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Analysis of drought using rainfall anomaly index (RAI) and NDVI in selected areas of Iraq

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सार – यह अनुसंधान इराकी पर्यावरण का मूल्यांकन रेनफॉल इरैडिएशन इंडेक्स - RAI विधि के माध्यम से करता है, ताकि यह समझा जा सके कि जलवायु परिवर्तन एवं सूखा किस हद तक नियंत्रित किए जा सकते हैं। इस अध्ययन में 1981-2021 की अवधि के वार्षिक वर्षा आँकड़ों का उपयोग किया गया है, जो NASA के POSECERES एवं MERRAS डेटाबेस से प्राप्त किए गए हैं। इराक में फैले छह मौसम स्टेशनों (बगदाद, निनवेह, अल-अनबर, वासित, मुथन्ना और बसरा) से मिली जानकारी का इस्तेमाल इराकी माहौल की जांच के लिए किया गया है, और इन छह गवर्नरेट के लिए नॉर्मलाइज़्ड डिफरेंस वेजिटेशन इंडेक्स (NDVI) की गणना की गई। नतीजे से पता चला कि रेनफॉल इंडेक्स (RAI) में नमी वाले (मुथन्ना में 15 गुना), सूखे (निनवेह में 14 गुना) और बहुत सूखे इलाकों (बगदाद और वासित में 10 गुना) में बारिश में ज़्यादा बढ़ोतरी हुई है, यह भी पाया गया कि (RAI) में बदलाव वनस्पति कवर में बदलाव से जुड़ा है। वासित स्टेशन पर RAI का न्यूनतम मान (0.0391) 37.7736% शुष्क भूमि की ओर संकेत करता है, जबकि इसी स्टेशन पर RAI का अधिकतम मान (4.8563) 36.0869% शुष्क भूमि से संबंधित पाया गया। उत्तरी एवं दक्षिणी स्टेशनों की तुलना में मध्यवर्ती स्टेशनों पर वर्षा अधिक स्थिर रही। ज़्यादातर समय, सभी RAI संदर्भ मूल्यों के आसपास, सूखा क्लस्टर इराकी ज़िले में प्रमुख उदाहरण है, जिसका मतलब है कि छह में से हर स्टेशन में बारिश में नकारात्मक भिन्नता है, और अध्ययन में सभी स्टेशन सूखा सूचकांक दिखाते हैं। NDVI मानचित्रों का नतीजा कहाँ है?

ABSTRACT. This research assesses the Iraqi environment using the Rainfall Irradiation Index (RAI) method to see if climate change and drought can be controlled. The data used are from NASA's POSECERES and MERRAS databases for the period 1981-2021, and are annual precipitation values. The information from six weather stations scattered across Iraq is used to investigate the Iraqi environment (Baghdad, Ninevah, Al-Anbar, Wasit, Muthanna and Basra), and Normalized difference vegetation index (NDVI) for those six governorates were calculated . The result showed that Rainfall Index (RAI) a higher upside of rainfall in humid(15 times in Muthanna), dry(14 times in Nineveh) and very dry regions(10 times in Baghdad and Wasit), it is also found that the variation of the (RAI) is related to the change in vegetation cover, The lowest value of (RAI) for Wasit station(0.0391) was led to (37.7736 %) aridity lands, and the highest value of (RAI) was for the same station (4.8563) led to (36.0869) aridity lands, compared to the northern and southern stations, the central stations had more stable precipitation. Most of the time, around all the RAI reference values, the dry cluster is the dominant example in the Iraqi district, which means that each of the six stations has a negative rainfall variance, and all of the stations in the study show a drought index,. Where is the result of NDVI maps???

Key words – Drought, Rainfall anomalies index, Precipitation, NDVI.

1. Introduction

Drought is an identified term that many people understand and that inspires images of arid, desert countries with few sources of regular surface water and rainfall (Maliva and Missimer, 2012). The arid world covers about 40 percent of the Earth's surface (Deichmann, and Eklundh , 1991). Desertification refers to land depletion due to climate variability and human activity in drought, semi-arid, and arid sub-areas (UNCCD, 2014). Climatological indices are used to describe and quantify drought, which is a complex process, all of which have their own characteristics and are mutually reinforcing. (Arora, 2002). Recent research has shown conclusively that the climate is changing rapidly as a result of global warming, with the desire to write the most accurate description of the level of aridity increasing (Al-Khalidi *et al.*, 2020). One of the most important consequences of climate change is the cumulative occurrence of droughts and the increasing impact of climate droughts on agroforestry ecosystems (Ferragina, 2010). Although it is difficult to distinguish their effects visually, the conceptual shift between drought and desertification is the same as that between weather and climate (Perini, 2008). In drought, the lack of rainfall is influenced by the local climate and is characterised by persistent or seasonal rainfall (Cook *et al.*, 2004). Several studies have demonstrated the relationship between drought and vegetation cover in Iraq, relying on the values of drought and rainfall indices in Iraq.

