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Spectral Indicators for Detecting Hydrological Changes of Southern Iraq Using RS-GIS

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Abstract: *Water resources are the lifeblood of arid and semi-arid environments. They are of great interest to researchers, particularly in areas whose economies are based on agricultural activity. This contributes to optimal and effective investment of water resources, as water is a strategic resource that defines economic development.*

The research aims to study the hydrological changes in southern Iraq and its causes for the study area located between -29.5°-32.45°N latitude and -45.66°-48.40°E longitude, which occupies an area of (47764,63 km) and constitutes (11%) of the area of Iraq, located in the southern and southeastern part of Iraq and overlooks the head of the Arabian Gulf in its southeastern part, and is bordered to the north by Wasit Governorate, to the south by Kuwait and the Arabian Gulf, to the east by Iran and to the west by Al Qadisiyah and Muthanna governorates.

In this study, multispectral bands of MSS, ETM, TM, and TIRS-OLI were downloaded to estimate the normalized water variation index from the USGU website in the United States of America, and then multispectral packages were prepared for subsequent calculations by analyzing the data.

By analyzing the satellite visualization of the surface areas of the waters of southern Iraq during the period (1975 - 2024) 2024), it was found that there is a spatial change represented by a large variation at the annual level for the selected years, as the largest hydrological change was observed in southern Iraq in 2000, as the areas of the marshes shrank significantly, including Haw al-Hawiza (the marsh), and some marshes dried up completely, including Hawr al-Hammar, as only a part of Hawr al-Sanaf remained, as well as the central marshes and the marshes southeast of Gharaf. Only part of Hoor Al-Sanaf remains, as well as the central marshes and the marshes southeast of Al-Gharaf dried up, as the area amounted to (662,75 km2), after the water area occupied large areas in 1975 (6596 km2), as shown by the NDWI index maps installed in the body of the research, then the water areas returned to occupy large areas in 2005, as it reached (6596 km2). Large areas in 2005, reaching (2085 km2) as a result of the revitalization of the marshes that occurred after 2003, but soon the water areas began to decline in 2010, reaching (1029 km2) as a result of the drought that occurred in this year and the lack of water income and the cutting of some tributaries feeding the rivers, then the water areas returned to occupy large areas in 2020 as a result of the increase in water income reaching the study area, and the year 2024 witnessed a decline in water areas due to the drought that occurred, thus the hydrological situation in southern Iraq has seen a stark contrast between water abundance and scarcity

Therefore, hydrological changes are among the most dangerous and complex problems facing the study area due to the multiple causative factors, including drought resulting from high temperatures and consequently a decrease in total rainfall and its fluctuations, and a decrease in the water supply of the study area, which led to a decrease in water areas, in addition to poor planning and management represented by weak management of water supply (dams and reservoirs) and water demand (water consumption for various types of use).

Keywords: *Spectral Indices, Hydrological Changes, Southern Iraq, Remote Sensing (RS), Geographic Information Systems (GIS), Marshlands, Drought, NDWI.*

Introduction

Water, first and foremost, is the source of life and the means of its continuity, in accordance with the words of Almighty God (and we made from water everything alive), water resources occupy a unique role in the life and development of human societies throughout history, and none of the other natural resources can match it in terms of importance and influence on the course of effective associated factors, as it is the natural resource that cannot be replaced, and man cannot be effective or continue to exist without it, so water resources are one of the most important natural resources for their role in achieving economic and social development and sustainability of ecosystems.

Water resources in the study area have faced many threats, some of which are natural, represented by low rainfall, high temperatures and evaporation rates, and some of them are human, especially in the second half of the last century, as large areas of the marshes dried up as a result of the internal policy that the previous regime worked on and left a great environmental confusion, by changing the water courses that used to end in the marshes, In addition to the policy of drying, there was a group of factors that contributed to a major hydrological change in the study area, the most important of which are the Upper Basin projects (Turkey, Iran, Syria), which worked to change the mouths of rivers by building many dams, reservoirs and irrigation projects, which led to a decrease in the quantity of water coming to Iraq in general and the study area in particular and deteriorating its quality, and the lack of vegetation cover due to the recession and dryness of water from its lands, in addition to poor planning and management of water.

The best method for monitoring hydrological changes in southern Iraq is the method that relies on the use of remote sensing technologies, especially high-resolution visuals that save effort and time, and because of their advantages and capabilities in the possibility of monitoring and observing this phenomenon in very large areas and at different times and periods of the years and within different wavelengths and resolution. To facilitate the process of collecting information, analyzing it, and employing it in an effective and influential manner, the use of geographic information systems was made by taking advantage of them in carrying out calculations and measurements and producing and analyzing maps to reach quick results.

