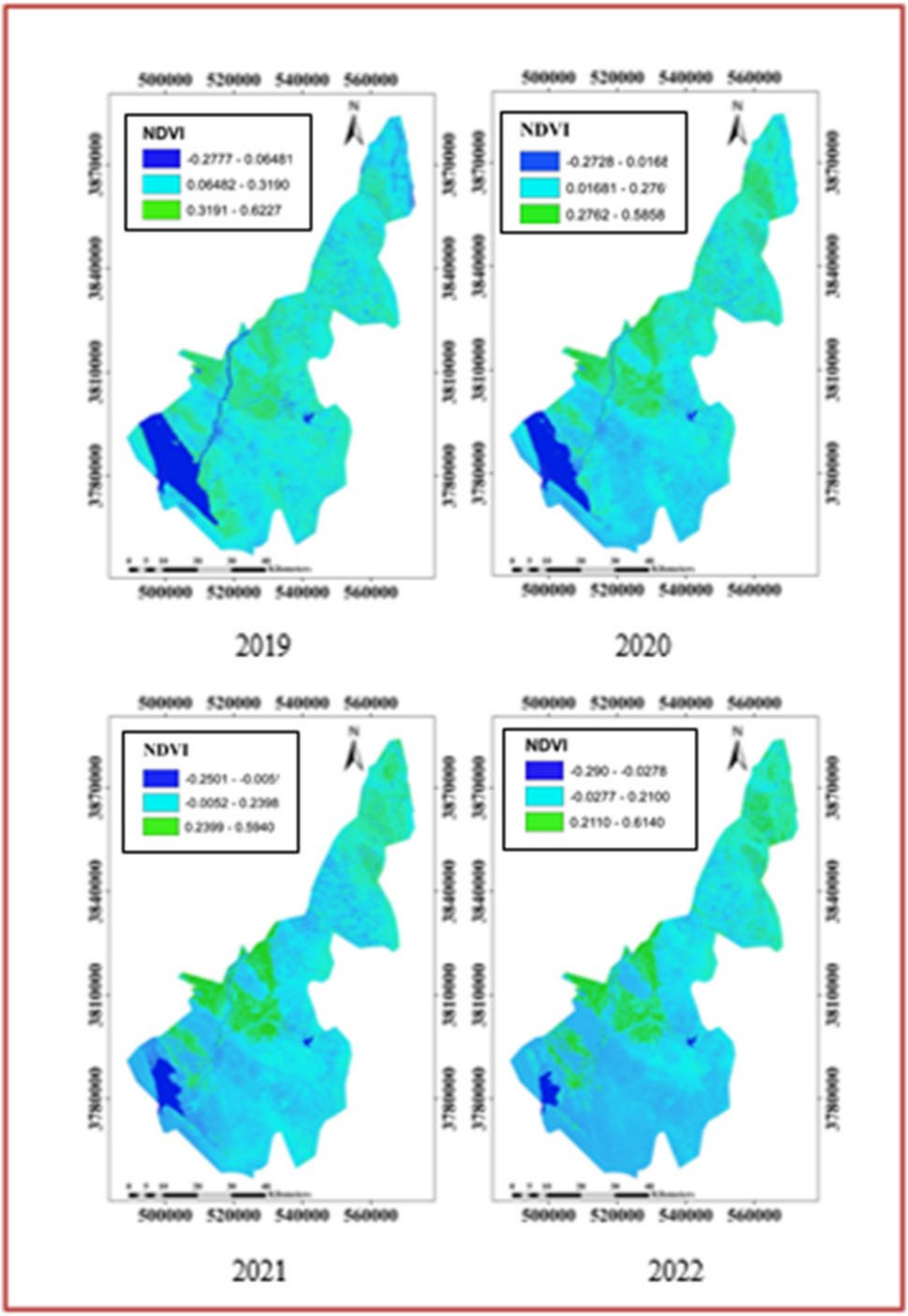

Fig. (5): NDVI map of the study area.

