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Spatio-Temporal Analysis of Al-Razaza Lake Changes by Using Derived Indices and Remote Sensing Analysis

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Abstract - AL-Razazah Lake is one of the Iraqi Lakes. it is known as big flood water store and fish's wealth source. At the last three decades it suffers from highly extent of dehydration. This research proposes approach to identify the changes of this Lake in between 1990 to 2025 using remotely sensed satellite images. This research is conducted by many phases; Pre-processing, Processing, and Analyzing to remove the image' s noise and applied the corrected image into next phase of the study. Then, this study was performed using different indices applied on the satellite images from Landsat Satellite System; Normalized-Difference-Water-Index (NDWI), and Normalized-Difference-Vegetation-Index (NDVI) to extract the AL-Razazah surface water Area. In addition, an unsupervised Approach was selected to perform image classification using the K-Means algorithm in order to classify the study area to many classes. The results reveal that the Lake was changed rapidly. The NDVI and NDWI show the highly decreasing in the area of AL-Razazah Lake about 81.17 % and 80.32% with area about of 1187.40 km2 and 1189.24km2. The results a highly dehydration extending, and all these drying areas were becoming a soil area, that will threat the wildlife and reduce the wealth of fish in AL-Razazah Lake. The outputs will be utilized for the researchers and analysts who would like to study the water bodies and the effect of the claim changes on water bodies in Iraq.

تحليل التغيرات المكانية والزمانية لبحيرة الرزازة باستخدام المؤشرات المشتقة وتحليل الاستشعار عن بعد

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المستخلص – بحيرة الرزازة تعد احدى البحيرات العراقية، كونها ذات خزان كبير لمياه الفيضانات ومصدرا غنيا بالأسماك. خلال العقود الثلاثة عانت البحيرة من جفاف حاد. لذلك يقترح هذا البحث منهجية لتحديد التغيرات التي حدثت على هذه البحيرة بين عامي 1990 و2025 وذلك باستخدام صور الأقمار الصناعية الملتقطة عن بعد. وتم البحث على عدة مراحل : المعالجة المسبقة ، المعالجة ، التحليل لإزالة التشويش من الصور ، بعد ذلك تم استخدام الصور المعالجة في المرحلة التالية ، تم استخدام مؤشرات مختلفة في صور الأقمار الصناعية من نظام لاندسات : (مؤشر الفرق الطبيعي للمياه) وأيضا(مؤشر الفرق الطبيعي) للغطاء النباتي ، ليتم استخراج مساحة المياه على السطح في هذه البحيرة ، وأيضا تم اعتماد منهجية لتصنيف الصور باستخدام خوارزمية وذلك لتصنيف المنطقة الى فئات عدة وقد اشيرت النتائج ان بحيرة الرزازة قد شهدت تغيرات سريعة ، وقد ظهر مؤشر انخفاض كبير في البحيرة بنسبة 81.17% و 80.32% على التوالي وكانت قد وصلت مساحتها الى 1187.24كم .وبينت النتائج الى استمرار الجفاف ومن الممكن ان تتحول هذه الى ارض قاحلة ، وهذا يهدد الحياة البرية ويقلل من الثروة الاقتصادية بالبحيرة. هذه الدراسة سوف تكون مفيدة للباحثين في دراسة المسطحات المائية وتأثير التغيرات المناخية بالعراق.

كلمات مفتاحية: تمديد الجفاف، استخراج المياه السطحية، الكشف عن الأراضي الرطبة، تصنيف K-Means، مؤشر الغطاء النباتي الطبيعي.

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Introduction:

Al-Razazah lake is considered as flood water' store coming from Euphrates-River, (Nawal *et al.,* 2012). Water elevation of Al-Razazah lake starts decreasing rapidly since 1990s. climate change, increasing atmospheric temperatures and reduced Euphrates River inflow have Contributed to the decline in the lake Water level. The elevation water of Al-Razazah Lake is reduced till reached about of 10m (Rawnaq *et al.,* 2010). The area of the study area and its surrounding areas should be detected. Remote-sensing (RS) and Geographical-Information-System (GIS) both of them were applied and utility widely to detect, monitor, and manage the degradation of wetland areas with very highly accuracy (Demers, 2005, Wu *et al*., 2006). The RS and GIS were applied for wetlands detect of surface water area changes (Wu *et al*., 2006). Satellite imagery was used for feature extraction of surface water (El- Asmar *et al*., 2011; Zhou *et al.,* 2011; Du *et al.,* 2012; Gong *et al*., 2012; Sexton *et al.,* 2013; Feyisa *et al.,* 2014; Dibs *et al*., 2014; Hayder *et al*., 2016; Hayder *et al.,*2017; Hayder and Thul-fekar, 2018).

