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Assessing Water Availability and Its Impact on Environmental Pattern Changes in Baghdad City Using NDWI and Web Mapping Techniques

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Abstract
The resilience of urban communities worldwide is a critical challenge, and Iraqi society, characterized by its size and numerous difficulties, is no exception. Notably, this society emerged along the banks of the Tigris and Euphrates rivers, underscoring the significance and influence of surface water extent on the rise of civilizations. Leveraging the capabilities of the Google Earth Engine platform, this research aims to assess the influence of water cover distribution in Baghdad, Iraq, through online mapping techniques. The study gathers and integrates geospatial data on surface water extent, land use, vegetation, and socio-economic factors, employing remote sensing data to evaluate changes in water bodies and land cover over time. The web-based mapping platform enables interactive visualization of the data, allowing stakeholders and decision-makers to explore the spatial connections of water cover distribution and indicators such as water availability, water quality, and land degradation. By analyzing the outcomes of this web mapping analysis, the research endeavors to provide valuable insights that can support evidence-based decision-making processes, inform urban planning strategies, and guide sustainable water resource management practices. This research contributes to a broader understanding of the intricate relationship of water cover distribution in urban areas, with the utilization of web-based mapping technologies enhancing the accessibility and usability of spatial data, thereby facilitating informed decision-making and promoting sustainable urban development in Baghdad City.

1. Introduction

Today, the shortage of water resources and their inappropriate distribution make it difficult to address various problems. The challenges related to producing energy and food as well as meeting the citizens' requirements cause a lack of water. Thus, the environment's health and ecosystem sustainability face many problems[1]. The city of Baghdad has a rich history that highlights the significant role of surface water availability in shaping its development [2].

The Tigris and Euphrates rivers have traditionally provided water resources, enabling the growth of civilizations in this region. Understanding this historical context is crucial for comprehending Baghdad's intricate relationship between surface water availability and environmental resilience. The distribution of water resources plays a critical role in determining the ecological resilience of urban areas. The findings of Research can inform policymakers and stakeholders about the need for sustainable practices to mitigate negative impacts on vital ecosystem. The study [3] provides important understanding of how freshwater ecosystems are influenced by human activities and climate change. This study utilizes the Digital Shoreline Analysis System (DSAS), which incorporates Geographic Information Systems (GIS) and remote sensing methods to examine shoreline changes. These results help solution makers to understand the pattern of water resilience and its role in urban development.

For example, in [4] the results indicate an insignificant relationship between Land Surface Temperature Land Surface Temperature and Normalized Difference Water Index (NDWI) . The LST-NDWI relationship varies with Land Use and Land Cover (LULC) types, showing a moderate negative correlation in water bodies across all four seasons. Ensuring the sustainable management and availability of water resources can contribute to sustainable development, ecosystem health, and the population's well-being. "Environmental resilience is greatly impacted by the availability and management of water resources, highlighting the need for a holistic strategy to ensure the performance and integrity of drinking water infrastructure[5-6]. As it is known, water is the most important element for living life. It is not only necessary for human beings, but it is also important for the plant and animal world. The global demand for drinking water, which remains inaccessible to many people, is increasing day by day. Although industries, population growth, and the unprecedented expansion of cities contribute to water pollution, it is essential to keep water sources clean and safe for consumption. Protecting water resources is not only vital for water itself but also for safeguarding land, forests, air, and other natural elements. The water cycle inherently links water and air through processes such as evaporation, condensation, and precipitation, which regulate humidity levels and influence air quality. Conversely, air pollution can deteriorate water quality, as pollutants like sulfur dioxide and nitrogen oxides contribute to acid rain, further contaminating freshwater sources.[7] . There are solutions to address the challengs. Improving infrastructure through large-scale project, Investing in groundwater recharge techniques, and Enhancing public awareness on conservation practices are the mentioned approaches[8].

Before addressing the challengs using the above solutions, it is necessary to know that satellite images plays crucial roles in monitoring water surface area and its changes over the years. Underscoring the importance of satellite technology in environmental monitoring and provides valuable data can inform future research and policy-making regarding the waterland ecosystem and climate dynamics[9].

Urban developments through water resources sustainability can decrease the mentioned challenges and enhance the security of living in cities, and it looks more possible these days considering the new technology such as Global Positioning System (GPS), Remote Sensing imagery in surveying, and land special traits[10].

Environmental resilience refers to a system's ability to absorb disturbances, adapt to changing conditions, and maintain essential functions [11]. Various environmental factors, including climate extremes, climate change, land use/land cover alterations, and other ecological shifts, can profoundly influence the distribution, dimensions, types, and seasonal variations of water [12-14].

Some studies are applied to enhance environmental resilience in several ways. In short, ecological resilience is a natural system's ability to respond to change without altering its basic structure, or with only minor modifications[15].

By understanding the relationship between water availability, vegetation cover, and urban human activities, city planners make informed decisions regarding the allocation of green spaces, the design of sustainable urban landscapes, and the preservation of natural areas. One of the most common solutions to address the problems caused by urbanization and its challenges is urban green infrastructure (UGI), which can enhance the resilience of cities' resources[16].

Copenhagen, Denmark, has accepted and applied the blue-green infrastructure that uses rainwater to feed the green roofs. By storing the rainwater, the vegetation planted on the roofs of the buildings absorbs it, and this can reduce water usage and provide other positive insulations[17].

This can contribute to improving the overall environmental quality, mitigating the urban heat island effect, and enhancing the city's resilience to climate change.

Additionally, Wu in [18] helps identify areas where surface water availability positively or negatively affects ecosystems and biodiversity. This information guides restoration efforts, such as the rehabilitation of wetlands, the reforestation of degraded areas, and the protection of critical habitats. Restoring and conserving ecosystems enhances environmental resilience and provides multiple benefits, such as improved water quality, carbon sequestration, and increased biodiversity.

As climate change impacts become more pronounced, understanding the relationship between water availability and hydrological dynamics and environmental resilience[19] becomes crucial for developing effective adaptation strategies. Nowak in [20] contributes to identifying vulnerable areas, assessing risks, and implementing measures to adapt to changing hydrological conditions. This includes implementing green infrastructure solutions, such as rainwater harvesting systems, sustainable drainage systems, and urban green corridors, to mitigate the impacts of extreme weather events and promote water sustainability.