Al-Kakey *et al.*, 2024 studied the spatial and temporal characteristics of drought in the upper basin of the Little Zab River from 2004 to 2018, The Reconnaissance Drought Index (RDI), the Second Adjusted Soil Vegetation Index (MSAVI2), and the Normalized Difference Water Index (NDWI) were adopted as indicators of meteorological, agricultural, and hydrological drought, it was found that severe to extreme drought was recorded in the hydrological year 2007-2008, and continued until 2008-2009 (Al-Kakey *et al*., 2024).

The rainfall anomalies for 12 stations in Erbil Governorate. The results showed that multiple consecutive drought years occurred at all study stations to varying degrees. (Khalid, 2024).

The changes in vegetation cover in Halabja city, Iraq, using Landsat-5 the matic mapping images. NDVI image discrimination and subsequent classification techniques were applied, and the results indicated a sharp decrease in dense, sparse and moderate vegetation cover, with an increase in the non-dense vegetation cover category (Aldoski , 2013).

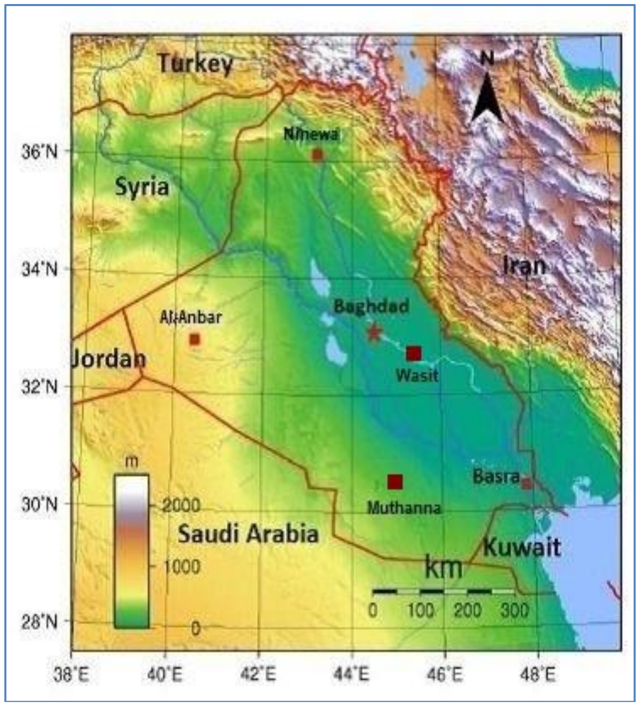


Fig. 1. The location of study stations (GIS analysis).

Among the existing VIs, the Normalised Difference Vegetation Index(NDVI) is the most commonly used and is the most fully operational, worldwide vegetation index, due to its ratio of properties, which allows the NDVI to capture a large proportion of the noise generated by different sun angles, geography, shadow or cloud conditions and atmospheric conditions. (Bakr *et al*., 2024 ; Huete *et al*., 1999; Khalaf and Hummadi, 2023).

The aim of this study is to investigate the impact of rainfall on the distribution of vegetation cover in selected areas of Iraq using the Rainfall Anomaly Index (RAI) and NDVI to determine the nature of the relationship between them.

2. Data and methodology

2.1. *Datasets used*

The study area is represented by six stations, these stations are spread over different parts of Iraq and differ in terms of their geological characteristics, surface area, soil type and water source, as well as altitude (Table 1). These six stations are characterized by different climatic elements in terms of the average values of the table (Table 2).

These stations are: Nineveh, Anbar, Baghdad, Basra, Al-Muthanna, and Wasit Station (Fig. 1). The data used

TABLE 1

Geographical location of the six station of study

Stations	Altitude (m)	Longitude (deg)	Latitude (deg)	Area (km^2)
Baghdad	34	44.37	33.31	4555
Ninevah	223	43.16	36.35	37323
Al-Anbar	375	43.3	33.41	138501
Wasit	30	45.83	32.50	17153
Muthanna	30	31.32	45.28	51740
Basra	2.4	47.82	30.50	19070

TABLE 2

Average climate data for the study period

Stations	Temperature (C°)	Relative Humidity (%)	Wind Velocity (m/s)	Rainfall (mm)
Baghdad	23.68	35.99	3.41	138.81
Ninevah	21.29	42.36	2.93	246.92
Al-Anbar	22.44	38.695	3.996	76.66
Wasit	24.25	32.996	4.35	165.01
Muthanna	24.18	30.98	4.1	69.05
Basra	25.24	33.55	3.12	97.91

in this study were for time series (1981-2021) and annual precipitation component values obtained from NASA and Power for this period (https://power.larc.nasa.gov/data-access-viewer/). The ones we used are important and can be used to give us an idea of the climate in Iraq (Michael *et al*., 2016).

