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Assessing the impacts of climate change on the desertification of southern Iraq

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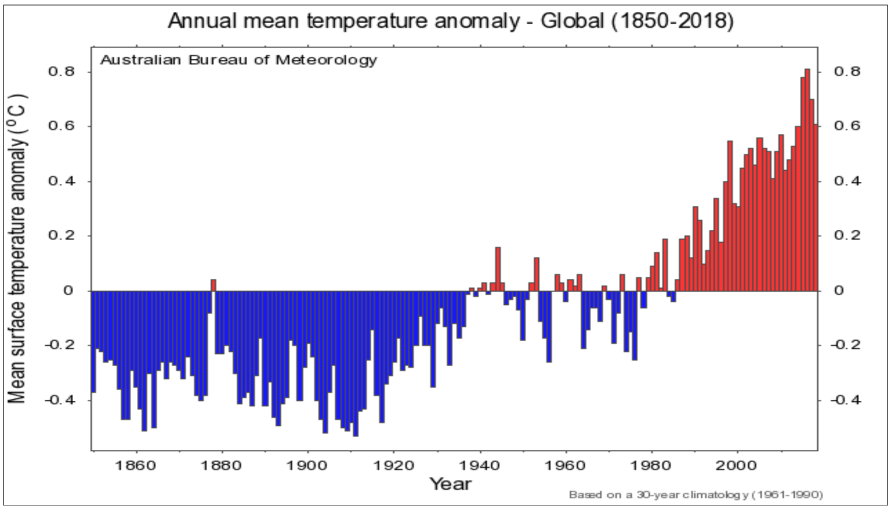
Abstract
The global surface temperature has been increasing mainly due to increased greenhouse gas concentration and emissions, which in turn causes global warming and climate change. Iraq has been experiencing the impacts of climate change, but there are no detailed studies up to date, especially at the local scale. This study locally discusses the relationship between changes in climate factors (mainly temperature and rainfall) and land degradation in drought and desertification in southern Iraq. We used the region's historical temperature and rainfall data, including satellite images from 1988 and 2018, to understand the extent of land use, land cover change, and degradation over 30 years. To accurately assess the extent of desertification in the study area, we used unsupervised classification to analyze the two satellite images. We found that the annual average temperature consistently increased while the yearly average rainfall showed significant fluctuation in the study. Changes in temperature and precipitation have contributed considerably to drought, which has led to the expansion of desertification in southern Iraq. Results generally showed a clear relationship between the change in climatic factors and desertification. In addition, there was a significant increase in the land covered by dunes, but barren lands and wetlands have shown a noticeable decrease. We concluded that climate change combined with land degradation has caused an increase in the extent of desertification in the study area. Therefore, southern Iraq needs mitigation measures and strategies for climate change and desertification.

Keywords: Climate change, drought, temperature, rainfall, desertification, Iraq

Introduction

Climate change effects on Earth's atmosphere have caused significant changes in most of the world's environments. Iraq and the Middle East are among the most severely affected by these locations (Adamo, Al-Ansari *et al*., 2022). Air temperatures have increased, heat waves have been severe, precipitation has been erratic and diminishing, and water resources have generally depleted. In conjunction with the increase in CO_2 concentration, the global mean temperature is expected to rise. The researchers have expected that the worldwide temperature average for 2081-2100 will be 2 °C up to the 1850-1900 average. The inevitable consequences of rising temperatures with lower precipitation decrease the soil moisture and hide the vegetation cover. In addition, drought, as a consequence of climate change, represents the driving force of desertification. According to the United Nations Convention to Combat Desertification (UNCCD), desertification is 'land degradation in the arid, semi-arid and dry sub-humid areas resulting from various factors, including climate change and human activities (Sivakumar 2007). Climate change, drought, and desertification are, therefore, strongly interlinked. Desertification is a serious threat to arid and semi-arid lands covering 40% of the Earth's surface. Hot extremes' duration, frequency, and magnitude are expected worldwide (Collins, Knutti, *et al*., 2013). On the other hand, the current models may not be able to simulate the trends of climate factors (Kondratyev 2004). Moreover, increasing the Earth's temperature will be responsible for the spatial variation of the precipitation average. For instance, precipitation increased in arid and semi-arid regions as well as in mid-latitude and subtropical areas (Collins, Knutti *et al*. 2013). There is a projection that climate change will lead to severe impacts on natural systems in many regions worldwide [2]. Different ecosystems are expected to be affected by climate change [12].