The findings of the research study can be used to raise public awareness about the importance of water resources, environmental resilience, and sustainable practices. This can be achieved through educational campaigns, workshops, and community engagement initiatives. By increasing public knowledge and engagement, individuals and communities can actively participate in efforts to enhance environmental resilience, such as water conservation, sustainable land use, and the protection of natural resources [21].

Multi-temporal remotely sensed satellite data have been successfully used by several earlier workers for environmental impact assessment (EIA). various detection methods and systems used in remote sensing applications are reviewed. identifying specific objects within images or changes over time between different images of the same area and unusual patterns or features, are the issues which are particulary discussed in remote sensing technology[22].

In [23] by using Standardized Precipitation Index (SPI) and employed the Support Vector Machine machine learning algorithm, the drought periods are identified and the information related to the lakes and land use is extracted. Results showed a significant reduction in the surface area of the lakes, with lake experiencing periods of drying, which endangers the ecosystems and biodiversity. Jhanwar and Mahla [24] used temporal remote sensing data for the EIA of the Bijolia mining district. In that study, multidate remote sensing data was used for environmental monitoring in the Bijolia mining area. Web mapping techniques, particularly utilizing the Google Earth Engine platform, provide a powerful tool for analyzing spatial data and visualizing the relationship between surface water extent and environmental indicators. In [25], a methodology is presented for identifying optimal urban development zones. In this paper, Geographic Information Systems (GIS) and another technique which is called Analytic Hierarchy Process (AHP), are used to achieve a harmonious coexistence of sustainable urban development and environmental conservation.

In the other work, [26] valuates an integrated method which combines image indices, the normalized difference vegetation index (NDVI), and the normalized difference water index (NDWI), along with near-infrared bands and slope information to remove false results. Regarding this study, using the difference in indices generated a more accurate map of water bodies compared to using a single index.

Extraction of water information from remotely sensed imagery stands as an efficient and reliable technique, noticeably contributing to WRM, water environment monitoring, large-scale water assessment [27], and hydrological hazard forecasting [28]. Because Space-based remote sensing data plays a crucial role in mapping Earth's resources, monitoring their changes, and assessing environmental dynamics. Cutter et al. [29] investigate the impacts of surface water availability on environmental pressures and overall resilience. These impacts include changes in land cover, alterations in ecosystem services, and potential environmental degradation resulting from human activities and inadequate water management practices. While advancements in water resource monitoring and management have been significant, long-term ecological implications have accumulated over the years, raising concerns for conservation strategies.

The primary objective of this study is to assess the influence of surface water availability on environmental resilience in Baghdad City. By using web mapping techniques and NDWI analysis, the research aims to identify spatial patterns, hotspots, and trends related to surface water availability and its impact on vegetation cover and urban human activities. The spatial distribution of water resources in Baghdad City is closely linked to the environmental resilience of the region. Conversely, the application of web mapping techniques and NDWI analysis can effectively capture the relationship between surface water availability, vegetation cover, and urban human activities. Therefore, improved water resource management practices can contribute to the enhancement of environmental resilience in Baghdad City. The findings can provide valuable insights for sustainable water resource management, urban planning, and the enhancement of environmental resilience. The uneven distribution of water resources and the impact on environmental resilience in Baghdad City is a pressing concern that requires in-depth investigation.

2. Material, Methods, and Case Study

This section outlines the methodology, materials, and case study framework used to analyze surface water availability and environmental resilience in Baghdad City.

As shown in the procedure flowchart (Figure 2) the methodology is structured around several key components, each contributing to a comprehensive understanding of how surface water availability impacts environmental resilience.

The first step is related to data collection which is a critical step in this research, then Python Programming is used to analyze the collected data effectively, after calculating the needed index.

In the next step, data integration has occurred and after that, to enhance user interaction and data accessibility, customized maps are designed.

Finally, in the last step, Data transforming processes are conducted to ensure that the datasets are in formats suitable for analysis and visualization.

By utilizing web mapping techniques and analyzing the NDWI, the study seeks to uncover spatial patterns and relationships between water availability, vegetation cover, and urban human activities.

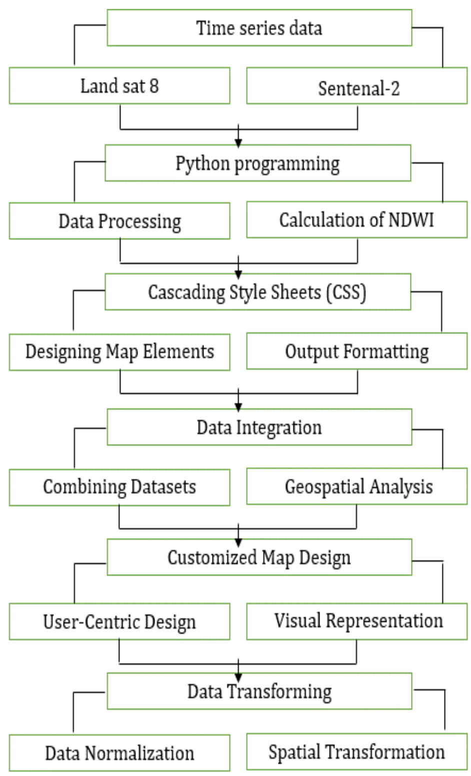

Figure 1. Research Flowchart

2.1. Case Study

In this case, the rate of water accessibility and economic and social attributes are analyzed, and the dependent and independent factors of this analysis are considered. It becomes clear that the water access and the under review factors are linked strongly. Women's education, agriculture, and other social and economic elements have significant effects on water resource sustainability.

The case study is the city of Baghdad which has the mentioned factors in its social and economic environment. Baghdad is the capital of Iraq (figure 2). There are 12 districts across the city limits in the northeast, namely Khalis, Baqubah, Al Wajihiya, and Dejail in the northwest. Tarmiyah, Hosseinia, and Taji are in the north, Abu Ghraib and Jisr Diyala are in the southwest and east, Mahmudiyah and Madain are in the southeast, and Ad Dulaimiya and Al Falluja are in the western districts of Baghdad [30]. Baghdad's population increased at an alarming rate over the last 70 years (between 1950 and 2020), starting with 579,167 people in 1950 and consistently increasing to 3,606,844 people in 1985, with its population exponential growth reaching 7,144,260 by 2020 [31].