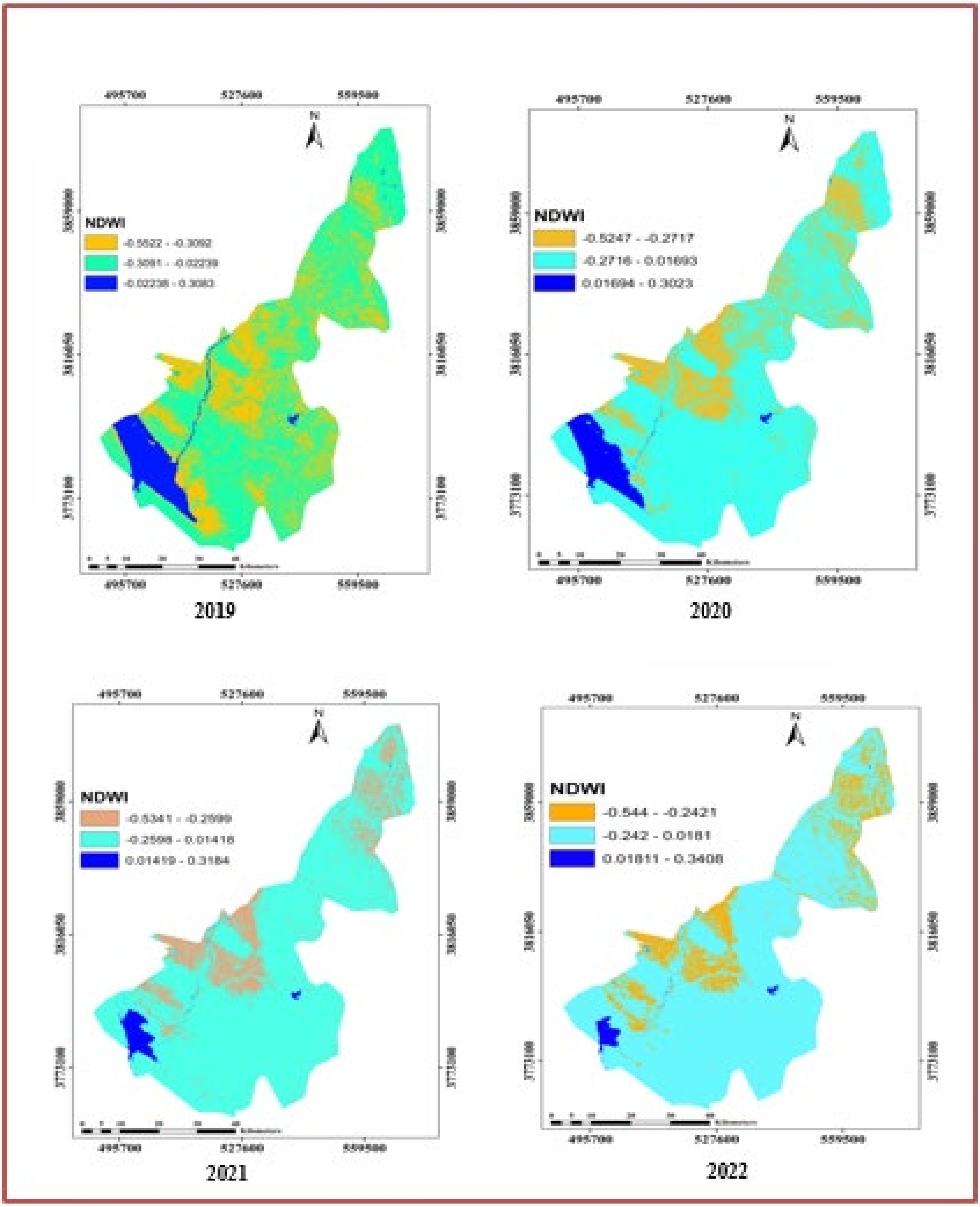

Fig. (6): NDWI map of the study area.