Over 200 years, atmospheric carbon dioxide (CO2) concentration has increased by about 120 ppm and thus caused an increase in greenhouse gas emissions. Fossil fuel consumption was the primary cause of the rise in greenhouse gases that blocked radiation from moving into free space [1]. The CO2 concentration and other greenhouse gases have increased significantly in the first decade of the twenty-first century [2], which has made the rise in surface temperature worse, even though the increase in CO2 concentration occurred between 1970 and 2010. y using a simple model, researchers have predicted the change in global temperature with increasing greenhouse gas in the atmosphere [3]. Another natural driver, sun activity, can also cause an increase in global temperature. Climate change should be studied using long-term data at various temporal resolutions [4]. During the 20th century, the mean surface temperature on the Earth increased by about 0.7 °C [5]. Both the Northern and South Hemispheres have experienced increases in surface temperature by 1.12 °C and 0.84°C, respectively, from 1901 to 2010 [6]. According to this, the temperature in the Northern Hemisphere has been greater than in the Southern Hemisphere. However, the most significant warming happened in the mid to lower latitudes of the Earth [4]. It is clear that the extent and magnitude of earth temperature are different in different regions around the world, and a few areas have become cooler [4]. For example, during the 1970s, the level of land surface warming was higher than that of sea warming [7]. Surface air temperature can be changed by many factors. To accurately determine temperature change, the observations of local air temperature should be joined with the temperature observations on a large scale [8].



(**Source:** Australian Bureau of Meteorology, 2020).

Fig 1: Annual mean temperature anomaly-Global (1850- 2018).

Study Area

The study area is located in the south of Iraq within latitude 31.38 north and longitude 45.15 east. It extends over two governorates, Al-Muthanna and Dhi Qar, within the sedimentary plain (Figure 2) and the western desert plateau.

Results

The mean temperature and rainfall

Samawah meteorological station

From examining the trend of mean temperature in the Samawah meteorological station, it is clear that marked temperature change has occurred for the period from 1973 to 2018 (Table 1). Overall, the mean temperature is generally above the mean value of the period 1973 to 2007 (Table 1). Moreover, annual averages experienced a significant increase in the 21st century, especially in the last few years compared to the 20th century, where the average of the previous thirty years (1979-2008) was 24.51℃. The average mean temperature for the years from 1973 to 2007 was 26 ℃ [13]. The significant change in annual temperature occurred from 2008 to 2018 (Table 1). The yearly average rainfall (97.05 mm) from 2008 to 2018 is very close to the yearly average rainfall of the previous years (1973 to 2007), which is 100.4 mm (Table 1). The rainfall average for the period from 1973 to 2007 was. However, the annual rain values have shown noticeable fluctuation since 1980 (Figure 3).

Table 1: The changes in the annual average of temperature and rainfall in Samawah meteorological station

Year	T, ˚C	Td, ˚C	R, mm	Rd, mm
2008	25.26	0.75	55.92	-44.48
2009	25.4	0.89	54	-46.4
2010	26.6	2.09	46.92	-53.48
2011	26.2	1.69	58.32	-42.08
2012	25.7	1.19	105.2	4.8
2013	25.5	0.99	247.9	147.5
2014	25.8	1.29	111.2	10.8
2015	26.2	1.69	101.1	0.7
2016	26.2	1.69	68.3	-32.1
2017	26.3	1.79	29.7	-70.7
2018	26.62	2.11	189	88.6
average	25.98	1.47	97.05	-3.35

Where T is the mean annual temperature, Td is the deviation from 24.51 ˚C [the average of mean temperature for the years preceding it (1973-2007)], R is the mean annual rainfall, and Rd is the deviation from 100.4 mm [the average rainfall for the period from 1973 to 2007].