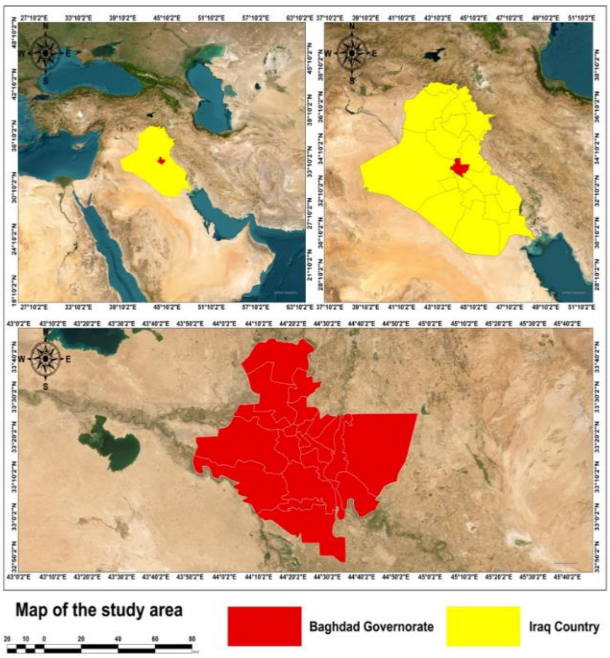

Figure 2. Maps of Study Area- Baghdad city in Iraq

In relation to the study site in Baghdad, the city's annual temperature typically ranges between 19°C and 23°C, with summer months July and August experiencing peaks around 40°C. In contrast, winter temperatures December and January drop to approximately 4°C. While winter temperatures rarely fall below 0°C, cold spells can occasionally bring temperatures to or below freezing, influencing surface water availability and vegetation cover in the area.

Regarding precipitation, the average annual rainfall is around 140 mm, with most of it concentrated between November and March. December and January typically receive the highest rainfall, while the remaining months April to October are characterized by very limited precipitation. Although annual rainfall can vary significantly, monthly fluctuations are considerable, ranging from less than 25 mm in some years to over 500 mm in rare cases. For instance, in 2008, Baghdad experienced light snowfall for the first time in recorded memory, highlighting the occasional occurrence of extreme weather events.

As for land cover, The land area of the city was 5169 Square kilometers. Baghdad's urban area is marked by a mix of land uses, including residential zones, agricultural areas, and small water bodies. Despite the impact of urban expansion on vegetation cover and water bodies in recent years, the city still maintains some green spaces and small water bodies, which become more pronounced during the winter months after rainfall.

Threfore these variations in temperature, precipitation, and land cover are key factors that influence surface water availability in Baghdad and provide valuable insight into the effects of climate change and human activities on the region's water resources.

2.2. Data

2.2.1 Data Collection

Data collection involves identifying and acquiring relevant data sources, including satellite imagery and geospatial datasets, which are critical for the accuracy and reliability of the analysis. The following datasets were collected and utilized in this study:

1. Remote Sensing Imagery: Satellite imagery from various sources, including Landsat and Sentinel-2, was obtained through Google Earth Engine. These datasets provide valuable insights into the spatial distribution of water bodies and vegetation in Baghdad, enabling the assessment of environmental conditions. A time series of Landsat imagery spanning 11 years, from 2012 to 2023, was used to analyze changes in water cover distribution in Baghdad. The selection of this timeframe is based on several factors.

- Landsat 7 (2012): The study begins with Landsat 7 data from 2012, despite the scan line corrector (SLC) failure that resulted in a 22% data loss. This year was chosen to provide a historical baseline for detecting long-term trends in water resources.

- Landsat 8 (2013–2023): From 2013 onward, Landsat 8 imagery was used, providing improved radiometric and spectral resolution, which enhances the accuracy of water body classification. The dataset continues through 2023 to capture recent water changes and assess long-term patterns influenced by climate variability and human activities.

2. Rainfall Data: Precipitation data were acquired from the meteorological records for Baghdad from the NASA Giovanni Platform and NASA Power Platform, detailing monthly rainfall averages and variations from 2012 to 2023. These datasets provide accurate and reliable precipitation data for the region

3. Population Data: Population data were sourced from national censuses and demographic surveys available through the Iraqi Central Statistical Organization (CSO) and international databases such as the World Bank and the United Nations. These datasets are reliable and consistent with other socio-economic and demographic data, enabling a comprehensive understanding of population dynamics in Baghdad.

4. Socio-economic Data: Socio-economic data, including income levels, employment rates, and urbanization patterns, were obtained from local and international statistical agencies such as the Iraqi Ministry of Planning and the World Bank. These datasets provide critical insights into the socio-economic drivers of land use change and water resource management in Baghdad.

5. Topographic Data: Digital Elevation Models (DEMs) and other topographic data were obtained from the Shuttle Radar Topography Mission (SRTM) dataset, available through NASA's Earth Observing System Data and Information System (EOSDIS). This dataset provides detailed elevation data that is essential for spatial analysis and modeling of topography and surface water availability in Baghdad.

6. Land Use/Land Cover Data: Data on land use and land cover (LULC) were obtained from satellite imagery and local land records, supplemented by the European Space Agency's Copernicus Land Monitoring Service, which provides free access to high-resolution land cover datasets for the region.

7. Water Bodies and Surface Water Data: Data on the location and extent of water bodies in Baghdad were sourced from satellite imagery and remote sensing databases, such as those provided by the USGS Earth Explorer platform and the European Space Agency (ESA). These datasets offer precise data on water bodies and their temporal changes, which are crucial

This study utilizes a time series of Landsat imagery spanning 11 years, from 2012 to 2023, to analyze changes in water cover distribution in Baghdad. The selection of this timeframe is based on several considerations. First, 2012 was chosen as the starting point to provide a sufficiently long historical baseline for detecting trends and changes in water resources. Although Landsat 8 was not operational in 2012, data from Landsat 7 were used despite the scan line corrector (SLC) failure, which resulted in a loss of approximately 22% of the data in each image. Including this year ensures continuity in the analysis and allows for comparison with subsequent years.

From 2013 onward, the study relies on Landsat 8 imagery, which offers improved radiometric and spectral resolution, enhancing the accuracy of water body classification. The dataset extends through 2023 to capture recent water changes and to assess long-term patterns influenced by climate variability and human activities. Thus, the 11-year duration provides a robust temporal framework for evaluating hydrological fluctuations and monitoring water resource management strategies, with a focus on water cover distribution in Baghdad.

