

Monitoring Hydrological and Climatic Changes in the Eastern Euphrates Project Using Geospatial Technique

Nareman Ali Kadhum, Alaa Salih Ati 

Department of Soil Sciences and Water Resources, College of Agricultural Engineering Sciences,
University of Baghdad, Baghdad, Iraq

ABSTRACT

The study area is geographically located in Basra Governorate, on the left bank of the Euphrates River, extending west from Al-Madina District to the Al-Sabbaghia River in the west. It is bordered by the Euphrates River to the south and the administrative boundaries of Maysan Governorate to the north. It lies within the administrative boundaries of Basra Governorate, between latitudes "48'38"35 and "55'34"33 North and longitudes "41'55"42 and "53'40"43 East. The study area is 17 km long and between 6 and 9 km wide, with a total area of 57,000 dunams. The results analyze changes in land cover over 23 years (2002-2025) using the Natural Vegetation Index (NDVI), the Soil Moisture Index (NDWI) (using multiple remote sensing indices), and the Land Surface Temperature Index (LST). The results highlight significant changes in vegetation cover and water bodies. Data showing the difference between the two years indicate a sharp increase in the percentage of land classified as non-vegetated (NDVI 0), with its percentage in the change reaching [amount missing in original text]. 64.09% of the total studied area, a clear indication of the local ecosystem's exposure to significant vegetation degradation. A comparison of NDWI data from 2002 and 2025 reveals substantial spatial and temporal changes in the distribution of surface moisture and water resources within the study area. The percentage of areas classified as water (0.630824 km² in 2002 to 44.52123 km² in 2025) increased from 0.448382% (0.630824 km² in 2002 to 44.52123 km² in 2025).

Keywords: geospatial analysis, LST, NDWI, remote sensing.



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INTRODUCTION

Climate change is at the center of the most crucial issues that have prevailed over the 21st century humanity, mostly affecting the ecosystems, agriculture, water resources, and general environment. Disrupted by climate change among its natural system components are hydrological features and soil properties, which play a key role in environmental stability and agricultural productivity. Soil is the basis of plant growth, water retention, and nutrient cycling; it could be realized now how central soil health and proper operation are to human existence. However, the basic functions of soil are already under disruption due to climate change, which in terms of the specific parameters has escalated the previous

temperatures and the regime mean temperatures and precipitation in different regions as extreme precipitation (Abbass et al., 2022, Ayada et al., 2024, Dawod et al., 2024, Reinsch et al., 2024, Yuan et al., 2024). Therefore, the present study combines both soil properties and hydrology due to the pressure of climate change for effective and successful management in terms of mitigation and adaptation. Cutting-edge surveying technologies are supported by aerial data and geographic information systems (GIS) which together espouse a lucid weapon in the inventory to undertake scrutiny and vigilance of such variations. Survey, thus, enables scientific workers to gather large scale environmental processes and make future

predictions with acute precision by intertwining spatial data with an assortment of models (Barrile et al., 2024, IPCC, 2021, Nigussie, 2024). These issues must be substantially addressed with advanced monitoring and analysis tools. Geospatial surveying has lately become a robust approach to the study of environmental transformations. It marries remote sensing, GIS, and spatial modeling for detailed and precise monitoring of soil and hydrological dynamics. Satellite imagery, aerial data, and field observations make it apt possible to trace the variation of soil properties in time and to determine degradation hot spots as a prelude to developing predictive models for future scenarios. This technological approach is most helpful in prioritizing areas for large-scale monitoring, such as the Eastern Euphrates, in which it is integral to better comprehend the cumulative impacts of climate change on soil and water resources. Therefore, this study pertains to the Eastern Euphrates lying in Basrah. It evaluates the variations in different parameters of soil hydrological characteristics with the help of geomatics technologies. Integration of spatial analysis with ground-based data would help in building up the ability of ecosystems and societies for resilience, in a highly agricultural area of Iraq. The Eastern Euphrates Project forms a case study area within Basrah Governorate, one of the most climate-affected provinces in Iraq. The study, therefore, aims to:

1. Analyze changes in selected hydrological soil properties in the Eastern Euphrates Project over the study period using spectral indices derived from remote sensing data.
2. Monitor local climatic changes based on land surface temperature (LST) analysis and determine their association with other environmental changes.
3. Classify land cover and land use patterns, compare their transformations across selected time intervals, and evaluate the impact of climate change and human expansion on these patterns.

MATERIALS AND METHODS

Location and Area: The Al-Sura project site is in Basrah Governorate on the right bank of the Euphrates River. This area extends west

from Al-Madinah District to Al-Sabbaghiyah River and is bordered by the Euphrates River to the south and the administrative boundaries of Maysan Governorate to the north. The study area lies between latitudes 30.570835 and 31.060776 N and longitudes 47.08024 and 47.13007 E. The total length of the area covered in this study is about 17 km, with widths ranging from 6 to 9 km, and a total area of about 57,000 dunams. The southern part of the project is where the main highway between Qurna and Al-Chibayish ran parallel to the levee along the Euphrates River. These lands were newly drained marshes up to 2002 and did not have transport infrastructure at the time. But by 2025, it had already entered the Marshland Restoration Agreement, due to which fact the area was to be re-flooded partially. Some parts of those former marshlands were again covered with water, and some parts saw the return of marsh ecosystems. After the establishment of residential housing, too, much of the former marshes was turned into agricultural land, pastures, and poultry farms and hatcheries, with drainage canals and irrigation channels added to the whole area.