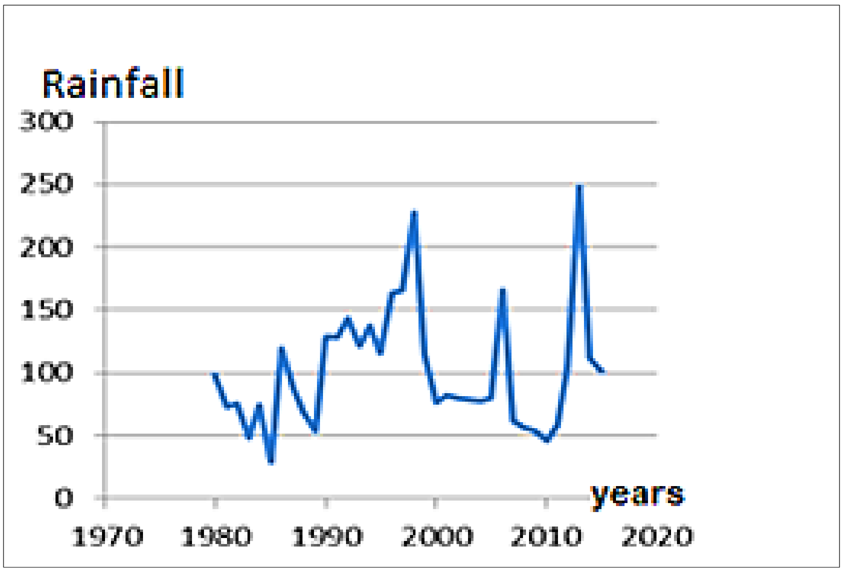


Fig 3: Annual average of rainfall in Samawah meteorological station since 1980.

Nasiriya meteorological station

The Nasiriya station has also shown similar trends in mean annual temperature change for the period from 2008 to 2018 with respect to mean temperature values from 1978 to 2008. Moreover, the yearly average significance has increased in the 21st century, especially in the last few years compared to the previous years (1979-2008), which was 25.5 ℃ (Figure 4).

Table 2: The change of annual mean temperature and rainfall in Nasiriya meteorological station for the period (2008-2018)

Year	T, ˚C	Td, ˚C	R, mm	Rd, mm
2008	26.4	0.90	65.5	-34.9
2009	25.9	0.40	56.9	-43.5
2010	25.7	0.20	57.6	-42.8
2011	25.3	-0.20	85	-15.4
2012	26.5	1.00	116.2	15.8
2013	25	-0.50	175.2	74.8
2014	26.6	1.10	219.7	119.3
2015	27	1.50	93.2	-7.2
2016	26.9	1.40	58.3	-42.1
2017	27.2	1.70	27	-73.4
2018	27.5	2.00	226.5	126.1
average	26.36	0.86	107.37	6.97

Where T is the mean annual temperature, Td is the deviation from 25.5˚C [the average of mean temperature for the years preceding it (1979-2008)], R is the mean annual rainfall, and Rd is the deviation from 100.4 mm [the average rainfall for the period from 1973 to 2007].

The Unsupervised Classification for the satellite images

Unsupervised classification has been used in this research, which is intended to group the image units (pixels) with similar spectral characteristics into clusters according to the number of classifications to be known or chosen. The computer is permitted to find the feature vectors without the intervention of the analyst. "In the simplest form, known as the K-means algorithm, K feature vectors are typically selected at random from the data space". When the feature vectors are to be identified, classification rules are applied to assign pixels within the image to one of the feature vectors [14]. The Landsat-5- 5 satellite images (Figure 4) of the study area for the year 1988 and the Landsat-8 satellite images for the year 2018 were used after the mosaic was created (Figure 5) for the purpose of doing an unsupervised classification to determine the extent of desertification (Table 3). Four classes were chosen, and these are on the maps of classification: water bodies (blue color), wetlands (green color), barren lands (red color), and sand dunes (yellow color) (Figure 6 and Figure 7).

Table 3: The satellite information used for the study.

Satellite	Date	Row	Path
Landsat- 5	15-8-1988	38	167
	22-8-1988	39	167
Landsat- 8	2/8/2018	38	167
	8-9-2018	39	167