These images were obtained through remote sensing cloud computing platforms, such as Google Earth Engine, NASA's Earth Observing System Data and Information System (EOSDIS), and the United States Geological Survey (USGS), ensuring consistency in seasonal conditions and minimizing variations caused by temporary weather anomalies.

Web mapping applications such as Google Earth Engine provide tools and functions for efficient pre-processing. Analysis methods and statistical techniques, such as descriptive statistics, inferential statistics, spatial analysis, and modeling, are applied to analyze the data and address the research objectives and questions.

The acquired data is then subjected to preprocessing and analysis[32, 33]. This involves formatting, cleaning, and transforming the data and performing atmospheric correction, radiometric calibration, and geometric correction on the satellite imagery.

Eventually, Data transforming processes are conducted to ensure that the datasets are in formats suitable for analysis and visualization. First, the raw data underwent normalization processes to ensure consistency across different datasets. This is crucial for accurate comparisons and analysis and then Spatial transformations are applied to align the datasets with the geographic coordinate system used in Google Earth Engine. This alignment is essential for accurate geospatial analysis and interpretation.

2.3 Methods

The research methodology is documented, detailing the data sources, processing steps, analysis techniques, and limitations. Additionally, classification techniques, such as thresholding or supervised algorithms, can be employed to categorize the NDWI image into water and non-water classes. Spatial analysis techniques, such as overlaying the NDWI data with other spatial layers like vegetation cover or land use maps, can be applied to explore spatial patterns and correlations. Thematic maps and visualizations can be created to effectively communicate the results.

2.3.1 Calculation of NDWI Times-series

In the present research, the collected data must be analyzed effectively. Data processing tasks are performed using Python programming. This ensures that the data is suitable for analysis and accurately represents the environmental conditions.

Additionally, by using the NDWi, water resources are identified first and then separated from other land covers. NDWI is one of the most common indicators used for water body at a regional or global scale. The amount of water -which is liquid, not vapor- Surface water area or water inundation extent can be detected from optical satellite images using the NDWI or the Modified Normalized Difference Water Index (MNDWI). These indices enhance the distinction between water bodies and other land cover types by utilizing the spectral differences in the green and near-infrared for NDWI or shortwave infrared for MNDWI bands.

The NDWI formula calculates the difference between the NIR and Green bands and normalizes it by dividing it by the sum of the NIR and Green bands. This normalization helps to remove the influence of varying brightness or atmospheric conditions.

This index is calculated based on equation (1), where NIR represents the Near-Infrared band (B5) and GREEN represents the green band (B3).

$$NDWI = (NIR - GREEN) / (NIR + GREEN) \quad (1)$$
$$MNDWI = (Green-SWIR) / (Green+SWIR)$$

The green band in the NDWI and MNDWI calculations plays a crucial role in distinguishing water bodies from surrounding land cover [35]. While the NDWI uses the near-infrared band (NIR) to highlight water features, the MNDWI replaces NIR with shortwave infrared (SWIR), improving water detection in urban areas by minimizing interference from built-up surfaces.

This index is calculated on Landsat 8 and Sentinel 2 time-series images. The imagery allows for a more accurate comparison of water content. When applying the NDWI formula, the resulting values range from -1 to 1. By calculating NDWI, you can effectively identify and map water bodies or areas with high water content within satellite imagery. This information is valuable for various applications, including water resource management, hydrological analysis, and environmental monitoring.

2.3.2 Image Classification

Since water bodies exhibit distinct spectral reflectance characteristics compared to vegetation, buildings, and bare soil, their extraction from satellite images is a relatively straightforward task. However, challenges may arise in distinguishing between different water types, such as shallow versus deep water or turbid versus clear water, due to variations in spectral responses.After calculating the necessary index, a classification process is conducted to extract different water classes based on the chosen dates. Subsequently, the values are exported and extracted, specifically for the relevant categories after classification. These findings can be utilized to understand the changes in natural landscapes and the spatial distribution of vegetation and water bodies over consecutive years.

In this study, for simplifying the classification and avoiding complicated and time-consuming methods, the fact that higher NDWI values indicate a higher likelihood of water presence, while lower values indicate less water content, is considered for classifying the land covers. For this aim, for each image of time-series the threshold that separates the classes from each other is changed. However, it must be noted that typically, water bodies have higher NDWI values, while non-water areas, such as land surfaces or dense vegetation, have lower NDWI values.

2.3.3 Visual Presentation of Outcome

Visualization Cascading Style Sheets[1] Are utilized to enhance the visual presentation of the output maps and reports generated from the analyses. This aspect of the methodology included Designing Map Elements and Output Formatting. CSS was employed to style various elements of the web maps, ensuring that they are user-friendly and visually appealing. This includes customizing color schemes, fonts, and layout structures to facilitate better interpretation of the data. The final maps and reports were formatted using CSS to ensure consistency and clarity. This is essential for effectively communicating the research findings to stakeholders and the broader audience.

For synthesizing the various datasets collected for this research, data integration plays a crucial role. This process involved: Combining Datasets and Geospatial Analysis. The integration of remote sensing data, hydrological data, was performed to create a comprehensive dataset that reflects the influence of water cover distribution .This step is vital for understanding how water availability influences ecological dynamics in Baghdad.

Additionally, the design of customized maps is an essential component of this research, aimed at enhancing user interaction and data accessibility. User-Centric Design and Visual Representation are two important parts of this level. The maps were designed with the end-user in mind, allowing for easy navigation and interpretation. Interactive features were incorporated to enable users to explore different aspects of the data. Customized maps effectively displayed NDWI values, highlighting areas of significant surface water availability. This visual representation facilitates a clearer understanding of the spatial dynamics of surface water availability in relation to environmental resilience.

3 Results

To facilitate comparison and analysis of the surface water availability results, the attribute table, which contains the analysis values, is converted into an Excel sheet. table 1 and figure 4 represent an analysis of the NDWI results for monitoring Water cover in Baghdad using web mapping applications such as Google Earth Engine.