The research problem represented the following questions :

1- Are there hydrological changes in southern Iraq during the period (1975-2024)?
2- Do remote sensing technologies play an effective role in detecting hydrological changes in southern Iraq during the period?(2024-1975)

The research was based on the hypothesis that :

1- There are hydrological changes (temporally and spatially) in southern Iraq during the period-1975) .(2024
2- Remote sensing technologies are the best method for detecting hydrological changes during the period under study.(2024-1975)

The importance of the study comes from the fact that it is a study that examines the hydrological field, as it witnesses a noticeable change in the water cover in its spatial and temporal dimensions. Hence, the importance of the research in adopting an advanced scientific and technical method capable of detecting and monitoring hydrological changes .

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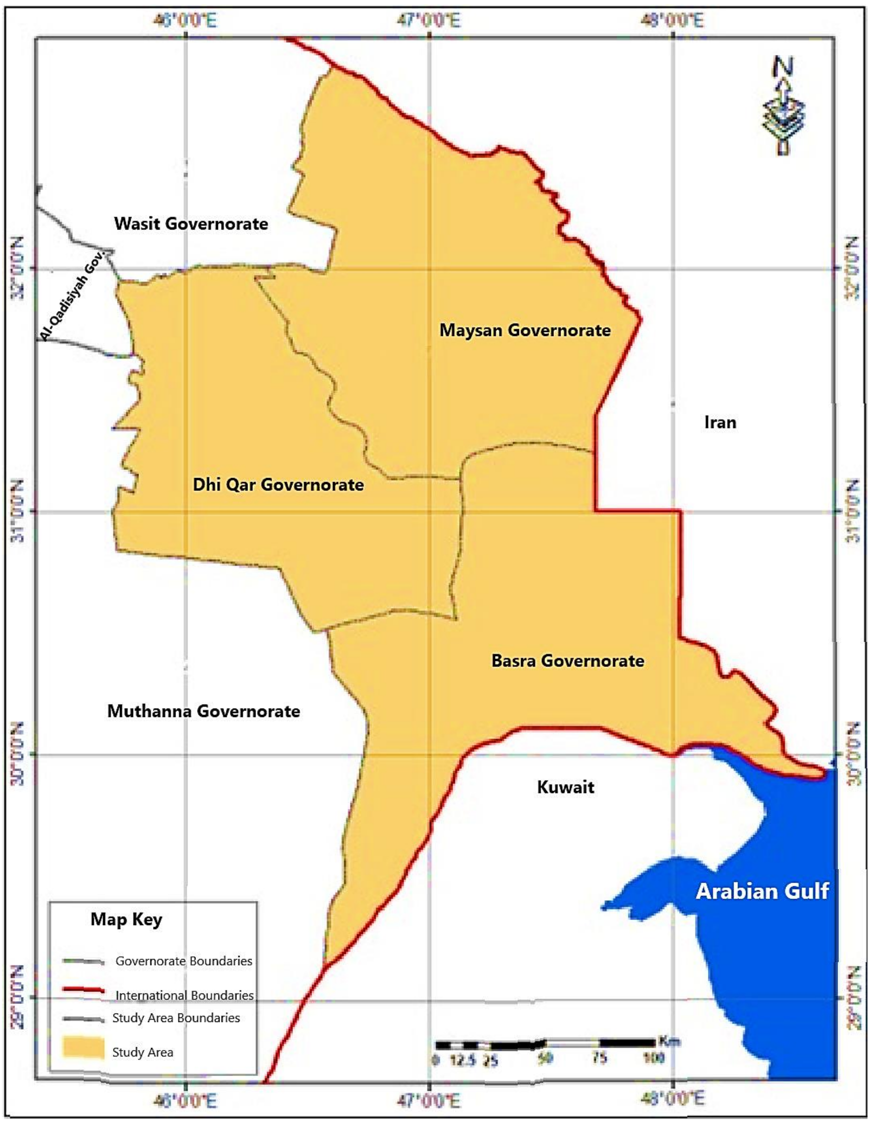
Utilizing remote sensing and geographic information systems technologies to detect and monitor changes in the water cover of southern Iraq during the period (1975-2024) for each of the selected years .