2.2. *Rainfall anomalies Index (RAI)*

The Rainfall Anomaly Index is a method for assessing the spatial distribution and intensity of rainfall events, comparing the current rainfall situation with historical values and characterising and monitoring the spatiotemporal variability of rainfall in a given region. It works best in semi-arid areas (Nobrega and Santiago, 2014) .

We can categorise wet and dry periods in different intensity levels by using the rainfall anomaly index, which is used to classify the significant anomalies of negative and positive rainfall periods in rainfall time series. The main feature of this index is its ease of use, as it requires only the calculation of precipitation data. (de Oliveira Sanches *et al*., 2014).

Van Rooy (1965) indicates that the basis for calculating the RAI is very simple and efficient and that Equations 1 and 2 allow comparison of rainfall variations in the standard form of different locations. (Van Rooy, 1965).

$$RAI = 3\left[\frac{N-\bar{N}}{\bar{M}-\bar{N}}\right] \text{ for positive anomalies} \quad (1)$$

$$RAI = -3\left[\frac{N-\bar{N}}{\bar{X}-\bar{N}}\right] \text{ for negative anomalies} \quad (2)$$

where: N = current yearly rainfall, which is the year that RAI is generated (mm). $\bar{N}$= yearly average rainfalls of time series (mm). $\bar{M}$ = mean of the ten biggest yearly rainfalls of time series (mm). $\bar{X}$ = mean of the ten lowermost yearly rainfalls of time series (mm).

Where positive anomalies are situated above the average and the negative anomalies are lower (Sá et al., 2018). In this study, an Excel sheet was used to calculate the values of RAI.

The values can be categorized giving to Table 3.

TABLE 3

Categories of the Rainfall Anomaly Index (RAI).

	RAI range	**Classification**
Rainfall Anomaly Index (RAI)	Above 4	Extremely humid
	2 to 4	Very humid
	0 to 2	Humid
	-2 to 0	Dry
	-4 to -2	Very dry
	Below -4	Extremely dry

2.3. *NDVI*

In a natural organic framework, vegetation fulfils a role. It continues to trade energy and hydrological, global environment and carbon patterns in different ways (Peng *et al*., 2012).

From local to global, vegetation differences are useful indices for natural and environmental assessment. In the tropics, this transformation is masked by thick vegetation and overcast. As NDVI is sensitive to growth conditions, productivity and other biophysical and biochemical parameters of vegetation, changes in NDVI may reflect changes in vegetation growth conditions. Standardised vegetation record NDVI has become the norm for vegetation (Huete and Liu, 1994).

NDVI is one of the most widely index used vegetation indexes, its usefulness in satellite assessment and general vegetation coverage has been well established over the last many years. (Leprieur et al., 2000). NDVI is following on the near infrared band (band 5) and the red band (band 4), it is an efficient and practical device for observing vegetation (Birtwistle *et al*., 2016)