[1] CSS

Table 1: NDWI Results and Statics

NDWI 2012		
Vegetation Classes	Count	Percentage
Drought	782174	12.97144099
Moderate drought	2806988	46.55061302
humidity	2314200	38.37830039
Water surface	126608	2.099645604
NDWI 2013		
Vegetation Classes	Count	Percentage
Drought	803174	13.97074606
Moderate drought	2306988	40.12871871
humidity	2524200	43.90699551
Water surface	114608	1.993539712
NDWI 2014		
Vegetation Classes	Count	Percentage
Drought	819706	14.2583131
Moderate drought	2205754	38.36781865
humidity	2611177	45.4199179
Water surface	112332	1.953950352
NDWI 2015		
Vegetation Classes	Count	Percentage
Drought	594956	10.34891468
Moderate drought	1803488	31.37062813
humidity	3241458	56.38328257
Water surface	109068	1.897174624
NDWI 2016		
Vegetation Classes	Count	Percentage
Drought	700250	12.18044276
Moderate drought	2421612	42.12253673
humidity	1929928	33.56997862
Water surface	697180	12.12704189
NDWI 2017		
Vegetation Classes	Count	Percentage
Drought	628521	10.93275839
Moderate drought	1791263	31.15798134
humidity	3178657	55.29089559
Water surface	150529	2.618364681
NDWI 2018		
Vegetation Classes	Count	Percentage
Drought	651558	11.33347365
Moderate drought	2001220	34.81006163
humidity	2403149	41.80138355
Water surface	693043	12.05508117
NDWI 2019		
Vegetation Classes	Count	Percentage
Drought	500736	8.735846269
Moderate drought	1306173	22.78750984
humidity	2996763	52.28156328
Water surface	928297	16.19508061
NDWI 2020		
Vegetation Classes	Count	Percentage
Drought	437736	7.614165253
Moderate drought	1256173	21.85040483
humidity	2906763	50.56146589
Water surface	1148297	19.97396403
NDWI 2021		
Vegetation Classes	Count	Percentage
Drought	714841	12.43424474
Moderate drought	2101638	36.55677452
humidity	2761699	48.03815292
Water surface	170792	2.970827818
NDWI 2022		
Vegetation Classes	Count	Percentage
Drought	661997	11.515054
Moderate drought	2158789	37.55088303
humidity	2763440	48.06843661
Water surface	164744	2.865626364
NDWI 2023		
Vegetation Classes	Count	Percentage
Drought	706703	12.29269109
Moderate drought	1278449	22.237883
humidity	3562408	61.96603252
Water surface	201409	3.503393391

- Across all the years listed in the table, it is evident that the categories of drought and moderate drought represent a lower percentage of vegetation cover, while the humidity category represents a higher percentage.This suggests that Baghdad enjoyed a relatively good distribution of water resources and vegetation cover throughout the studied years.

- From 2012 to 2023, there is a noticeable expansion in surface water coverage during wet seasons and a gradual reduction in the frequency and intensity of drought and moderate drought periods, as observed through satellite-based water monitoring.

- This trend can be attributed to improvements in water resource management and increasing attention towards environmental conservation and sustainable development.

- In terms of the NDWI results, the Drought class indicates the lowest presence of water bodies, with percentages ranging from 7.6% in 2020 to 14.3% in 2014.

- The Moderate Drought class shows a higher presence of water than the Drought class but is still below optimal levels, ranging from 21.9% in 2020 to 46.6% in 2012.

- The wetness classification reflects changes in surface water extent and moisture availability, as derived from NDWI and satellite-based water area analysis. The monitored water coverage varied from 33.6% in 2016 to 62.0% in 2023, indicating fluctuations in hydrological conditions over the study period.

- The Water Surface class indicates the highest presence of water bodies, ranging from 1.9% in 2015 to 20.0% in 2020.

The analysis suggests that Baghdad has experienced fluctuating water conditions over the studied period.

There are some annual variations in the distribution of categories, which can be explained by climate fluctuations and yearly weather patterns. The increase in surface water coverage in certain years can be attributed to heavy rainfall or local flooding conditions, which lead to the expansion of water bodies. Groundwater, on the other hand, influences surface water availability by feeding rivers and lakes, particularly during dry periods, but it does not directly affect rainfall. Figure 4 represents the classification results in the year which is the driest

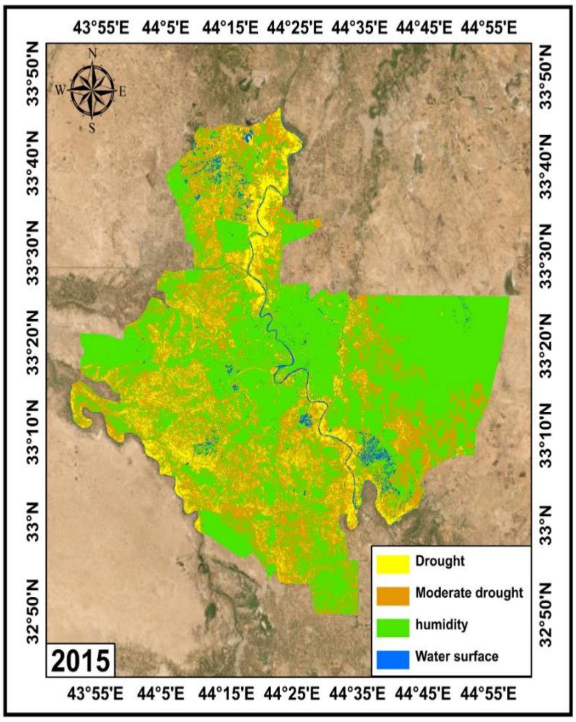

Figure 4. NDWI image for 2015- the driest year

Due to the the highest humidity (56.38%) and the lowest drought (10.35%), the year 2015 is known as the year – through the years studied here- is the driest year. İt has higher drought and moderate drought percentages. Also, in figure 5, the map of the wettest year is represented.