Climate: The study area has a very hot and dry long summer and a cold and rainy short winter. In the period between 1980 and 2002, the annual rainfall varied from 83 to 191 mm, with an average of 137 mm, and a peak of about 292 mm that was recorded in 1986. It is expected to rain from October through May, and then almost no rain during the months of summer (June to September). Evaporation and evapotranspiration rates become very high in this period since the temperatures also rise and there is little vegetation cover. In the year 2025, which is the reference year of this work, the place had hot and dry summers and mild and dry winters. The annual rainfall varied from 0.1 to 4.3 mm, with most of it falling in January-March. At the same time, the evaporation rate goes up and reaches 8.6 mm daily on average. In the first three months of the year, air temperature ranges from 29.93°C to 45.98°C, showing a steep climb in heat compared to earlier years.

Agricultural Status and Natural Vegetation: Except for the extreme south adjacent to the

Euphrates River, where the field crops were wheat and barley and vegetables were tomatoes, cucumbers, and melons, 2002 had almost no agricultural activity in the region due to the plain topography and it having been marshland areas recently reclaimed, marshes having been very recently drained. The natural vegetation at the site was reed and bulrush, with the latter most dominantly occurring. Perennial phreatophytes such as *Tamarix*, *Aeluropus lagopodes*, and *Halocnemum strobilaceum* were also located closer to the marshes. By 2025, agricultural activity had gained more importance and was widespread on the riverbanks where maize and wheat are grown extensively along with tomatoes, eggplants, and radishes. Some plastic greenhouses were also seen growing okra and melons beside date palm orchards and many cultivars of *Ziziphus (sidr)*. The native vegetation still over reeds and bulrush, but other plant groups such as *Tamarix*, *Aeluropus*, *Euphorbia (Um Al-Haleeb)*, *Echinochloa (Madid)*, and *Marsh fleabane (Pluchea)* as well. Drip irrigation systems were introduced in the area a sign of improved farming practice.

Study Stages

Field Study Stage: This part entailed carrying out an on-site visit to the study area to observe key geographical and environmental features, with particular focus on land use patterns, human activity, and water utilization. The major objective of the fieldwork was to verify the interpretations that were derived from satellite imageries through direct ground observations to make sure that there was no possibility of error and prepare the spectral signature of land cover and land use, to enhance accuracy in spatial analysis.

Office Work Stage: This involved downloading and processing satellite pictures of our study area for analysis. Key tasks included clipping images, using spectral indices, and creating maps of land use and hydrological features. Also, the surface size of nearby water areas was measured and linked to recorded human activities. Weather data was also analyzed to see how it affected the changes in the environment in the area. A check of the right readings and past studies on

the geologic, geomorphologic, and hydrologic traits of the area was done to form a strong scientific base for the study.

1. Downloading Satellite Imagery: Satellite pictures were received from the USGS Earth Explorer platform, an important tool for getting to old remote sensing data, especially from the Landsat program, which is key in aerial analysis and digital elevation modeling. To start, you must make a user account on the platform because its search and download functions are closed to registered users. Using the Search Criteria panel, set the area of interest by inputting the place name, geographic coordinates, or by selecting it manually on the map interface. Apply the Date Range filter to set the temporal coverage and use Cloud Cover to get rid of unsuitable images where the cloud is big. Choose relevant datasets under the Data Sets tab, primarily the Landsat archive, organized by mission type and processing level; apply filters. Click on Results to get preview images which can be checked for coverage adequacy, cloud interference, and metadata accuracy before downloading.

2. Remote Sensing Data Used in the Study:

The satellite data take the form of a raster, which is a picture element arranged in rows and columns. A digital number (DN) of the brightness of the electromagnetic radiation reflected by the Earth's surface at that specific location describes each of these pixels. These values are what constitute the satellite imagery used in spatial analysis. The study made use of imagery data mainly from Landsat 5 and Landsat 7 (Enhanced Thematic Mapper Plus). The digital image manipulation followed the procedure described in the Landsat 5-7 Data User Handbook to convert the raw DN values into quantities with physical meaning such as radiance or surface reflectance. Such conversions are very critical in maintaining the accuracy and reliability of spectral analyses to be carried out in this study. The Normalized Difference Vegetation Index (NDVI) (Huete, 1988, Muhammad & Hassan, 2018) was calculated using the formula: $NDVI = (NIR - RED) / (NIR + RED) \dots (1)$ where *NIR* is the reflectance in the near-infrared band and *RED* is the reflectance in the

red band. This index is widely used to assess vegetation cover and health (Tucker, 1980).

To assess surface water presence, the Normalized Difference Water Index (NDWI) (Gao, 1996, Xu, 2006) was employed using the equation:

$$\text{NDWI} = (\text{NIR} - \text{SWIR}) / (\text{NIR} + \text{SWIR}) \dots (2)$$

where *SWIR* refers to short-wave infrared reflectance. This index effectively detects moisture and water content in vegetation and bare soil (Gao, 1996). Land Surface Temperature (LST) was estimated using the equation:

$$\text{LST} = \text{BT} / [1 + (\lambda \times \text{BT} / C_2) \times \ln(E)] \dots (3)$$

where *BT* is brightness temperature, λ is the wavelength of emitted radiance (10.895 μm for Landsat 8 Band 10), C_2 is Planck's constant (14388 $\mu\text{m} \cdot \text{K}$), and *E* is land surface emissivity. This method provides a physically based estimation of surface temperature from thermal imagery. The Brightness Temperature (*BT*) was derived using the formula: $\text{BT} = 1321.0789 / \ln(774.885 / (\text{TOA} + 1)) - 273.15 \dots (4)$

based on the top-of-atmosphere radiance values obtained from thermal bands (USGS/EROS, 2021).