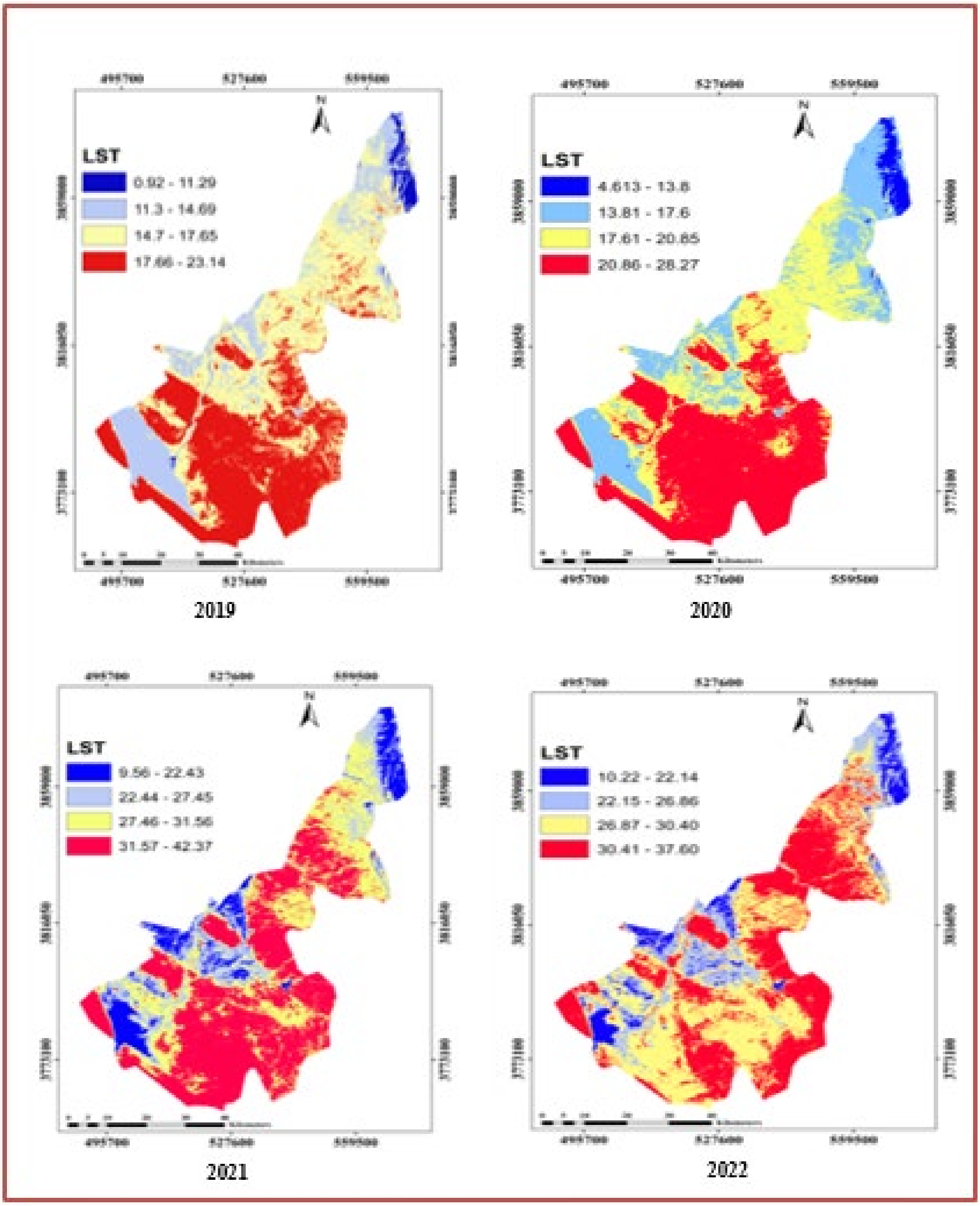

Fig. (7): Land Surface temperature in the study area and for the years of the study.

Conclusions and recommendations

The study concluded that there is a change in the climatic conditions (temperature and rainfall) for the years of the study, as the average temperature reached 12.29 degrees Celsius for the year 2019 and 25.967 degrees Celsius for the year 2022, meaning that there is an increase, which is offset by a decrease in the annual airport quantity, as it reached 469.43 mm for the year 2019 and 105.49 mm for the year 2022, and this negatively affected water and agricultural resources, as the amount of water storage for the Hamrin Dam or Lake and Alwand reached 2,314,584,000 m3 and 40,404,000 m3 for the years 2019 and 2022, respectively, which led to a decrease in the vegetation area from 1587.29 km^2 for the year 2019 to 356.17 km^2 for the year 2022. The study also concluded that the use of geospatial techniques represented by remote sensing (the use of spectral evidence and different classification methods for satellite data) and geographic information systems (GPS and software such as ArcGIS) along with field data have a positive role in reaching accurate and rapid results that support decision makers in setting Agricultural and water plans to achieve sustainability for these important resources.

The study recommends the adoption of laws that conserve water, such as the law of the National Water Council, putting water in the same rank as oil and the rest of the general natural resources for all Iraqi people, paying attention to developing and managing irrigation and drainage systems with the use of modern technology, benefiting from saline water, including drainage water, and providing water desalination systems. Treating desertification and improving the environment by planting billions of trees, especially evergreen and drought-tolerant trees. Improving the soil through agricultural cycles and others, and selecting appropriate crops for that to preserve the soil with the same sustainability of food security. Finally, activating memorandums of understanding and international laws with neighboring countries, especially co concerning to water releases.

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Conflict of interest

As for the requirements of the publishing policy, there is no potential conflict of interest for the authors.

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استخدام التقانات الجيومكانية لتحليل تأثير تغير المناخ على موارد المياه والزراعة: دراسة حالة منطقة خانقين في ديالى، العراق

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المستخلص: صنفت منطقة الدراسة باستخدام اربعة صور فضائية للقمر الصناعي لاندسات 8 ملتقطة شهر اذار وللفترة 2019–2022 الى ثلاثة اصناف (الغطاء النباتي، مياه واخرى) واشتقت الادلة (NDVI,NDWI) وحسبت درجة الحراة السطحية LST من الصور الفضائية. توصلت الدراسة ان هناك تغير في الظروف المناخية (درجة الحرارة والامطار) لسنوات الدراسة اذ بلغ معدل درجة الحرارة 12.29 درجة مئوية لسنة 2019 و 25.967 درجة مئوية لسنة 2022 اي ان هناك زيادة ، ويقابله تناقص في كمية الامطار السنوية اذ بلغت 469.43ملم لسنة 2019 و 105.49ملم لسنة 2022، وهذا ما اثر سلبا على الموارد المائية والزراعية اذ بلغ مقدار الخزين المائي لبحيرة حمرين وبحيرة الوند 2.314.584.000 م^3 و 40.404.000 م^3 للسنوات 2019 و 2022 على التوالي مما ادى الى تناقص في مساحة الغطاء النباتي 1587.29 كم^2 لسنة 2019 الى 356.17 كم^2 لسنة 2022 .

الكلمات المفتاحية: التغير المناخي، LST, NDVI, NDWI، الغطاء النباتي.