Many Studies discuss the water bodies detection and monitoring by satellite system images is very well-known (Lunetta and Balogh, 1999; Ozesmi and Bauer, 2002; Hayder 2018; Aljanbi *et al.,*2020; Kheiralipour *et al*., 2024). Moreover, the wetland areas can be mapped and estimated using UAVs, Aerial Photography, and Satellite Images (Dahl, 2006). The aim of this research is to present a method for mapping the dehydration extend of Al-Razazah lake between (1990 – 2025) from applying Geo-spatial analysis.

Materials and Methods:

There are many and different techniques examined for surface water feature extraction and the most suitable method was applied to estimate and map the Geo-spatiotemporal changes of Al-Razazah Lake dehydration extent (Yousef *et al*., 2024; Salim *et al*., 2025; Jabber *et al.,* 2025). Landsat satellite imagery uploaded for the period 1990 up to 2025 were used in this study. These images were downloaded from using the following link (http://edcsns17.cr.usgs.gov) freely. The next steps of this study were performed; radiometric, atmospheric, geometric corrections to all images. In Addition, series of NDWI and NDVI were mapped and then the satellite images were classified using the unsupervised (K-Means method) to detect the changes in Al-Razazah lake water surface area from images by performing a comparison between the outputs of NDWI, NDVI and classified images. Figure (1) presents the applied methodology.

Study Area:

Al-Razazah is the second biggest lake and water storage in Iraq after Al-Thurthar Lake. It is located in Karbala province in the northen-west and surround with Al-Anbar city from the north-east in Iraq as illustrates in Figure (2). It has coordinates between {33°10′ 00” N} To {32° 20′ 00” N} and {43° 55′ 00” E} To {43°15′ 00”E}. AL-. When the elevation of water in this Lake reaches 40m based on mean sea level (MSL), it will have a surface area about of (1810 km2). This lake has two parts, the first one located in in Karbala province, and the second once is located within Al-Anbar province. This lake holds about 26BMm3 of water (Nawal *et al*., 2012). Water resources of Al-Razazah lake come from different resources such as: AL-Habbaniya, Rashidiya, Euphrates River, many springs and finally from rainwater. The lake has cold climate in winter and has dry and hot climate in summer season (Nawal *et al.,* 2012).

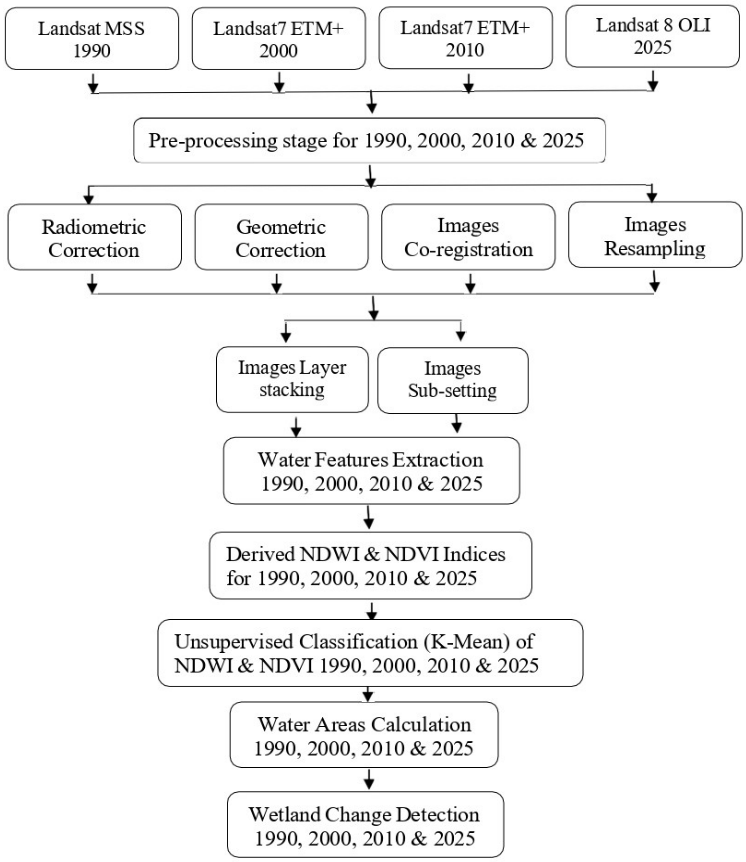

Figure 1. Flowchart showing the overall methods adopted in the study.