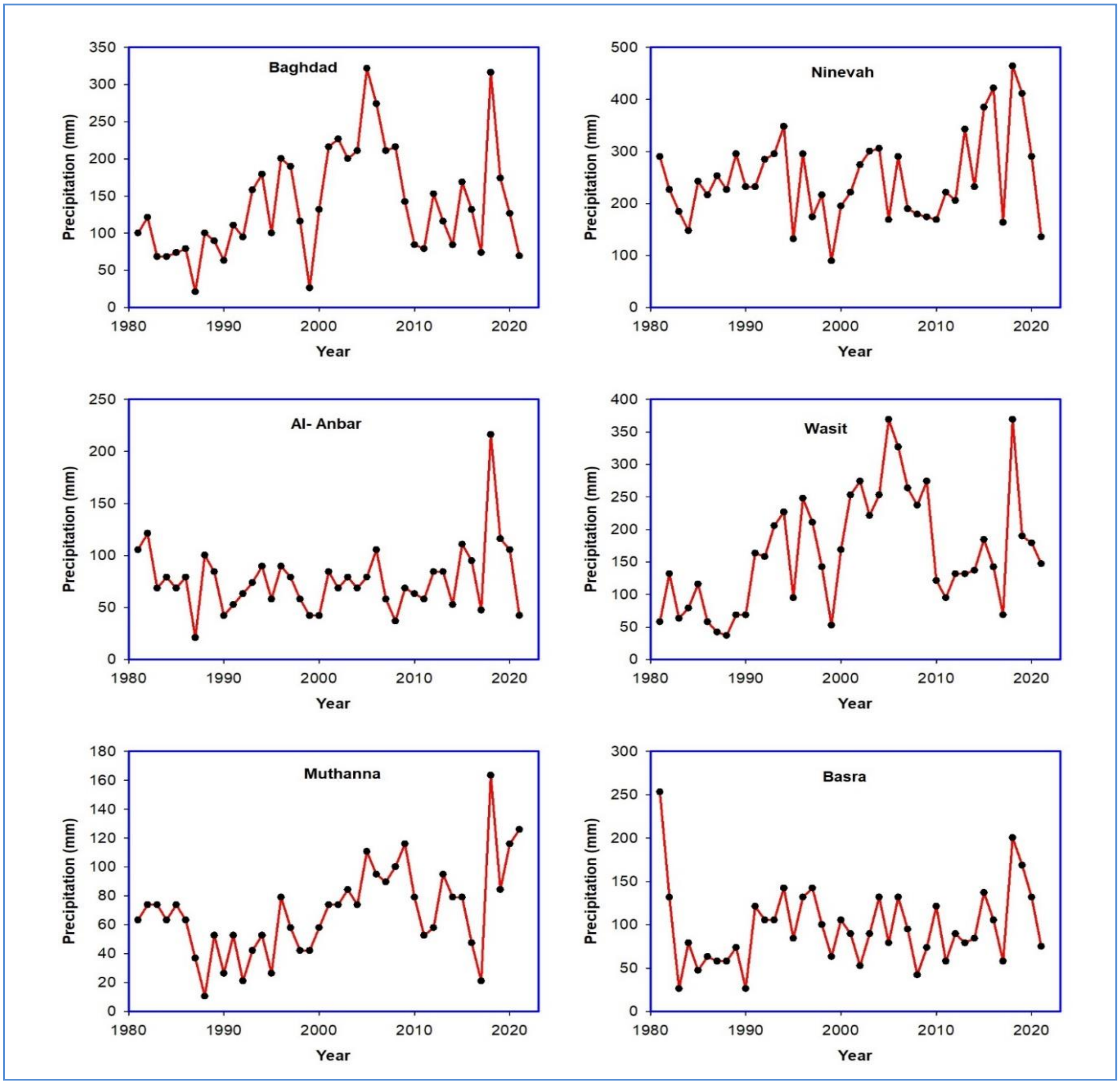


Fig. 2. Temporal Analysis of Rainfall for the study stations

$$NDVI = \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{Red}} \quad (3)$$

where is the R_{NIR} reflectance of NIR and R_{Red} is the reflectance of visible red radiation Vegetation images (NDVI) were used for the last two decades and were taken for the month of May, years when vegetation cover is greatest, and for the month of August, when vegetation growth is least, over a period of 21 years.

3. Results and discussion

3.1. *Temporal analysis of rainfall*

The highest annual precipitation value at the Baghdad station was in 2005, while the highest precipitation value at the Basra station was in 1981. For the other five stations, 2018 was the wettest year on record (Fig. 2). Rainfall rates vary between study stations due to differences in geographical features as well as differences