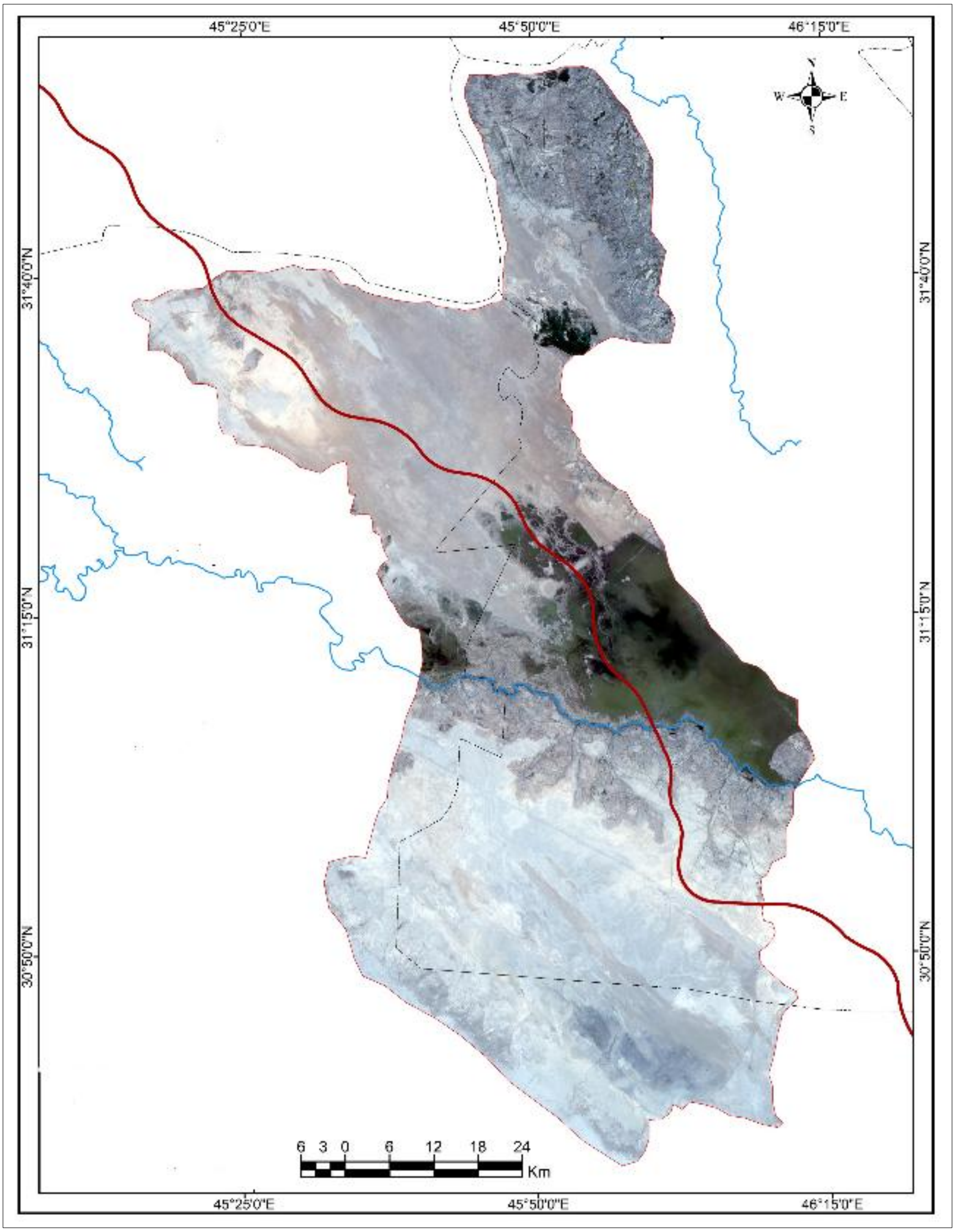


Fig 4: Landsat-5 satellite image in 1988