Top-of-Atmosphere Radiance (TOA) was calculated as:

$$\text{TOA} = (0.0003342 \times \text{B10}) + 0.10 - 0.29 \dots (5)$$

where B10 represents the pixel value of Band 10 from Landsat 8 (USGS/EROS, 2021). To compute land surface emissivity (*E*), the equation used was:

$$E = 0.004 \times \text{PV} + 0.986 \dots (6)$$

where *PV* is the proportion of vegetation (Hulley et al., 2019, Sobrino et al., 2011). The Proportion of Vegetation (*PV*) was derived using the expression:

$$\text{PV} = [(\text{NDVI} - \text{NDVI}_{\min}) / (\text{NDVI}_{\max} - \text{NDVI}_{\min})]^2 \dots (7)$$

where *NDVImin* and *NDVImax* refer to the minimum and maximum NDVI values observed in the image (Sobrino et al., 2011).

RESULTS AND DISCUSSION

Temporal Change in Land Cover in the Study Area during the Period (2002–2025)

NDVI-Based Vegetation Cover Assessment – Year 2002: Figure 1a illustrates the spatial distribution of the Normalized Difference Vegetation Index (NDVI) for the year 2002,

while Table 1 summarizes the NDVI classification ranges across the study area. The analysis identified three vegetation cover classes: non-vegetated areas (NDVI < 0.0), weak vegetation (NDVI between 0.0 and 0.15), and moderate vegetation (NDVI between 0.15 and 0.29). The weak vegetation category dominated the landscape, covering 99.38% of the total area, which corresponds to approximately 139.82 km². In contrast, non-vegetated areas accounted for only 0.35% of the area (0.496 km²), while moderate vegetation covered 0.27% (0.377 km²). The map reveals a relatively homogeneous distribution of weak vegetation across most parts of the region, with non-vegetated areas slightly concentrated in the southern fringes, which are primarily associated with residual water bodies. Although this distribution may suggest relative ecological stability in terms of vegetative cover, it in fact reflects a transitional state following the large-scale marsh drainage operations implemented in the region. During this period, the dominant vegetation was limited to surviving wetland species such as *Phragmites australis* (reed) and *Typha domingensis* (bulrush). Additionally, certain dry areas had begun to be integrated into agricultural development plans initiated at the time, particularly for wheat and barley cultivation. Therefore, the observed vegetation patterns do not represent a stable ecological condition but rather a transitional phase shaped by recent environmental interventions and land reclamation activities in formerly inundated marshlands.

NDVI-Based Vegetation Cover Assessment for the Year 2025:

Figure 1(b) illustrates the spatial distribution map of the Normalized Difference Vegetation Index (NDVI) for the study area in the year 2025. The comparison with the 2002 map reveals evident changes in the region's vegetation cover. According to Table (1), which presents the NDVI value ranges, corresponding areas, and vegetation density classes, it is evident that the non-vegetated areas (NDVI $\approx$ 0) account for 20.8% of the total area, covering approximately 29.34 km², indicating a significant expansion in barren and water-covered surfaces. The second class, representing weak vegetation or semi-

wetlands, with NDVI values ranging from 0 to 0.15, dominates the area with a proportion of 77.88%, equivalent to 109.57 km². This class likely indicates semi-wetland conditions, which is consistent with the 2002 NDVI classification, where this category also prevailed. The third class, representing moderate vegetation density (NDVI between 0.15 and 0.29), covers 1.19% of the total study area, corresponding to an area of 1.68 km². Unlike the 2002 data, the 2025 NDVI map reveals the emergence of a fourth vegetation class, namely dense vegetation (NDVI>0.29), which constitutes 0.059% of the area, or approximately 0.083 km². Although relatively small, this new appearance of dense vegetation reflects localized zones of intense plant growth, largely attributed to human interventions such as land reclamation projects and the adoption of modern irrigation techniques. These findings are supported by field observations, where several agricultural rehabilitation efforts were recorded in parts of the study area using crops suited to the prevailing environmental conditions.

Monitoring NDVI Change between 2002 and 2025: Figure (2) presents a difference map of the Normalized Difference Vegetation Index (NDVI), illustrating the spatial distribution of vegetation cover changes between the years 2002 and 2025. A binary classification approach was employed, categorizing areas into two main types of

change: **Positive Change:** Represented by the green color, this indicates an increase in NDVI values, which reflects an improvement in vegetation density. Such enhancement may result from natural vegetation regeneration, improved climatic conditions, or positive human interventions such as agricultural rehabilitation or enhanced irrigation practices. **Negative Change:** Indicated in red, this classification includes areas that have either experienced a decline in vegetation cover or remained unchanged without improvement. These trends are often associated with adverse climatic factors such as prolonged drought, reduction in water availability, or anthropogenic pressures like overgrazing, deforestation, and urban expansion. The northern and central parts of the study area exhibit widespread zones of negative change, signaling significant vegetation loss over the examined period. This suggests that local ecosystems in these regions have shown limited resilience or recovery potential under increasingly stressful environmental conditions. Conversely, scattered patches of positive change appear in the southern and southeastern sections of the area. These improvements are likely attributed to localized land reclamation efforts, the availability of irrigation water, or modest enhancements in environmental conditions that have supported the regrowth of vegetation in these zones (Hu et al., 2021, Pan et al., 2020).