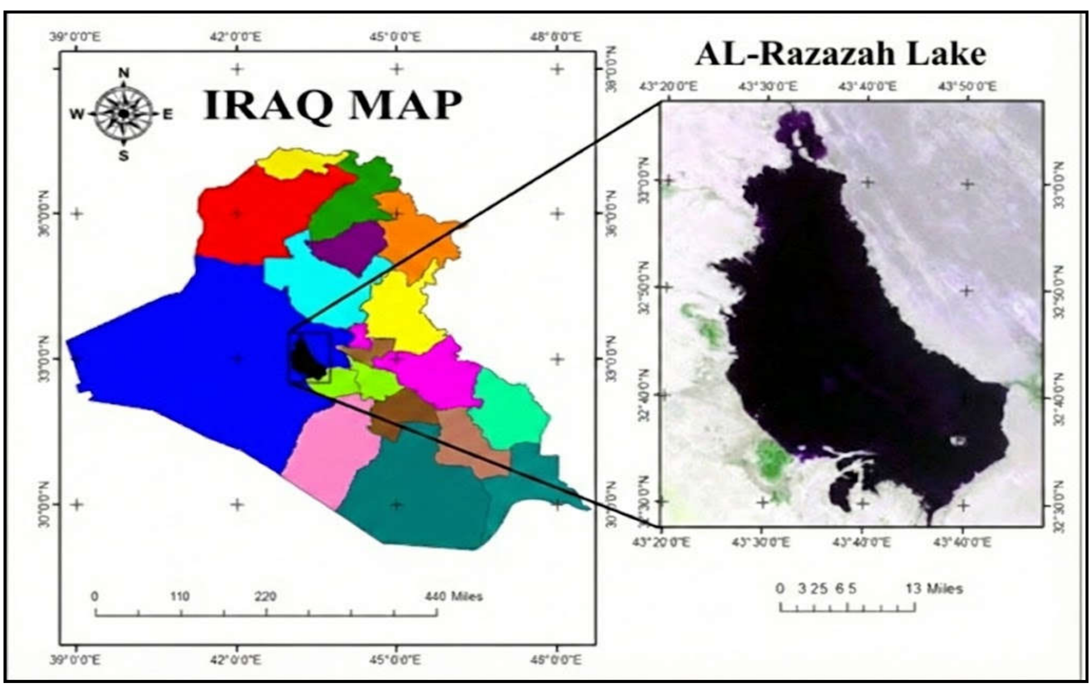

Figure 2. Location of AL-Razazah Lake, Iraq. (Source: Authors).

Applied Satellite Images:

Four satellite images were applied in this study all the used data were downloaded from Landsat satellite Systems. There are two images, the first one is Landsat-thematic-mapper (TM4) image was applied in this research and it was captured in August 1992, and the second one is a Landsat Thematic Mapper (TM) sensor 5 was also used to conduct this research, capturing time was in (February 2010), respectively. The third used image was got from the Landsat-Enhanced-Thematic Mapper-Plus (ETM+7), the capturing time was in (January,2001). However, from Landsat-8 Operational Land imager (OLI) the fourth image was got and it was captured in (May 2018). The satellite TM-images have (6 Bands) with a Spatial-Resolution about (30m) of 1-5 and band 7.

The band (6) has a Spatial-Resolution about of 120m. The imagery of the sensor Landsat Satellite (ETM+) has eight bands, the bands from 1 to 5 and 7 has a Spatial-resolution about 30m. But, the band 6 has spatial-resolution about 60m (Yousef *et al*., 2025). However, the launched new satellite system (OLI) on (February, 2013) has nine bands with two 2 as thermal bands (10&11) (Yousef *et al.,* 2025). Each band of this sensor has spatial resolution about 30m, however, the thermal bands have 100m. The collected satellite images (1990, 2000, 2010 and 2025) that applied in this research were from path (169) and row (37). All the satellite images were downloaded from the united-state-geological-survey (USGS) and it was free of charge. Both of Figure (3) and Table show the characteristics of downloaded satellite image and the sensors: Landsat TMs, ETM+ and OLI.