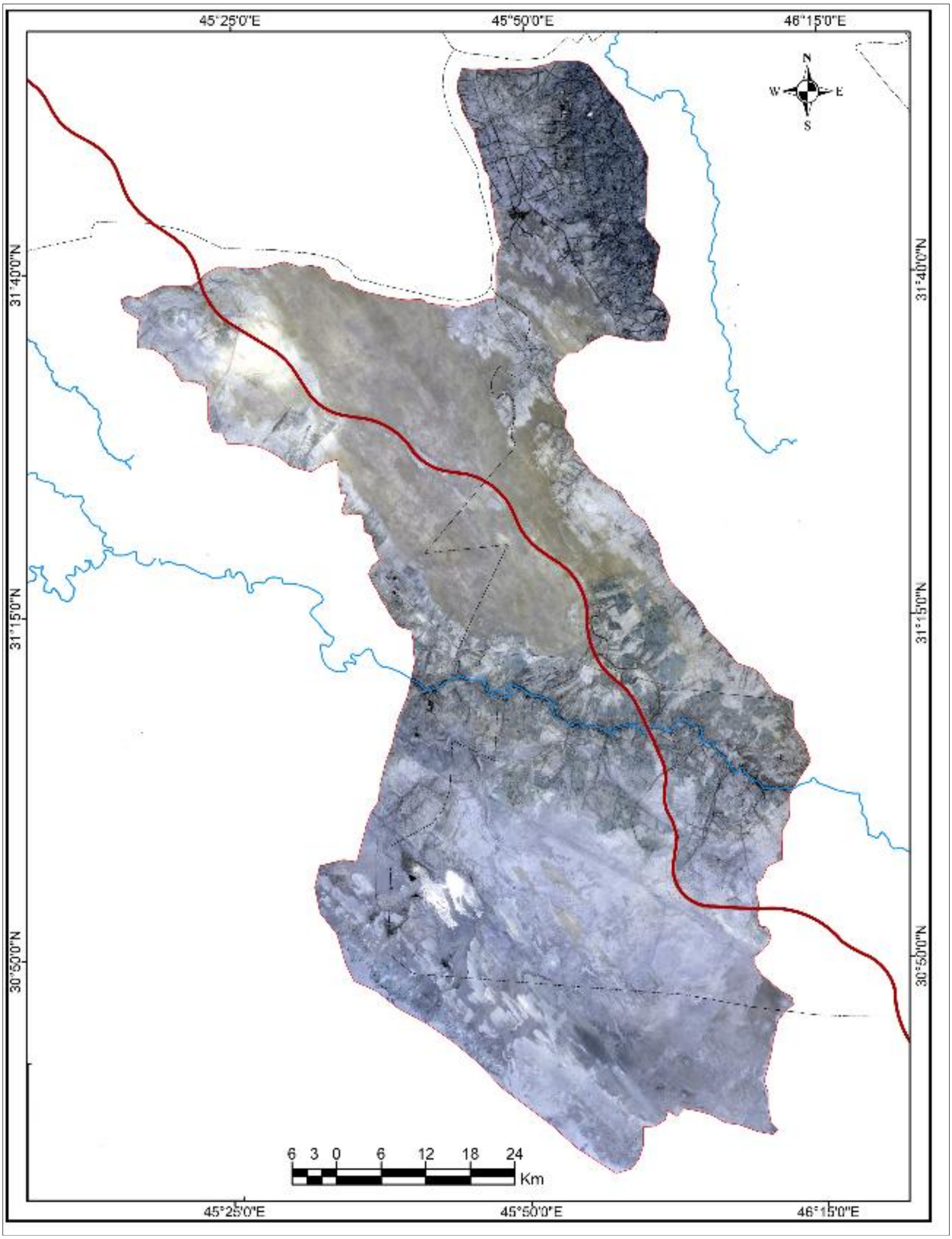


Fig 5: Landsat-8 satellite image in 2018

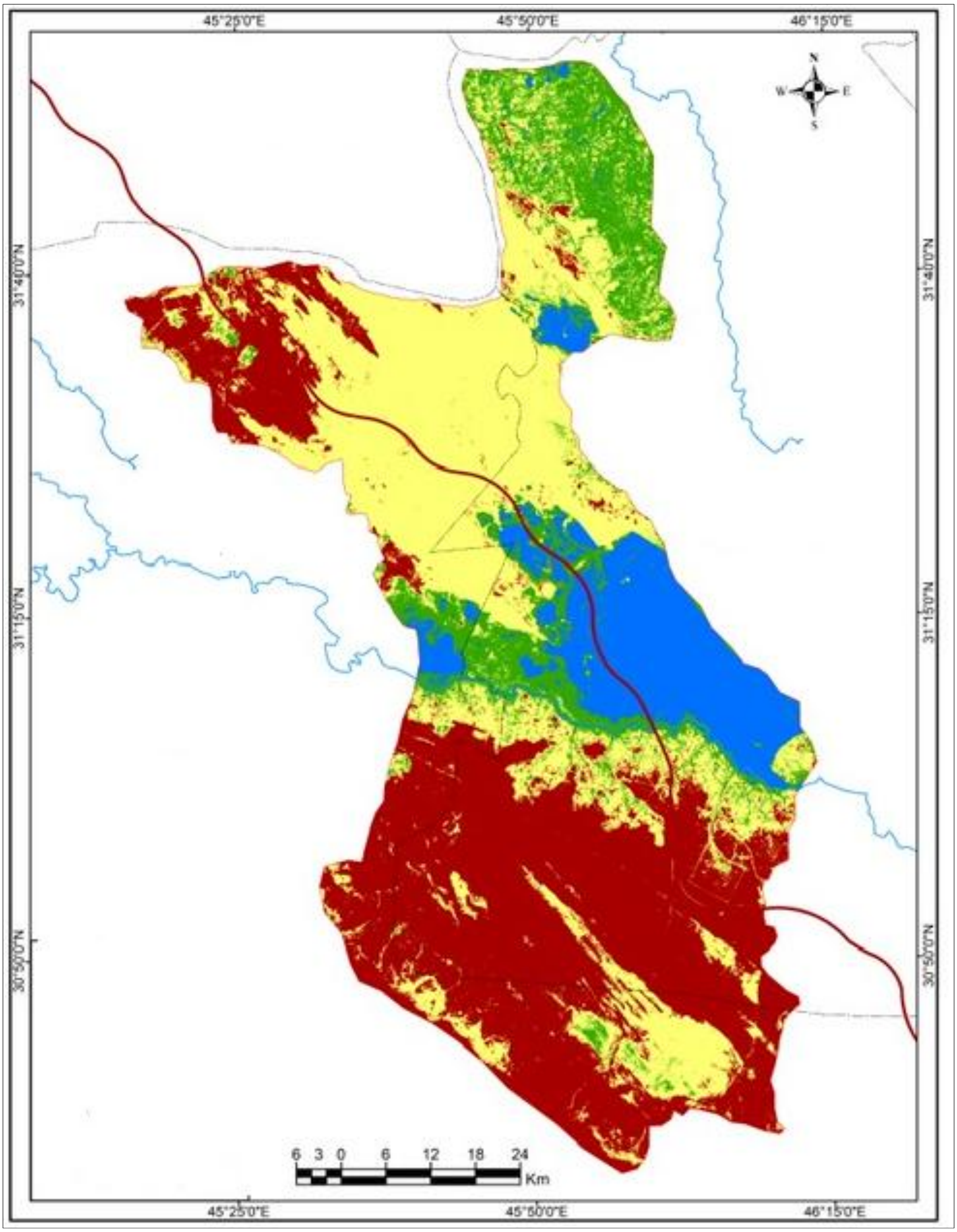


Fig 6: The map presents the result of unsupervised classification for the satellite image in 1988