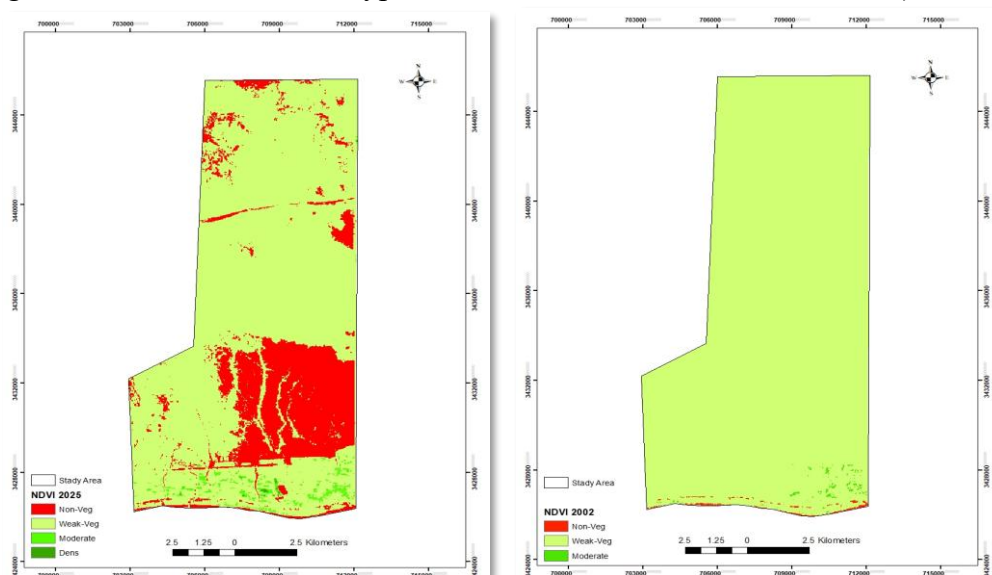


Figure 1. Spatial distribution map of NDVI for the years 2002 and 2025

Table 1. Vegetation covers classes for the study years

NDVI				year
Value	Area Km ²	%	Type	
<0	0.49674	0.353077	Non-Veg.	2002
0 – 0.15	139.815234	99.378918	Weak Veg	
0.15 – 0.29	0.377055	0.268006	Moderate	
Value	Area Km ²	%	Type	
<0	29.34996	20.861584	Non-Veg.	2025
0 – 0.15	109.571683	77.88218	Weak Veg	
0.15 - 30	1.683697	1.196751	Moderate	
0.30 – 0.39	0.08369	0.059486	Dens	
Value	Area Km ²	%	Type	
>0	50.519906	35.908916	Negative Change	2002
0 - 0.33	90.169123	64.091084	Positive Change	2025

Expansion of land use covers into unsustainable activities through overgrazing, wood utilization, and expansion of built-up areas aggravates the decline, particularly on ecologically stressed areas where there is no dense vegetation cover. This supports the findings of (Khalid & Zhou, 2021) who found a significant relationship between the decrease in NDVI and the variation in hydrological soil properties in arid regions. Quantitatively, the NDVI shift from 2002 to 2025 not only signifies reduced vegetation cover, but more intense environmental conversion impacting physical soil characteristics and, hence, formidable sustainability challenges. However, the context of this observation must also

reflect the fact that the low NDVI value captured in 2002 largely represented the decaying reed and papyrus vegetation remains subsequent upon the desiccation of the marshland deliberately carried out since 1993. So, the values of NDVI were low, to begin with, because of the transition of the landscape. Furthermore, the decline that keeps going in NDVI is getting worse due to climatic stressors like drought and extreme heat as well as anthropogenic pressures such as overgrazing, unsustainable agriculture, and soil degradation (Rogers & Kearney.,2004; Sharma et al., 2024; Zhang et al., 2021).

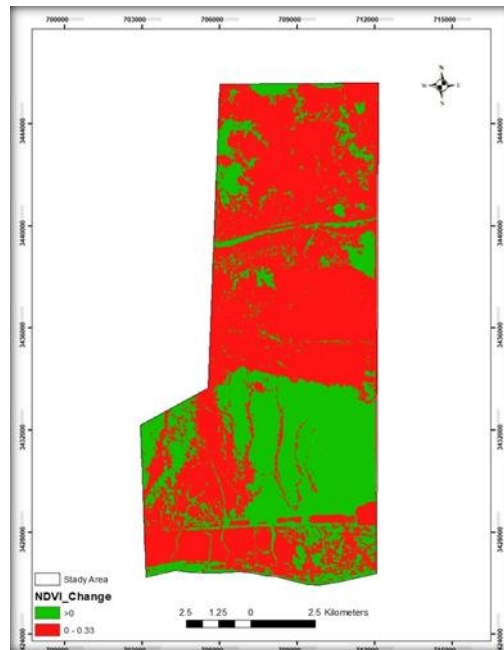


Figure 2. Monitoring NDVI Change between 2002 and 2025

Spatial Distribution of Water Cover Based on NDWI in 2002: Figure (3a) gives the spatial distribution map of the Normalized Difference Water Index (NDWI) for the study