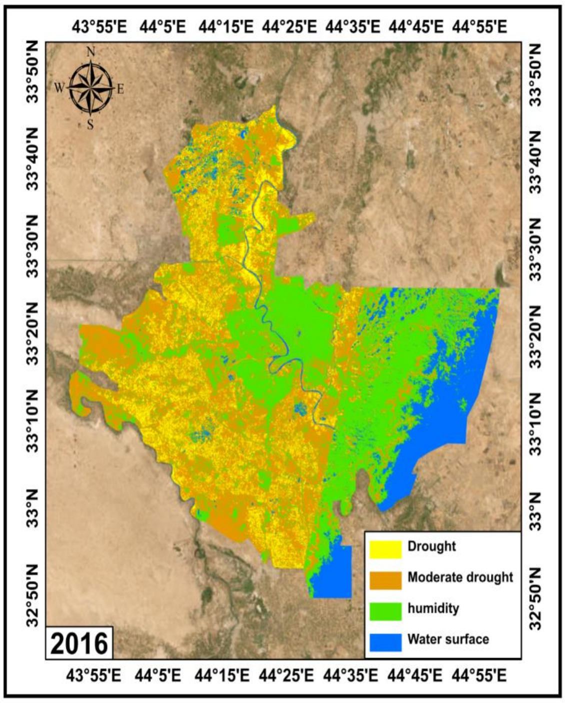

Figure 5. NDWI image for 2016- the wettest year

İt is clear that the year 2016 is known as the wettest year, because of its higher humidity and water surface percentages. According to results it has high drought (12.18%) and high moderate drought (42.12%), along with low humidity (33.57%).

The maps of results for every single year is attached as appenix at the last page of paper.

The analysis of the Normalized Difference Water Index data provides insights into the distribution of water bodies and moisture conditions in Baghdad over the studied years.

For better visualization, figure 6 shows four different categories' values using the chart.

The relatively high percentages of Drought and Moderate Drought classes in some years indicate water scarcity or limited water availability.

The Wetness class reflects the surface water extent and moisture availability in the area, influenced by factors such as precipitation, groundwater contributions, and evaporation. The variations in the Wetness class percentages suggest changes in surface water availability and moisture levels over time, with groundwater playing a role in maintaining water availability, especially during dry periods.

These results highlight the importance of monitoring water resources and understanding their dynamics in Baghdad. The findings can contribute to water resource management and inform decision-making processes related to water allocation, irrigation practices, and drought mitigation strategies in the region.

4 Discussion

The measures and efforts undertaken to protect the environment in the Baghdad region, as outlined in the research, focus on assessing the distribution of water resources and their impact on ecosystem resilience. This is achieved using satellite image analysis and mapping techniques on the Google Earth Engine platform.

Summary of the Results

- The Normalized Difference Water Index (NDWI) analysis, spanning from 2012 to 2023, revealed significant changes in water coverage in Baghdad. The land was classified into four categories: drought, moderate drought, moisture, and surface water. The data shows that the percentage of surface water and moisture tended to increase in certain years, such as 2016 and 2020, indicating improved water availability during those periods, while years like 2015 were characterized by greater aridity.

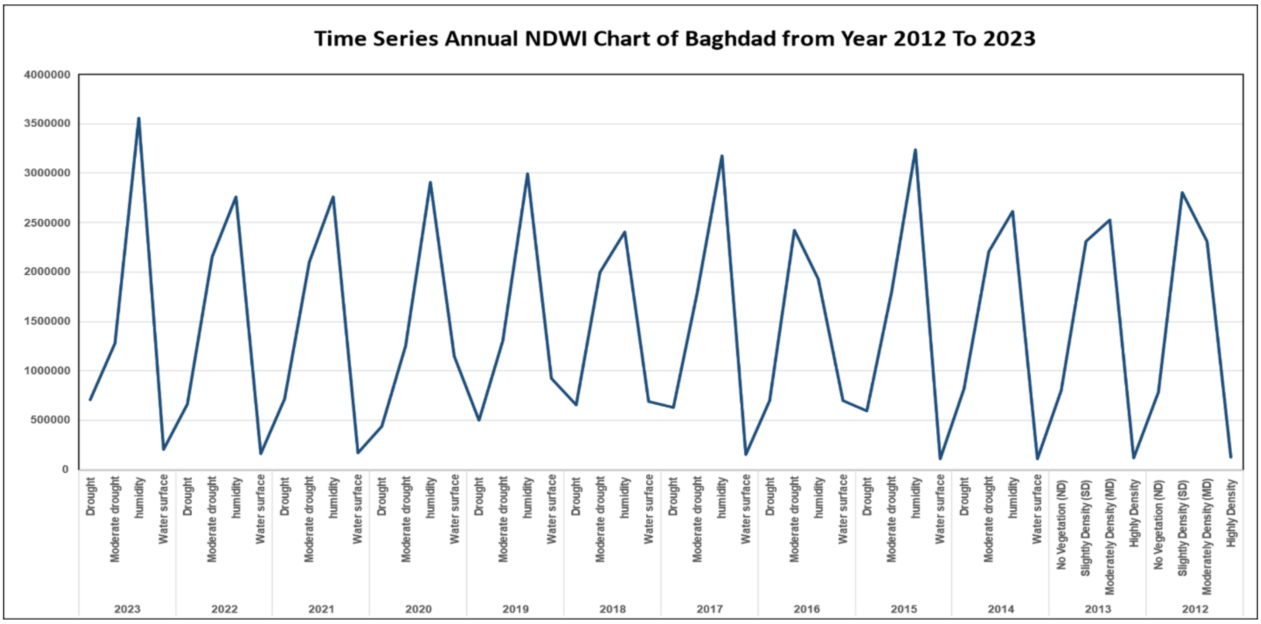

Figure 6. NDWI Chart

- The results demonstrate a strong correlation between water resource distribution, vegetation cover, and urban human activities, reflecting the impact of water on ecosystem resilience and sustainable urban planning.

- Fluctuations in the distribution of drought and moisture categories were attributed to climatic variations such as rainfall patterns and changes in groundwater levels, highlighting the ecosystem's sensitivity to water resource fluctuations.

Explanation of Concepts and Models Used

- Normalized Difference Water Index (NDWI): This index uses spectral data from satellites to identify and assess water bodies on the Earth's surface. It is calculated by taking the difference between the near-infrared (NIR) and green spectral bands, and then normalizing the value to eliminate the effects of lighting and atmospheric conditions. - Web mapping technologies: These were used to

provide an interactive interface that allows users to explore geospatial data related to water distribution performance and vegetation cover changes, facilitating evidence-based decision-making and promoting transparency.

- Time series analysis: This technique was employed to analyze changes in water distribution patterns over a period of more than a decade, highlighting long-term trends and seasonal fluctuations.

The second challenge pertains to institutional capacity and coordination.

Accurate and up-to-date data are essential for evidence-based decision-making. Overcoming data gaps and ensuring data quality requires improving data collection systems, enhancing data sharing mechanisms, and investing in data infrastructure. Collaboration with research institutions, local universities, and other relevant organizations can help address data challenges and ensure access to reliable information.