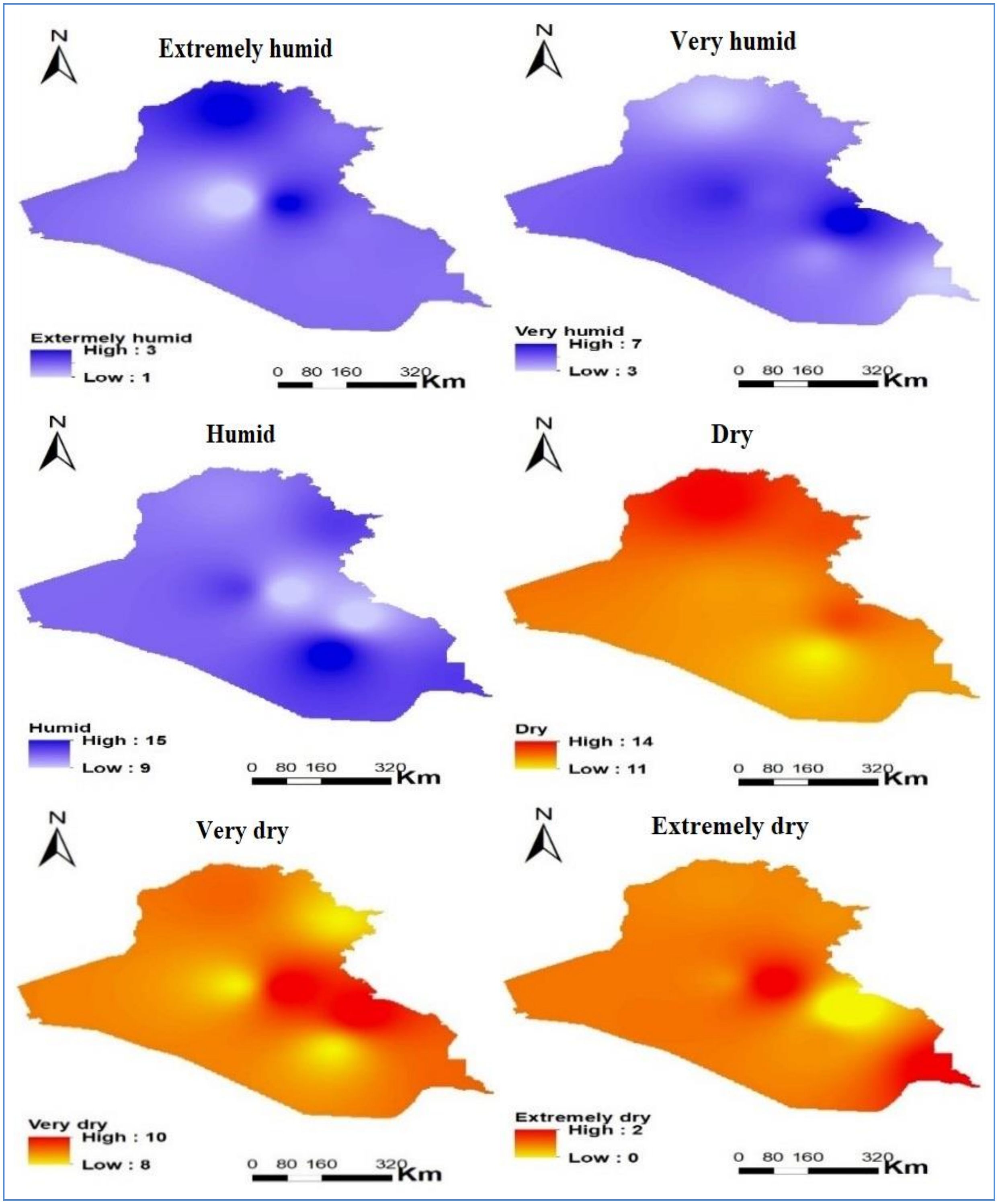


Fig. 3. Frequency of RAI spread of study area

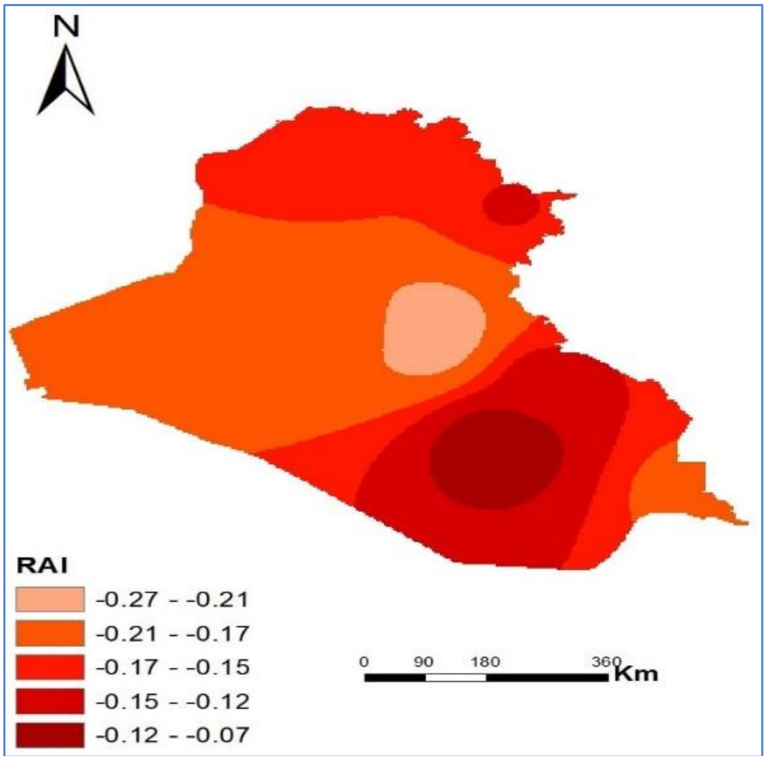


Fig. 4. RAI average values for the study stations

TABLE 4

The classification of the RAI frequency for stations

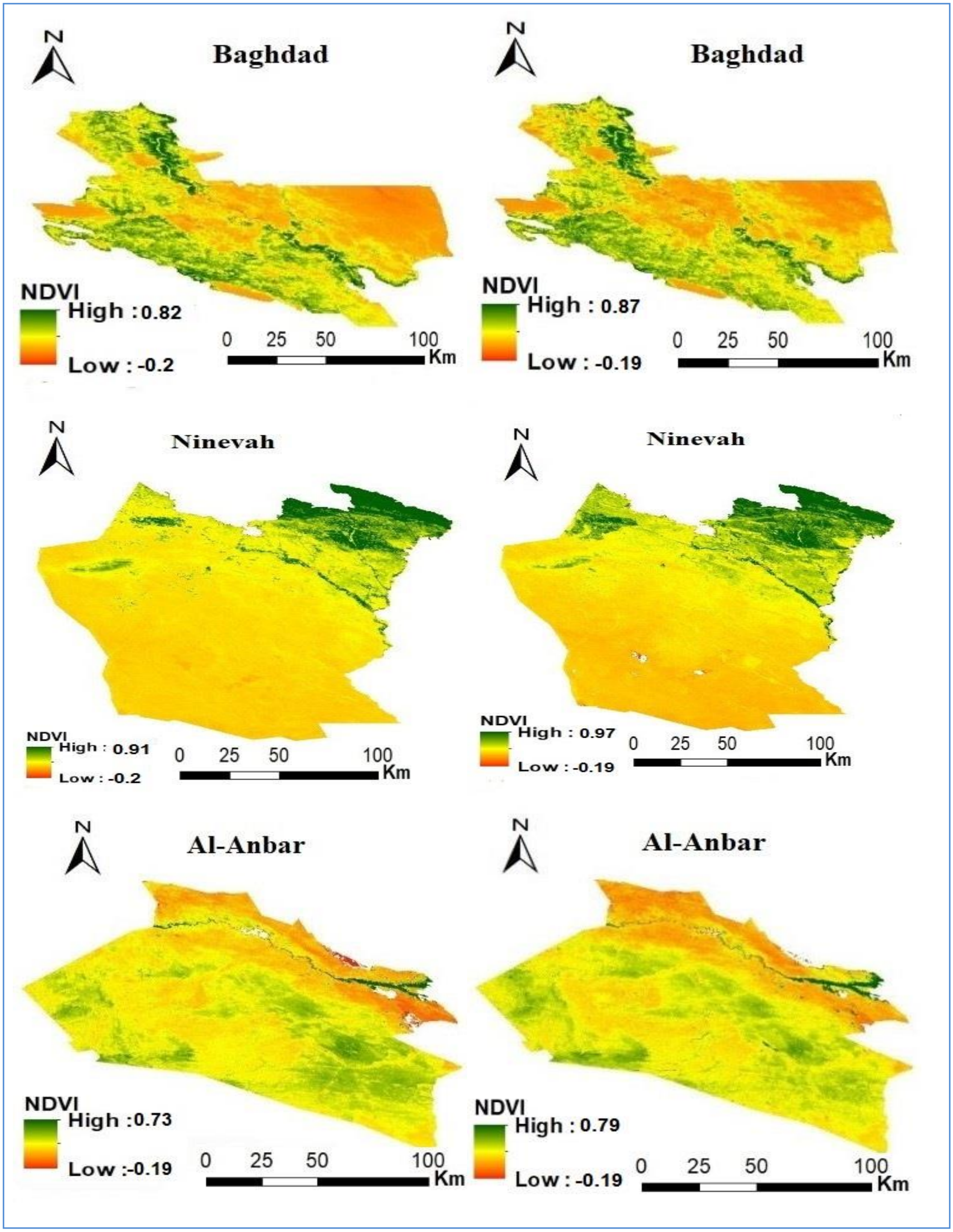
Stations	Extremely humid	Very humid	humid	Dry	Very dry	Extremely dry
Baghdad	3	5	9	12	10	2
Ninevah	3	3	11	14	9	1
Basra	2	3	13	12	9	2
Anbar	1	6	13	12	8	1
Muthanna	2	4	15	11	8	1
wasit	2	7	9	13	10	0

in the impact of climatic events such as the North Atlantic Oscillation and the El Nino. In general, the lowest precipitation value was at Al-Muthanna station, while the highest precipitation value was at Nineveh station.