area in 2002. In Table (2) is a summary of the corresponding analytical results. They show an overwhelming presence of non-water surfaces, which accounts for about 99.55% of the total

area—140.058 km². Implement the spectral values, of the non-water class covering the range from -0.286 to 0 . These are negative values and typically indicate dry surface features, for instance, bare soils and built-up areas. This indicates low surface moisture content, in line with the observation of (Gao, 1995) that negative NDWI values normally result from a high reflectance in the infrared domain and a low reflectance in the green visible band arid surface type. Positive values (0 to 0.103) were observed in water-covered areas, indicating the existence of small surface water bodies such as small streams or individual pools. The scarcity of that coverage indicates a time of fairly acute water stress. The environmental situation of that time,

particularly at the height of reducing marshland drainage, served to exacerbate this scarcity. These findings are also results of the context of the intense water crisis in Iraq in the early 2000 as described in reports by the Food and Agriculture Organization (FAO, 2021). A significant decrease in NDWI values means decreased soil water-holding capacity; in such a situation, salinization and physical soil deterioration will be easier to happen, both factors that work against the growth of vegetation by imposing hydrological stress. The results are in line with the findings of (Tsendbazar & Vrieling, 2021), who established a strong relationship between low NDWI values and environmental degradation in dryland ecosystems.

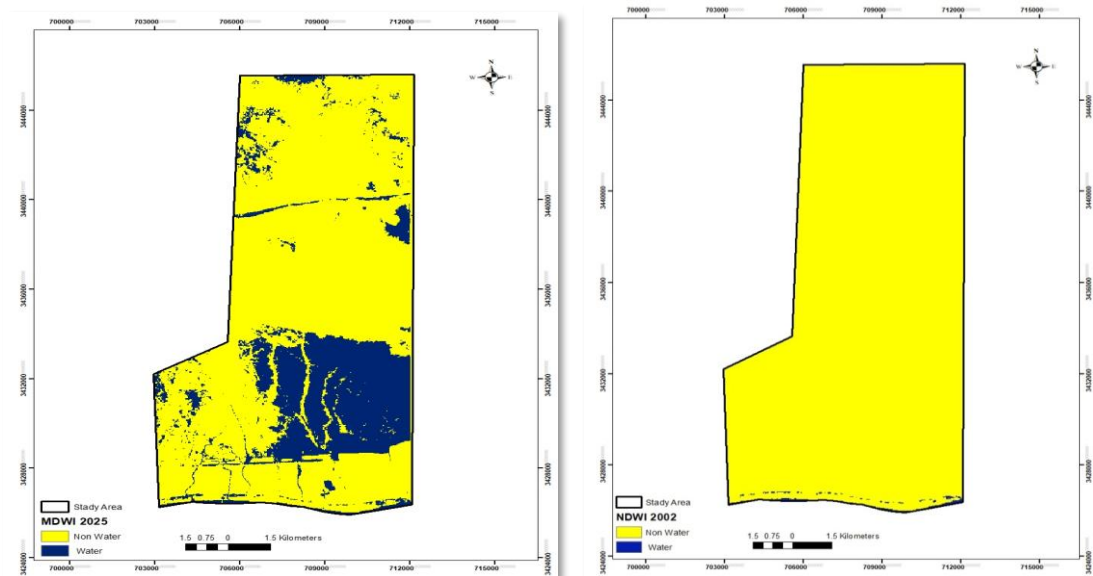


Figure 3. Spatial distribution map of the Normalized Difference Water Index (NDWI) for the years 2002 and 2025

Table 2. NDWI value ranges and corresponding classifications for the study years

NDWI				year
Value	Area Km ²	%	Type	
-0.286219567 - 0	140.058205	99.551618	No-Water	2002
0 - 0.103944682	0.630824	0.448382	Water	
Value	Area Km ²	%	Type	
-0.346299678 - 0	108.896764	77.402456	No-Water	2025
0 - 0.222630903	31.792265	22.597544	Water	
Value	Area Km ²	%	Type	
-0.370964229 - 0	96.167799	68.354868	No-Water	2002 and 2025
0 - 0.260596484	44.52123	31.645132	Water	

Water Cover Distribution Using NDWI in the Study Area for the Year 2025: The results of the analysis of the Normalized Difference Water Index (NDWI) for the year

2025 shown in part b of Figure 4b and detailed in Table 2 show a marked change in the distribution of water cover from 2002. The percentage of non-water areas reduced to