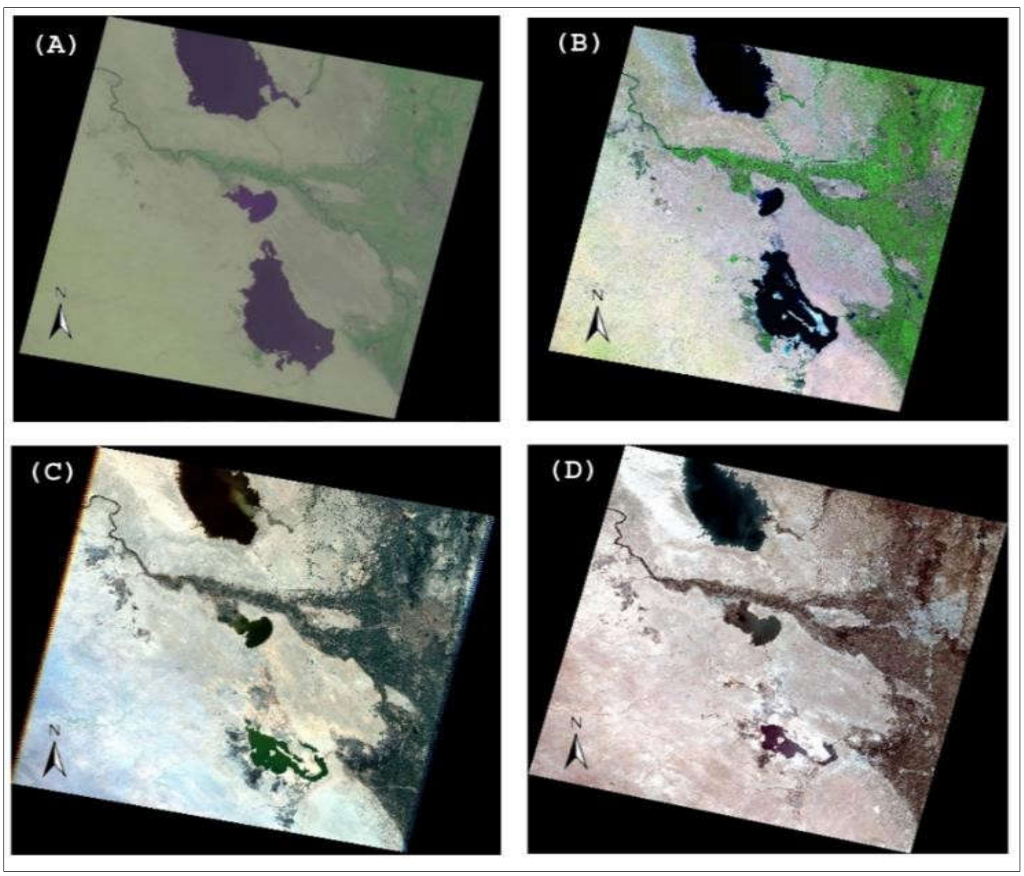

Figure 3. The Downloaded and uncorrected Satellite images: (A) 1990; (B) 2000 (C) 2010, (D) 2025.

Table 1. Sensors and dataset characteristics.

Projection	Collecting Time	Path/Row	Sensors
UTM - 38N	02/09/1990	169-037	Landsat4
UTM - 38N	08/09/2000	169-037	Landsat7
UTM - 38N	06/09/2010	169-037	Landsat5
UTM - 38N	04/09/2025	169-037	Landsat8

Pre-Processing:

The pre-processing stage applied to insure the is applied satellite images are ready to jump to the next stage and doing further processing, in this stage the atmospheric and radiometric calibration, geometric-noise removal, and images-resampling. However, it is important when we have multi- images classification (Lu and Weng 2007). The Atmospheric correction and radiometric calibration conducted referenced by Schroeder *et al*., (2006), and Calibration-Tools in ENVI v 5.0 software were applied. The UTM Project was selected in images geo-registration within zone 38N, WGS84. As shown in Figure 3, all images were free of cloud. The radiometric and atmospheric correction were made to all the satellite images, then the geometric correction was performed using referenced image. The OLI satellite image was considered as the referenced imagery, to use the image-to-image method for performing the registration of images, the root-mean-square-error equal to (<0.5 pixel). The 2025 image had been geo-referenced using collected ground truth points and map and with less than (0.3 pixel). About 25 ground control points were applied for performing the co- registration of each single imagery.