3.2. *Classification of RAI*

The values of the RAI indicate the frequency of the precipitation. From the stations of study the highest value was for the type (humid) at Muthanna Station and the lowest value was for the type (extreme drought) at Wasit, Ninevah and Anbar stations. The wet and dry types were also found to be the most common types of drought at almost all study stations, as they are non-extreme types (Fig. 3; Table 4). The six study areas can be classified according to the drought type (extreme, very dry, dry, very dry and extreme dry) in Table 3, using the mention in methodology, with the extreme drought occurring more often at Baghdad and Basra stations. This is because of the higher temperature extremes. As for rainfall variability, it was highest at Baghdad, Nineveh and Wasit stations and more stable at Anbar station, as these are flat areas and contain moisture levels that are not extreme due to precipitation. As for the wet part, it's most common at Al-Muthanna station. Moreover, the dry variety was most common at Nineveh, This is due to the impact of climate change and the decrease in the amount of rainfall, while the very dry variety was more common at Baghdad and Wasit. In general, the highest (RAI) for the extremely dry class was recorded at Basra and Baghdad stations, and the lowest for this class was recorded at Wasit station (Fig. 3).

In general, drought types and frequencies vary between regions and time periods depending on the characteristics of the region, in addition to global climatic


Baghdad
NDVI
High : 0.82
Low : -0.2
0 25 50 100 Km
Baghdad
NDVI
High : 0.87
Low : -0.19
0 25 50 100 Km
Ninevah
NDVI
High : 0.91
Low : -0.2
0 25 50 100 Km
Ninevah
NDVI
High : 0.97
Low : -0.19
0 25 50 100 Km
Al-Anbar
NDVI
High : 0.73
Low : -0.19
0 25 50 100 Km
Al-Anbar
NDVI
High : 0.79
Low : -0.19
0 25 50 100 Km