77.402%, which is 108.896 km², with water cover increasing to 22.597%, which is 31.792 km². Spectral values for the non-water category fall in a range between -0.346 and 0, meaning dried up or low-moisture surfaces. The extension of the negative NDWI range from 2002 (which was -0.2862) shows the development of new areas where extreme desiccation or surface moisture dispersion has taken place; this could be a result of either geomorphologic changes or human activities, for example, increased bare lands or unsustainable agricultural practices. This is also reported in (Sun et al., 2020) in terms of land use effects on soil moisture in arid regions on the other hand, the water category revealed a sharp rise both in proportion and magnitude since the high NDWI values were between 0 and 0.222, showing a significant increase in surface water bodies as of 2002, where the maximum NDWI value recorded stood at only 0.103. This improvement in the water index results, among other factors, from the remobilization of the marshes, more rainfall in recent years, and relatedly, more irrigation projects and dams built on reports, such as (FAO, 2021), that deliver general improvement in water resources management in the west of Iraq. It may also indicate better soil water storage, whether by way of a return to a more structured state or thanks to a return of plant cover that provides for reduced surface runoff and evaporation. Even more, the generally wider set of high NDWI values up to 0.22 approaches areas of average to strong moisture content, signifying a kind of relative hydrological balance at the surface. This, in a positive way, affects the rates of germination of vegetation and reduces erosion, in agreement with (McFeeters, 2022) had earlier said about NDWI being a major indicator of sensitive-ecosystem soil that sustains vegetation. The data for 2025, therefore, show a qualitative environmental change to relatively better surface moisture conditions, both in spatial extent and spectral intensity. This is a promising improvement for the best agricultural reclamation efforts and ecological balance in the study area so long as, provided with these conditions, it can continuously be built up and sustained over time.

Change in the Normalized Difference Water Index (NDWI Change) for Surface Water Distribution:

Comparison of NDWI data for 2002 (Figure 4) with 2025 shows significant spatiotemporal changes in surface moisture and water resource distribution across the study area. The area percent classified as water in 2002 was 0.448382% (0.630824 km²) while 31.645132% (44.52123 km²) in the cumulative difference. Conversely, non-water decreases from 99.551618% (140.058205 km²) to 68.354868% (96.167799 km²), net gain being approximately 30 percentage points on surface water coverage across the total study area. Spectral values show a clear enhancement in NDWI as the positive range increased from 0.103944682 in 2002 to 0.260596484 in the different map and indicates a notable increase in surface moisture or the expansion of water bodies. This change can environmentally be due to many factors, such as better seasonal rain, new water building like dams or human-made lakes, or some return to how water used to flow here before it was made dry and had its sources used up. The rise in NDWI numbers also backs the idea of plant regrowth in wetland parts since NDWI shows not just open surface water but also surface soil wetness and plants with high water content, as said by (Gao, 1996; McFeeters, 2022). From a view based on nature, the greater NDWI numbers show a switch in how the surface acts on water, making it easier for the soil to soak up water and so lowering the stress on water. This then helps dynamic soil things like field capacity and effective porosity get better, as shown by (Zhang et al., 2021) in their study on how moisture indices link with real soil parts. The reason for NDWI low values before 2002 belongs to the drought of marshes that ordered in the properties regain, the following years witnessed better NDWI because the release of water to restore marshes. Thus, the temporal difference between 2002 and 2025 serves as quantitative evidence of a relative improvement in the study region. These findings offer a scientific foundation for re-evaluating practices and strategies aimed at enhancing environmental sustainability and hydrological balance in arid and semi-arid zones.

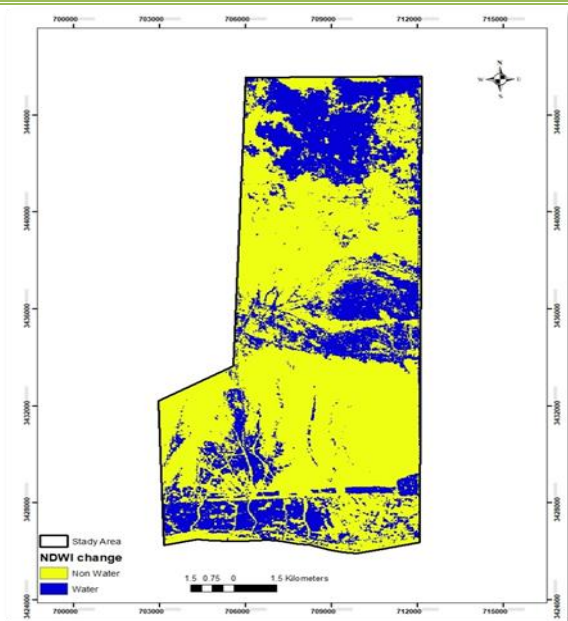


Figure 4. Change Detection Map of Water Cover (NDWI Change) (2002-2025).

Land Surface Temperature (LST) for the Year 2002: Table 3 indicates the values of surface temperature for the study area for the years 2002 and 2025 while Figure 5a provides the spatial distribution map of LST for the year 2002. Values of temperature have been described based on the thermal classification system of the United States Department of Agriculture (USGS/EROS, 2021). An analysis of Land Surface Temperature for the year 2002 has values of Moderate Temperature as 69.24% of the total study area that is 97.414 km² for 15–22°C. Normally such areas are moderate to scanty in vegetation cover with soils of balanced moisture content. This offers relatively stable surface energy balance, middle albedos, and moderate levels of albedo. In comparison, High Temperature is 29.15%

(41.0125 km²) areas with surface temperatures ranging between 22–26°C. These high temperatures indicate prevalence has the least cover of bare soils or dry surface scantily covered with vegetation, which is associated with low specific heat capacity and less soil water retention. This leads to higher surface heating as the solar radiation absorbed and evaporative cooling that takes place is little, as described by (Sobrino et al., 2011). The Low Temperature class, which ranges within 10.42–15°C, was only 1.61% of the study area (2.262 km²). These areas are assumed to have high vegetation density or are marshy; high specific capacity and surface moisture content continuously absorb a larger fraction of solar energy without sensible heat being created. Such thermal patterns underline the importance of the kind of surface cover and the distribution of vegetation in shaping the surface temperature regime. The LST values relate well with vegetation indices such as NDVI and SAVI and are influenced by soil physical properties including color and bulk density. This connection coincides with what Zhang and the others found, that there is an inverse relationship between plant density and surface temperature in dry areas. The values of LST give very important information on the process of land damage beside local variability of the climate and vegetation response to climatic and water changes from a hydrological point of view. Thus, the analysis of LST is a very important part of it in environmental checks of agriculture and semi-arid landscapes.