Imagery Processing:

In this section two steps have been applied to the used satellite images:

a) Layers-Stacking stage,

b) Images-Resizing to Sub-Setting the satellite images to fit with the study area,

The image Layers-Stacking was the first stage. Layer stacking technique was utilized and applied to satellite images, it was conducted using a tool in Envi software. The images of 1990, 2000, 2010 and 2025 were sub-setting to be fitted to AL-Razazah Lake. Both of the Layer-stacking stage and Sub-setting stage are conducted for Saving processing time and reducing the size in computer storage (Hayder *et al.,* 2014; Hayder *et al.,* 2015). Figure (4) shows the outputs of conducting these steps.

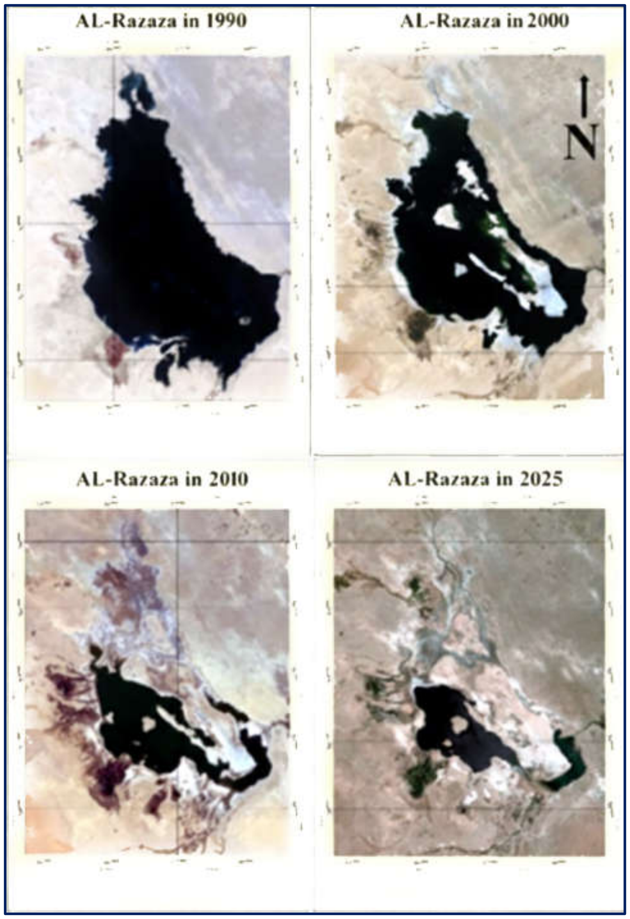

Figure 4. Satellite Images with performing Layer-Stacking and Resizing.

Results and Discussion:

Results should be clear and concise. This section may be divided by subheadings. It should provide a precise description of the experimental results.

The Derived Remotely Sensed Indices:

In this phase of this research, the water surface was extracted using two multi-temporal of remotely sensed indices from the satellite images' bands, the derived indices: NDVI index and NDWI index reported by (Sun *et al*., 2012; Feyisa *et al*., 2014; Dibs *et al*., 2016). The applied indices were used to extract the water surface of AL-Razazah Lake. Table (2), the derived indices used the Landsat images: Green=(B2), Red = (B3), Near-Infrared (NIR) = (B4). In image visual interpretation of water, the B4 is preferred to do so. This is because the band, absorbs water, and it is reflected by the vegetation and soil surface (McFeeters, 1996). Therefore, the B4 of Landsat-satellite dataset was selected to discriminate both of water bodies and dry land (Komeil *et al*., 2014).

Table 2. NDVI and NDWI Indices (Source: Komeil *et al*., 2014).

Notes	Indices Equations
Water Bodies with (positive values)	$NDWI = \frac{(B2 - B4)}{(B2 + B4)}$
Water Bodies with (positive values)	$NDVI = \frac{(B4 - B3)}{(B4 + B3)}$