Outdated or inadequate policies, weak enforcement mechanisms, and regulatory barriers can hinder progress. It is important to assess existing policies, identify gaps, and develop new regulations or amend existing ones to support sustainable practices. This may involve establishing incentives, setting standards, and providing guidance on environmental resilience. Climate change uncertainty presents a significant challenge. Strategies need to consider the potential impacts of climate change, such as changes in the hydrological cycle and water availability. Incorporating adaptive management approaches and regularly updating strategies based on the latest scientific knowledge is crucial for addressing these uncertainties. Flexibility and the ability to adjust strategies based on changing climate conditions are key to building long-term resilience.

Sociopolitical factors, including instability, conflicts, and governance challenges, can have a profound impact on implementation efforts.

Political stability, will, and good governance are necessary for ensuring the continuity of environmental resilience initiatives. Resolving conflicts, promoting inclusive decision-making processes, and fostering political commitment are essential for overcoming sociopolitical barriers [36]. In conclusion, addressing the challenges and barriers to implementing strategies for enhancing environmental resilience in Baghdad City requires a comprehensive and integrated approach. This research primarily focuses on enhancing data availability through the use of remote sensing datasets, which plays a crucial role in improving urban planning and management. By leveraging satellite imagery and geospatial data, Baghdad can enhance its decision-making processes, particularly in monitoring water resources, land use changes. These advancements in satellite technology and data accessibility can help cities adapt to changing By proactively addressing these challenges, Baghdad City can work towards a more resilient and sustainable future.

5 Conclusion

This research aims to assess the influence of surface water availability on environmental resilience in Baghdad City by utilizing the capabilities of Google Earth Engine (GEE), an open-source platform designed for geospatial data analysis. Landsat 8 and Sentinel 2 images captured from 2012 to 2023, are considered to apply Normalized Differential Water Index. To analyze these data, it is essential that the collected data are processed and the Normalized Differential Water Index is calculated for each image. NDWI is the most common method used to extract water bodies from satellite imagery. This index helps differentiate water surfaces by exploiting differences in spectral reflectance, particularly in the green and near-infrared bands.

The resulting NDWI serves as a crucial indicator, highlighting the impact of surface water availability on the ecological resilience of urban areas in Baghdad.

By integrating diverse datasets, employing advanced programming techniques, and designing customized visualizations, this research provides a comprehensive framework for understanding the intricate relationships between water availability and environmental conditions.

Overall, the practical application of the research findings can lead to more informed decision-making, improved policies, and targeted interventions that enhance environmental resilience in Baghdad City.

It can be useful to integrate these findings into urban planning or water resource management in the future works to aware public, so the city can progress towards a more sustainable and resilient future.

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Conflicts of interest

We wish to confirm that there are no known conflicts of interest associated with this publication.

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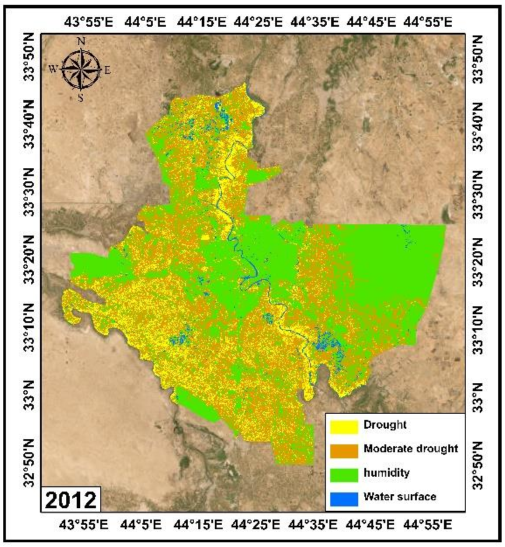
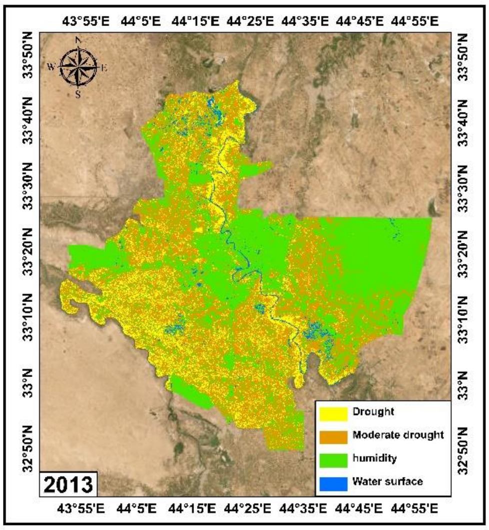
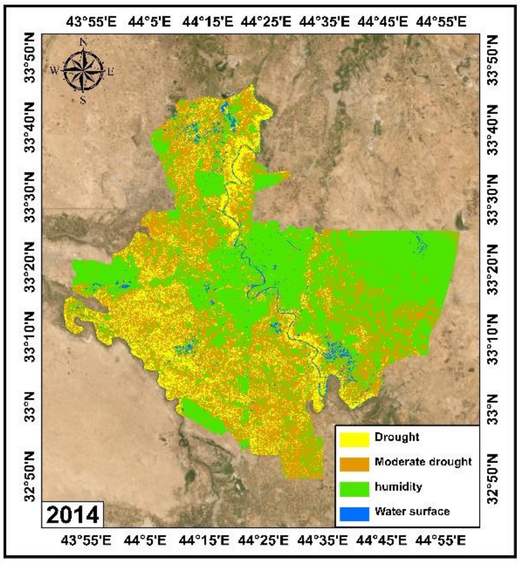
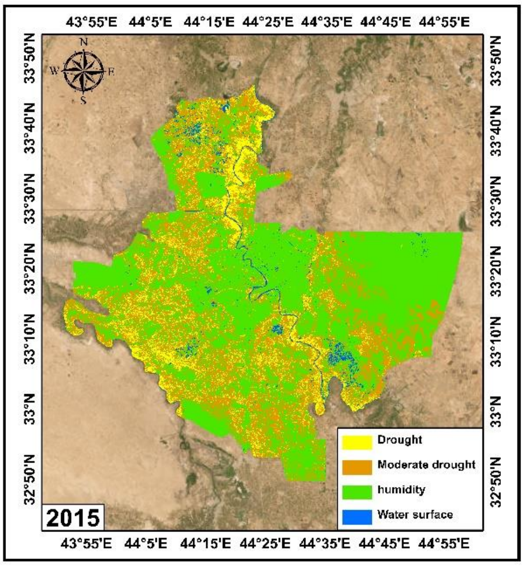
Appendix:

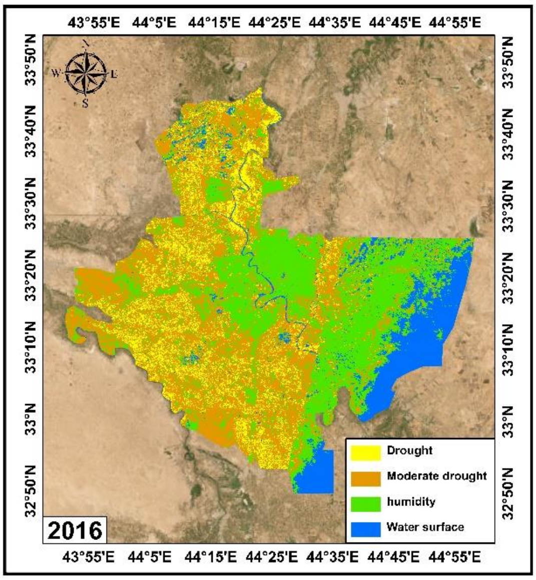
The maps of results for every single year is attached as appenix here. They are related to NDWI Results and Statics.

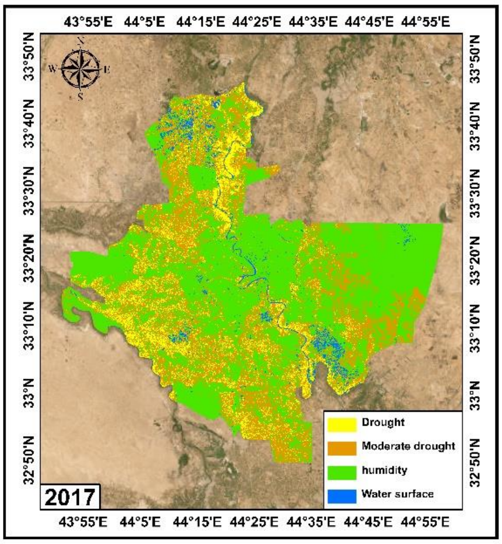












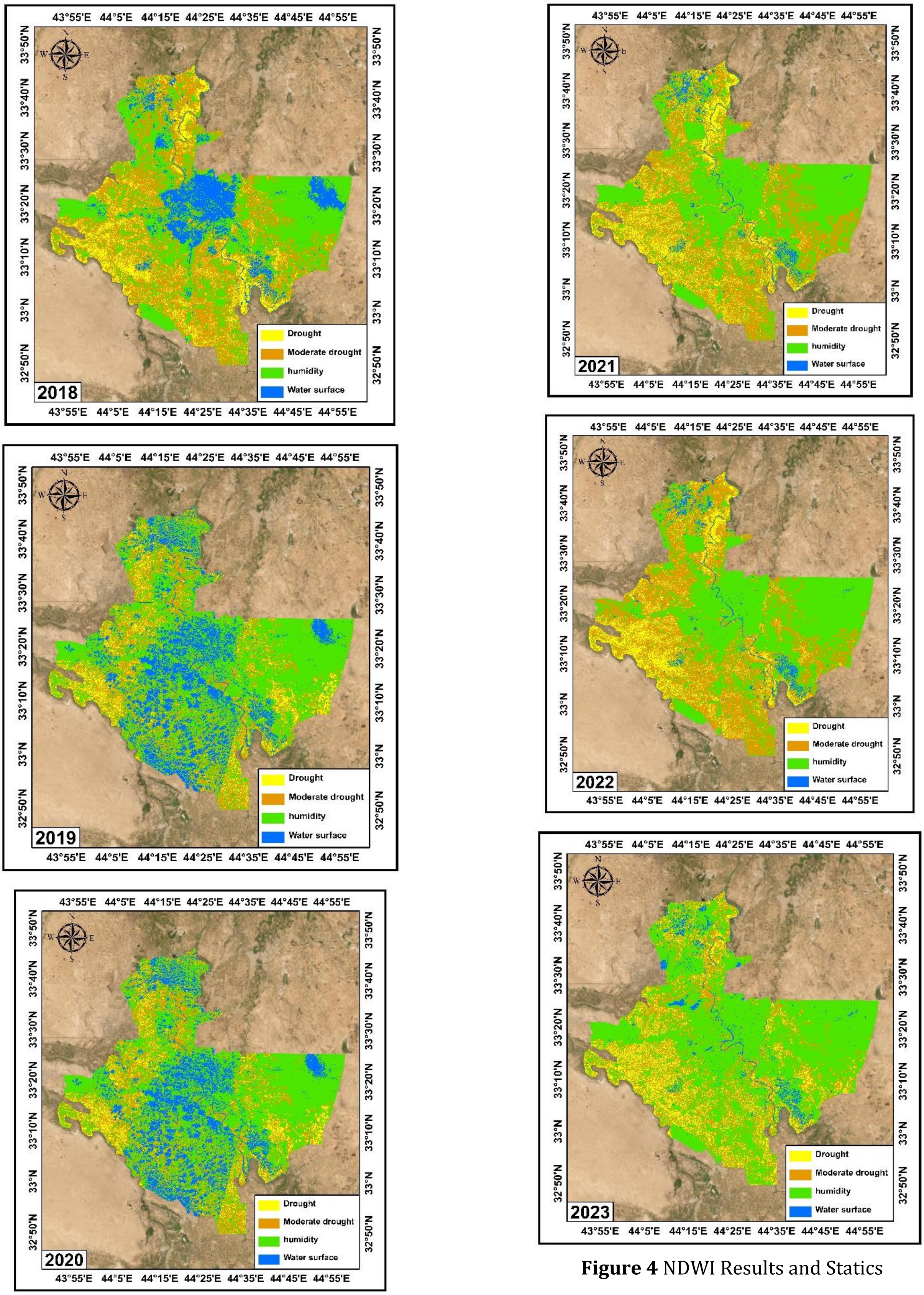


Figure 4 NDWI Results and Statics