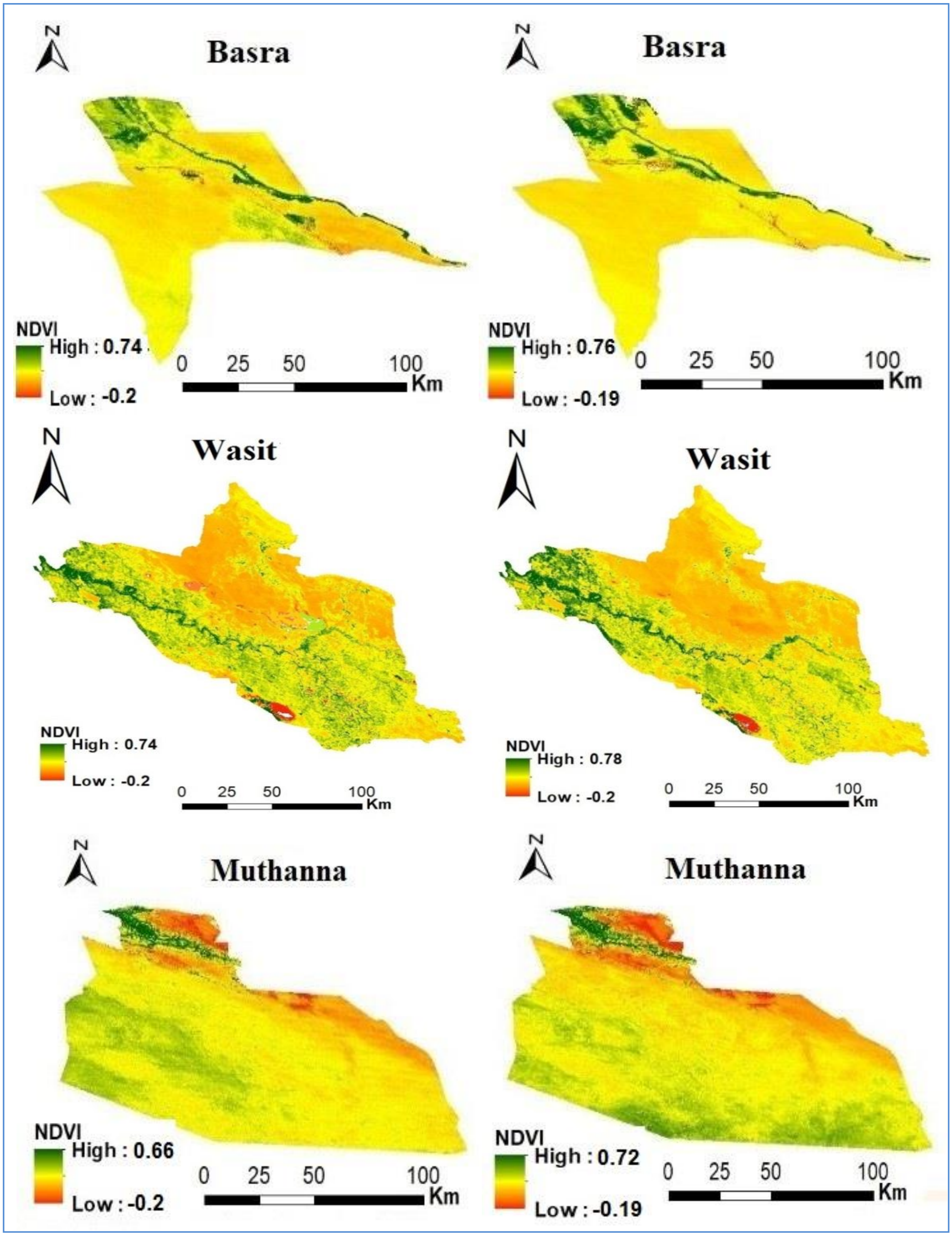


Fig. 5. The vegetation lowest, highest (RAI) for any months of NDVI image

TABLE 5

Aridity areas change the maximum and minimum values of the RAI

Stations	Minimum			Maximum		
	year	(RAI)	Aridity land area percentage (%)	year	(RAI)	Aridity land area percentage (%)
Baghdad	2021	-2.72	27.0319	2005	5.45	22.0109
Ninevah	2021	-3.56	27.8778	2018	5.92	32.0526
Basra	2008	-3.42	84.8102	2018	5.19	83.3778
Al-Anbar	2008	-3.63	34.0971	2018	10.50	35.9192
wasit	2017	-2.75	37.7736	2018	5.03	36.0869
Muthanna	2017	-3.85	62.0987	2018	6.99	61.9811

events such as the El Nino Southern Oscillation and the North Atlantic Oscillation.

3.3. *Frequency of RAI*

The rainfall index values for all six study areas (Baghdad, Nineveh, Al-Anbar, Wasit, Muthanna and Basra) were negative and classified as dry. This in turn provides a clear and significant indication that all study areas have identified a decrease in rainfall and have also experienced drought (Fig. 5). Generally, the mostfluctuate amount of precipitation was at the Wasit station, while the Baghdad station was the most stable in the amount of precipitation.

All stations studied showed drought, but in different ways, therefore, the necessary decisions to mitigate drought and to reduce its impact on the environment and vegetation cover can be made by this variation in the RAI. Areas with the highest RAI require more drought management in terms of provision Alternative methods of rain include using groundwater and applying modern irrigation techniques such as distillation to maintain the environment and vegetation cover.

3.4. *Relationship RAI to vegetation cover*

The relationship between (RAI) and vegetation cover has been studied by using the six study stations' satellite images. The vegetation cover area, whether natural or cultivated, is directly influenced by changes and variations in rainfall, which in turn affect the vegetation cover area for the last two decades of the study period, using annual NDVI images. This means that changes in RAI values lead to changes in vegetation cover, which fluctuate and are not symmetric, depending on the nature of the area and on the type of plant (Fig. 4). The maximum value of (RAI) was in 2018 for most stations, which was a year of abundant rainfall, while the minimum value of the index was in years of little rainfall. It was observed that the barren areas devoid of vegetation cover increased with an increase in the value of (RAI) as in Ninevah station, Al-Anbar, Muthanna and Basra. The increase in rainfall anomalies has been accompanied by a decrease in rainfall in most regions due to a decrease the vegetation covered area, but, the situation was reversed in the Muthanna and Baghdad areas, where the increase in RAI led to a decrease in the area of barren land and an increase in vegetation (Table 5).

4. Conclusions

This study can provide us with a good proxy for studying climate change. The results of this study include:

(*i*) Iraq's climate is characterised by variability and instability in terms of rainfall over the last four decades, as investegated by RAI.

(*ii*) Rainfall is dominated by wet and very dry conditions.

(*iii*) The rainfall index values for all study areas were negative, and were classified as dry. This indicates that all study areas experienced a decrease in rainfall.

Authors' contribution

D. I. Bakr: Data analysis.
J. Al-Khalidi: manuscript review. (*email-jasimkhalel77@yahoo.com*).
Sardar.M.R. K: wrote the paper.(*email-Sardar.kareem@su.edu.krd*).
A.F. Hassan: review and collected the data. (*email-ahmedfalih 1122@gmail.com*).
S Gh Hameed: performed the experiments. (*email-Safa.hameed@su.edu.krd*).
A. m Al Salihi: collected maps. (*email-Alialsalihi.atmsc @uomustansiriyah.edu.iq*).

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