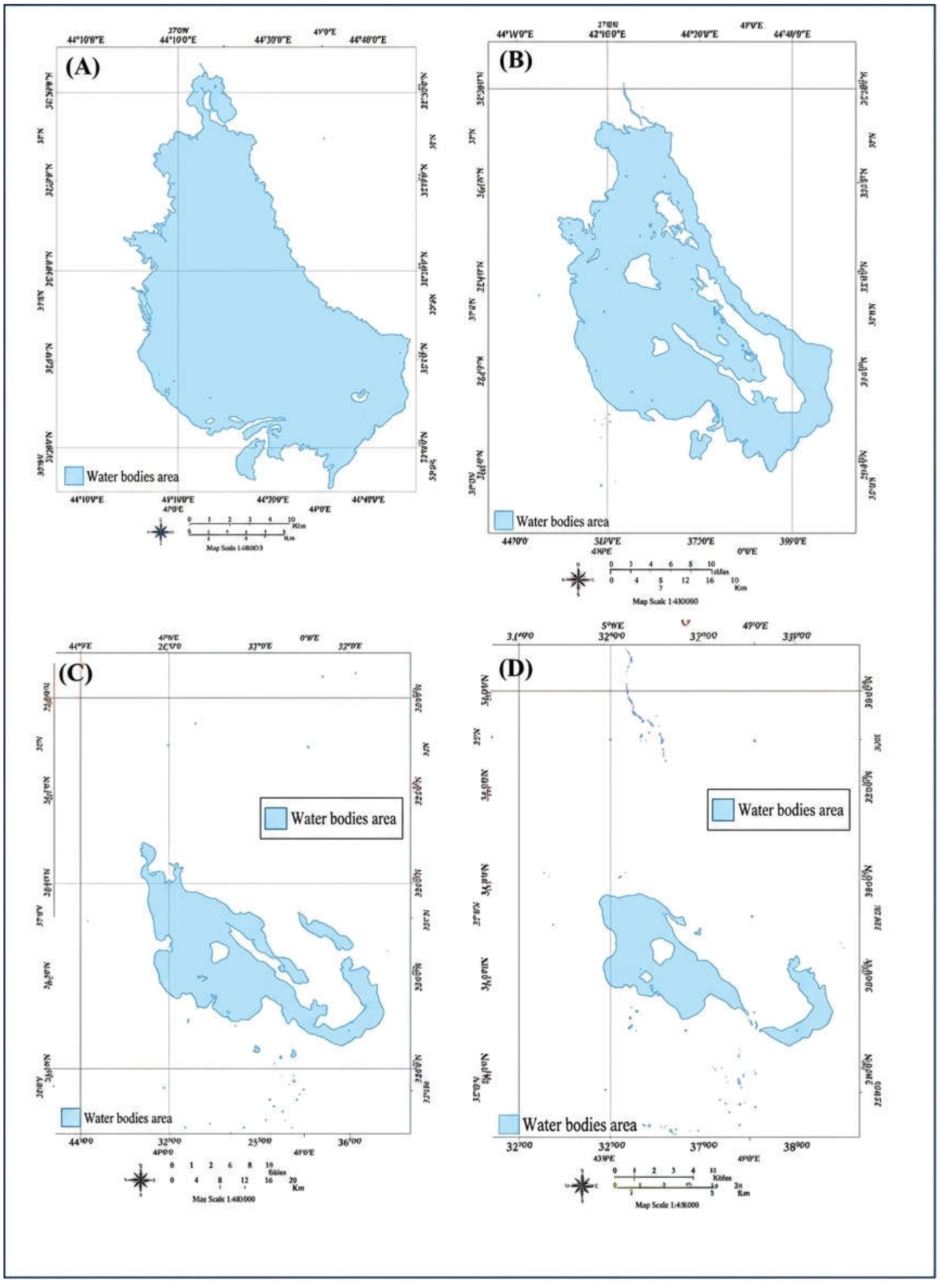

Figure 5. Four NDWIs index (1990 - 2025): (a) The NDWI index of 1990; (b) The NDWI index of 2000; (c) The NDWI index of 2010; (d) The NDWI index of 2025.

Figure 5, shows the water bodies represent in blue color, while the rest of study area represent in white color. The Figures 5 and 6 illustrate the NDVIs and NDWIs between (1990 – 2025), it was very incapable of extracting AL-Razazah Lake water surface area. The NDWIs indices give highest accuracies result as reported (Komeil *et al*., 2014). On the other hand, the NDWIs indices were considered for modelling the Spatial-Temporal off AL-Razazah Lake between 1990 to 2025. Then The NDWIs and NDVIs were determined from applied the Landsat satellite images, then unsupervised classification approach was selected to classify the indices of NDWIs and NDVIs maps of 1990, 2000, 2010, 2010, and 2025. The K-Means algorithm utilities to perform the classification with selecting three different classes (Soil-1, Soil-2 and Water Bodies).

Moreover, the post-processing and the post classification were made to make the classified images with just two classes only, the first one is representing the water bodies, while the second is the area surrounding the water as shown in Figures 5 and 6.