Table 3. Land Surface Temperature (LST) Classes for the Years 2002 and 2025

LST				year
Value	Area Km ²	%	Type	
10.42428589 - 15	2.262327	1.608034	Low Temp.	2002
15.00000001 - 22	97.414149	69.240757	Moderate Temp.	
22.00000001 - 26.30441284	41.012553	29.151209	High Temp.	
Value	Area Km ²	%	Type	
8.637199402 - 15	55.974148	39.785723	Low Temp.	2025
15.00000001 - 22	61.480584	43.699629	Moderate Temp.	
22.00000001 - 26.59383011	23.234297	16.514648	High Temp.	
Value	Area Km ²	%	Type	
-14.48127937 - -7	48.759718	34.657797	SD	2002 and 2025
-6.999999999 - -1.5	36.471701	25.923628	MD	
-1.499999999 - -2	44.951378	31.950876	NC	
2.000000001 - 5	9.971697	7.087757	MI	
5.000000001 - 7.870616913	0.534536	0.379941	SI	

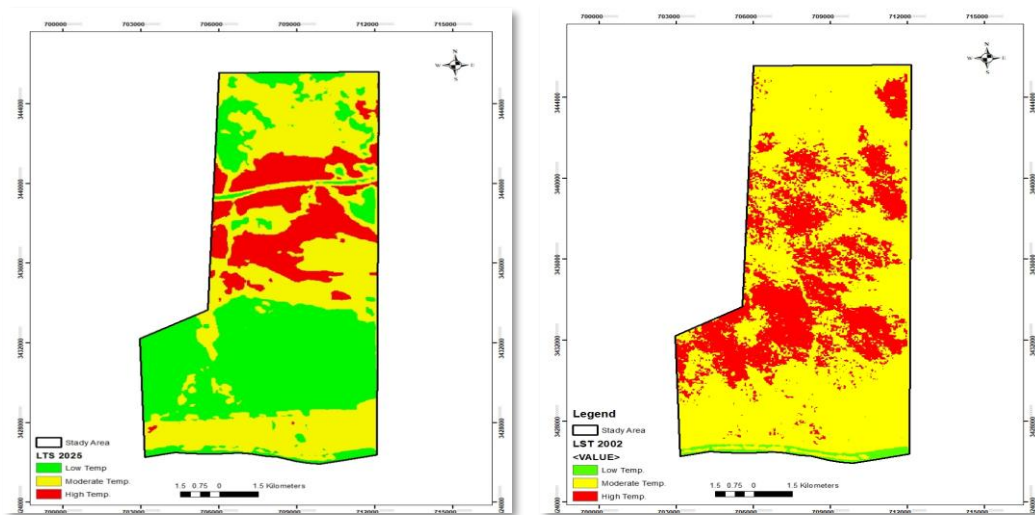


Figure 5. Land Surface Temperature (LST) Maps for the Years 2002 and 2025

Land Surface Temperature (LST) Index for the Year 2025: Results obtained from the tabular data and Figure 5b, illustrating the spatial distribution of land surface temperature for the year 2025, compared to 2002 show a major decrease in the area under the H category high temperature and now stands at only 16.514% of the total area, or 23.234 km², at a temperature range of 22–26.59°C. It is a very important environmental indicator relative to the properties of the surface that enhances solar absorption. This could be attributed to more surface cover or increased surface moisture, which results in reduced outgoing thermal radiation from the surface (Peng et al., 2022). On the contrary, there is a very great increase in the percentage area under the L low temperature class, now at 39.785%, or 55.974 km² at a temperature range of 8.63–15°C. This change indicates the increase in areas with moderate building properties, low sun absorption, or high surface moisture and dense vegetation. Such areas would also see efficient surface cooling processes building from evapotranspiration, enhancing the surface's capacity to decrease temperature during the day. The class of Moderate Temperature was at the highest percentage with 43.699%, which is 61.480 km², and it ranged between 15 – 22°C of heat. This domination shows that most of the land surface has the prevalence of the medium level of physical characteristics, typically related to sparse vegetation cover or annual agricultural regions. This category indicates relative

thermal stability and equal surface water content, serving as a favorable indicator of the effectiveness of dynamic environmental processes controlling heat exchange between the land and the atmosphere.