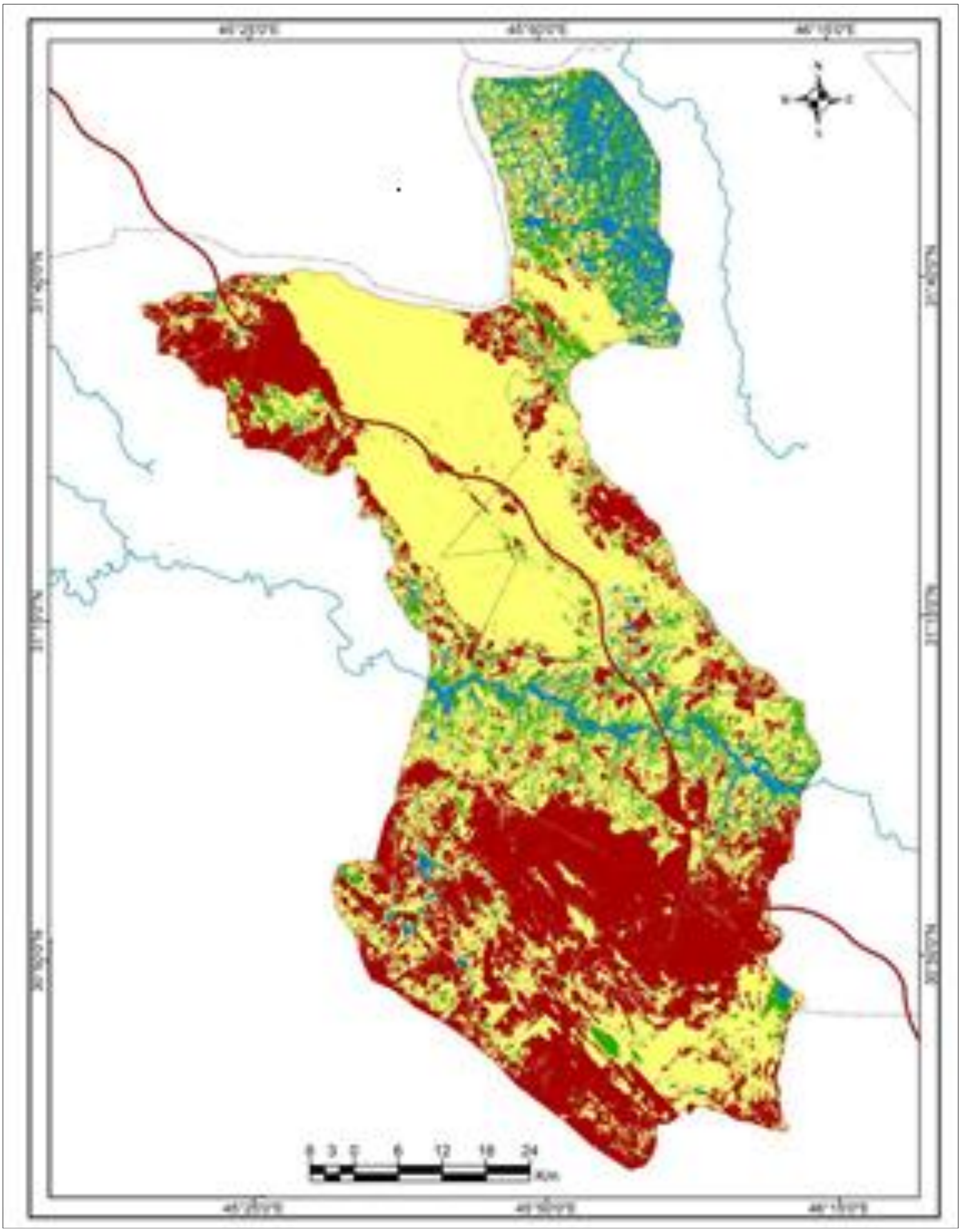


Fig 7: The map presents the result of unsupervised classification for the satellite image in 2018.

Discussion

Increasing temperatures over the surface of the Earth are considered a strong indicator of the anthropogenic causes of climate change [13]. However, many different drivers can affect the observed temperature within multiple scales. The variation of temperatures globally can be created by natural and anthropogenic drivers [5]. Therefore, it is not easy to examine historical climate data at multiple scales in order to make an assessment of the causes of heat trends [13]. In addition, the temperature of the earth's surface and atmosphere is expected to increase [14]. Although, there are many studies that have tried to determine the changes in the warming rate observed between the earth's surface and troposphere [15]. This study analyzed the average changes in mean annual temperature and rainfall for the southern part of Iraq. We found that there were significant changes in temperature, as some years recorded a large increase in annual temperature values over the averaged historical values. For example, the year 2018 recorded a rise in temperature of more than 2 degrees Celsius than the yearly average temperature for both Samawah and Nasiriyah stations. Also, the annual rainfall values witnessed significant changes and fluctuations over the period from 1973 to 2018. For example, at Samawah station, an annual rainfall of 247.9 mm was recorded in 2013, while the yearly rainfall value in 2017 was 29.7 mm. The Unsupervised

Classification for the satellite images of the study area was made, and four classes were chosen for the purpose of determining the extent of desertification. By following up on the results of this classification, we found that there is a significant increase in the area of land covered by sand dunes and a decrease in the areas of barren lands and wetlands in favor of sand dune lands. The land area of sand dunes increased from 1988 to 2018 (Table 3). Overall, climate change and land degradation have contributed to an increase in drought and desertification in the southern region of Iraq.

Conclusion

Climate change has happened all over the world as a result of the high levels of concentrations of greenhouse gases. This study examines the impacts of changing the temperature and rainfall on the extent of desertification phenomenon in southern Iraq as a result of climate changes. The results showed that there are significant increases in the extent of desertification in the study area. Changes in annual mean temperature and rainfall rates were the leading cause of increasing desertification. For example, through the result of the unsupervised classification of satellite images for the study area, it seems clear that the extent of desertification and its aspects are quite different in 2018 from the extent of that phenomenon in 1988. There is a significant increase in the area of land covered by sand dunes and a decrease in the areas of barren lands and wetlands.

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