Table 3, shows the statistical results from 1990 to 2025 in km2 and its changes from used the K-Means approach on the obtained indices. The outputs show that the NDWIs has better and more accurate results than using the NDVIs indices for determining the water extraction area throughout using the images downloaded from Landsat satellite (Komeil *et al.*, 2014). Tables 4 and 5 demonstrate the Lake water surface area statistical results in km2, and also show the Lake dehydration extent's percentage of NDWIs and NDVIs respectively.

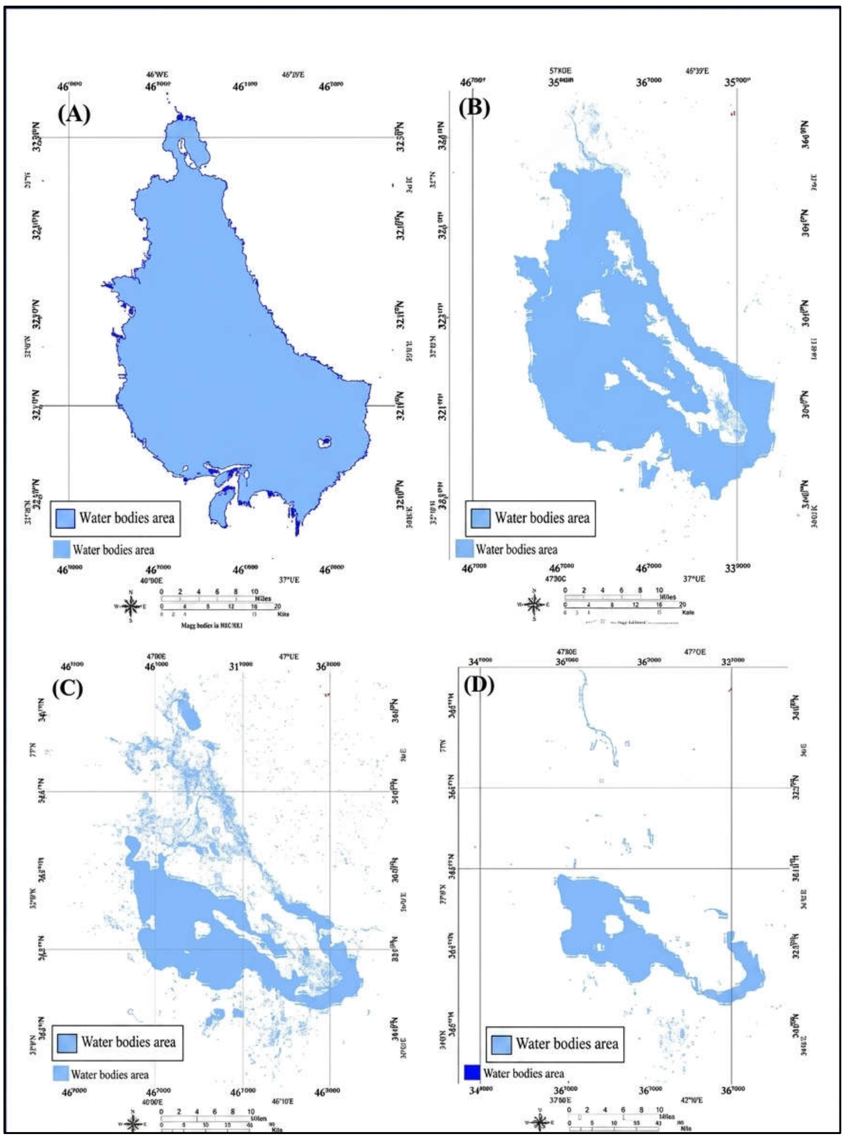

Figure 6. The classified-NDVIs Index of (1990 – 2025); (A) in 1990; (B); in 2000 (C) in 2010; (D) in 2025.

Table 3. The statistical results of K-Means classifications of NDVIs and NDWIs.

2025		2010		2000		1990		
(%)	(Area Km^2)	(Percent. %)	(Area Km^2)	(Percent. %)	(Area Km^2)	(Percent %)	(Area Km^2)	NDVI Indices
6.47	303.06	10.48	490.90	21.50	1107.06	29.86	1398.65	Water-Area
93.53	4380.97	89.52	4193.14	78.50	3674.01	70.14	3285.38	Surrounding-Area
								NDWI Indices
5.88	275.42	7.52	352.24	20.85	2342.01	28.23	1322.31	Water-Area
94.12	4427.61	92.50	4332,72	79.15	3707.41	70.77	3311.60	Surrounding-Area
Image's pixels= 5,204,474□ (5,204,474 * (900m^2)/1000000) = {4,684.0266}								**Total Area (Km^2)**

Table 4. The NDVI Statistic-Results of the changes from 1990-2025

Total changes in (km2)	Total Lost Water (%)	changes Area in km^2	Surface Area in km^2	Year
1365.59	82.47%		1398.65	1990
		- 291.59		
			1107.06	2000
		- 616.16		
			490.90	2010
		- 187.84		
			303.06	2025

Table 5. The result of NDWIs of Al-Razazah changes 1990-2025.