Land Surface Temperature Difference Index (LST change) between 2002 and 2025: The years 2002 and 2025 revealed great thermal changes across the study area, as shown in Figure (6) displaying changes in Land Surface Temperature (LST). These changes were classified into five major classes based on the variation of surface temperature in degrees Celsius. The first class, which shows a strong decline in LST, covers 34.65% of the total area, which is 48.75 km². The temperature ranges from -14.48°C to -7°C, indicating important change and positive environmental change likely due to increased vegetation, better surface moisture, or land use practices and hydrological management. This is in line with the study of (Peng et al., 2022) that postulated the cooling effects of restored ecosystems. The second class covers 25.92% of the area, accounting for 36.47 km², where the temperature ranges between -7°C and -1.5°C, showing a moderate decrease. These areas indicated some signs of partial recovery in surface status probably due to moderate regrowth of vegetation cover and application of sustainable soil and water management practices. The third class is defined as no change which, over 31.95% of the area (44.95 km²), depicted temperature fluctuation within -1.5°C and +2°C, hence large swaths of land

with more or less similar surface properties maintained during the study period. The fourth class, showing a moderate increase in LST, covers 7.087% of the area (9.97 km²). This relates to temperature increase between 2°C and 5°C and most probably brought about reduction in vegetation cover, increase in soil dryness, and the expansion of barren classes. The last class, which is a strong increase in surface temperature, is observed over only 0.379% of the area (0.534 km²) where the temperature increases are between 5°C and 7.87°C. These hotspots are a result of very intense human activities, very severe changes to the land, or very long dry conditions. In a nutshell, the analysis shows a general trend of surface cooling in study with about 65.5% of the land showing lowered temperatures. This indicates substantial improvements in surface cover and moisture, as shown by corresponding increases in vegetation and water indices which are NDVI, NDWI for the same period. The findings are similar to (Peng et al., 2022 & Telo da Gama, 2023) found in semi-arid regions that restoration of surface cover can reduce the surface temperature by 2-3 degrees Celsius due to increased surface reflectivity and reduced heat absorption. Therefore, the data of change in LST between 2002 and 2025 give strong quantitative proof of a regional eco-thermal shift to more optimum surface states.

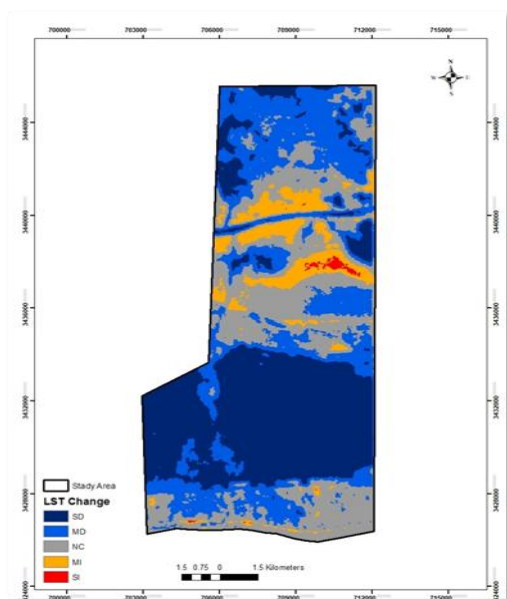


Figure 6. Land Surface Temperature (LST) Change Map for the Study Area between 2002 and 2025.

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رصد التغيرات الهيدرولوجية والمناخية في مشروع أيسر الفرات باستعمال التقانات الجيومكانية*
نريمان علي كاظم، الاء صالح عاتي
علوم التربة والموارد المائية/كلية علوم الهندسة الزراعية/ جامعة بغداد

المستخلص

تقع منطقة الدراسة جغرافيا في محافظة البصرة أيسر نهر الفرات حيث تمتد غرب قضاء المدينة وحتى نهر الصباغية غربا، ويحدها نهر الفرات من الجنوب والحدود الإدارية لمحافظة ميسان من الشمال. تقع ضمن الحدود الادارية لمحافظة البصرة، وتقع بين خطي العرض $35^{\circ}38'48''$ و $33^{\circ}34'55''$ شمالاً وخطي الطول $42^{\circ}55'41''$ و $43^{\circ}40'53''$ شرقاً. يبلغ طول المنطقة المشمولة بالدراسة 17 كم وعرضها يتراوح بين 6-9 كم، وتبلغ المساحة الكلية لمنطقة الدراسة 57 ألف دونم، تحلل النتائج تغيرات الغطاء الأرضي على مدى 23 عامًا (2002-2025) باستخدام مؤشرات استشعار عن بُعد متعددة - مؤشر الغطاء النباتي الطبيعي (NDVI)، ومؤشر رطوبة التربة (NDWI)، ومؤشر حرارة سطح الارض (LST). تُبرز النتائج تحولات كبيرة في الغطاء النباتي والمساحات المائية. إذ أظهرت بيانات الفرق بين العامين ارتفاعاً حاداً في نسبة الأراضي المصنفة ضمن الفئة غير النباتية ($NDVI < 0$)، حيث بلغت نسبتها في التغير % 64.09 من إجمالي المساحة المدروسة، ما يمثل مؤشراً واضحاً على تعرض النظام البيئي المحلي إلى تدهور كبير في الغطاء النباتي. وتكشف مقارنة بيانات NDWI بين عامي 2002 و 2025 عن تغيرات مكانية وزمانية جوهريّة في توزيع الرطوبة السطحية والموارد المائية ضمن منطقة الدراسة، إذ ارتفعت نسبة المناطق المصنفة ضمن فئة الماء (Water) من 0.448382% (0.630824 كم²) عام 2002 إلى 31.645132% (44.52123 كم²) في عام 2025.

الكلمات المفتاحية: التحليل الجيومكاني، مؤشر حرارة سطح الارض، مؤشر رطوبة التربة، الاستشعار عن بُعد.