Total changes in (km^2)	Total Lost Water (%)	changes Area in km^2	Surface Area in km^2	Year
-1046.89	80.32%		1322.31	1990
		-1019.69		
			1342.01	2000
		-989.77		
			352.24	2010
		-76.82		
			275.42	2025

The results of the NDWI of the period between 1990-2025 shows higher accuracy than of those of NDVIsfor the same period of time. Both results of the NDVIs and NDWIs are illustrated in Tables (3, 4, and 5). The results show that the area of water surface of AL-Razazah Lake derived from NDVI indices are 1398.65 km2 in 1990, 1107.06 km2 in 2000, 490.90 km2 in 2010 and 303.06 km2 in 2025. Then the outputs revealed that the decreasing the lake water surface between 1990-2000 was 291.59 km2, and from 2000-2010 was 616.16 km2, and it was 187.84 km2 between (2010 and 2025). In addition, the total Lake water surface-area changed from 1990 to 2025 to be about 1365.59 km2, that shows that the Lake losses around 82.47% of total its area from 1990 to 2025 as illustrates in Table 5. In same way the Tables 4, 5, and 6 demonstrate the results of the NDVI indices, and the final results of NDWIs represents the lossing in the water surface of AL-Razazah lake was about 80.32% over the last three decades, as show in Tables 5 and 6. Based on the results the dehydration extent increasing dramatically, and this extent has a negative impact on the study area, surrounding areas especially on the climate changes, ecosystem, loss wildlife habitat, inadequate water contained of the lake, and increase the salinity in the study area and it is a big disaster for AL-Razazah Lake. Table 6 shows comparison of K-Mean Classification between NDWIs and NDVIs.

Table 6. The comparison of K-Mean Classification of NDWIs and NDVIs.

Changes in Area (Km^2)	Changes (1990-2025) (%)	Index
1046.89	80.32	NDWIs results
1365.59	82.47	NDVIs results

Table 6 demonstrates the changes of Al-Razazah Lake from 1990 to 2025. The multi-temporal unsupervised classified images show the Lake loss about of 80.32 % of the (study area), and that equal 1046.89 Km2 from NDWIs. On other hand, On the other hand the loss was around 82.47% with an area of 1365.59 Km2 from generated NDVIs.

Conclusion:

Lake Al-Razazah has experienced significant desiccation between 1992 and 2025, during which its surface water level declined substantially, reaching depths of approximately 5 to 10 meters relative to mean sea level. So, the main results that were achieved from this research were pointed as follow:

(1) Key Environmental Findings

- Massive Surface Area Reduction: The lake has lost approximately 82% of its total surface area between 1990 and 2025.
- Significant Water Level Decline: Surface water levels are dropped substantially, reaching depths of 5 to 10 meters relative to mean sea level.
- Accelerating Desiccation: The statistical analysis reveals that the trend of water reduction is not just steady but is pronounced and accelerating.
- Risk of Total Disappearance: If the current trajectory continues, the study concludes it is highly probable that the lake will face complete desiccation in the near future.

(2) Methodological Results

- Effective Index Performance: The use of the Normalized Difference Water Index (NDWI) and Normalized Difference Vegetation Index (NDVI) successfully confirmed the historical decline in water surface area.
- Spectral Band Synergy: Integrating thermal and infrared bands with visible spectral bands significantly enhanced the performance of the classification.
- Improved Accuracy: This multi-band approach resulted in high-accuracy data, specifically improving the overall classification accuracy and the kappa coefficient (a statistical measure of reliability).

(3) Practical Applications

- Framework Scalability: The methodology developed for Lake Al-Razazah is proven to be a valuable framework that can be applied to monitor other surface water bodies globally.
- Disaster Management: Beyond simple monitoring, the research demonstrates that these techniques are effective for applications in flood monitoring and management.

This study offers a valuable framework for monitoring other surface water bodies globally, as well as for applications in flood monitoring and management.

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