The study area is located in the southern and southeastern part of Iraq, extending between latitudes -29.5° - 32.45° north and longitudes -45.66° - 48.40° east, occupying an area of (63,47764 km2) and constituting (11%) of the area of Iraq, and overlooking the head of the Arabian Gulf in its southeastern part, it is bordered to the north by Wasit Governorate, to the south by the State of Kuwait and the Arabian Gulf, to the east by Iran, and to the west by Al-Qadisiyah and Al-Muthanna Governorates. See map (1 .(

Map (1): Geographical Location of Study Area



Source: Based on: Republic of Iraq, General Authority for Survey, Administrative Map of Iraq, scale 1:1,000,000, Baghdad, 2015

Normalized Difference Water Index (NDWI)

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It was first proposed by researcher M.C. Feeters (1996) to detect water bodies in any region and indicate wet and dry areas. This indicator is used by remote sensing using space satellites (Mcfeeters, S.K., 1996, p. 3544-3561) and according to the following equation (Al-Obaidi & Al-Timimi, 2022, p. 41).

$$\frac{Band\ GREN - Band\ (NIR)}{Band\ GREN + Band\ (NIR)}$$

Whereas
GREN Band - Green visible band
NIR Band - Infrared band
The application is in the (MSS) sensor.

$$\text{NDWI} = \frac{Band\ 1 - Band 3}{Band\ 1 + Band\ 3}$$

Sensors (TM, ETM)

$$\text{NDWI} = \frac{Band\ 2 - Band 4}{Band\ 2 + Band 4}$$

TIRS-Oli sensor

$$\text{NDWI} = \frac{Band\ 3 - Band 5}{Band\ 3 + Band 5}$$

This indicator is applied on the assumption that water has a high reflectivity in the visible range (green) in contrast to the near infrared and shortwave infrared, and thus can easily detect water bodies and their contents, as well as distinguish water from other phenomena (Manohar Kumar
(Near infrared) and Shortwave infrared waves and therefore can easily detect water bodies and their contents, as well as distinguish water from other phenomena (Manohar Kumar, 2015, p. 15.) .

Most of the radiation falling on water surfaces is absorbed by the water or penetrated by it, and few of it is reflected back into the atmosphere again, as water absorbs most of the infrared radiation, which makes the contrast between it and other surface materials very large in satellite images taken in the near infrared range, while radiation in the visible waves, most of it passes through water and about 50% of it is reflected (Qusai Abdul Razzaq Wahib and Riad Khairuddin Abdul Latif, 2010, p. 3).

1. **Hydrological change in southern Iraq in 1975**

It is clear from Table (1) and Figure (1) resulting from the analysis of space visualizations in 1975 that the total area under water was estimated at (6596.45 km2) and (13.81%) of the area of land cover, which occupied an area of (41168.17 km2) and (86.18%), see Map (2). It is considered a base year, i.e. a year with stability and stability, and is thus the highest area during the years of the study, so it was adopted, as it is used to measure the spatial changes occurring for the rest of the years of the study because it was occupying large and integrated water areas and covered by This period of the 1970s was also characterized by increased rainfall, i.e. Iraq and the Upper Basin countries experienced higher rates of seasonal rainfall, which led to higher water levels in rivers and water bodies, and higher water imports to the Tigris and Euphrates rivers, which was reflected in the increase in the area of water cover in the study area, as well as the low demand for water during this year due to the decrease in population numbers compared to the subsequent years of the study .

Table (1) Area and percentage of the NDWI water cover index in the study area for the period (2024-1975)

Rate %	Area (km2)	Cover Class	Year
86.18	41168.17	Dry cover	1975
13.81	6596.45	Water cover	
92.42	44144.65	Dry cover	1985
7.57	3619.97	Water cover	
94.47	45125.66	Dry cover	1990
5.52	2638.96	Water cover	
95.77	45744.56	Dry cover	1995
4.22	2020.06	Water cover	
98.61	47101.87	Dry cover	2000
1.38	662.75	Water cover	
95.63	45679.48	Dry cover	2005
4.36	2085.14	Water cover	
97.84	46735.58	Dry cover	2010
2.15	1029.04	Water cover	
94.78	45273.60	Dry cover	2015
5.21	2491.02	Water cover	
92.51	44187.54	Dry cover	2020
7.48	3577.08	Water cover	
96.30	46000.70	Dry cover	2024
3.69	1763.92	Water cover	

Source: Author based on data from the US Geological Survey earthexplorer.usgs.gov, MSS Land Sat OLI™ satellite data, and ArcMap 10.4.2 software technologies

Map (2) NDWI wet season water cover index for the year 1975 in the study area

The Author is based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 1 satellite, the MSS sensor, and ArcMap 10.4.2 software technologies .

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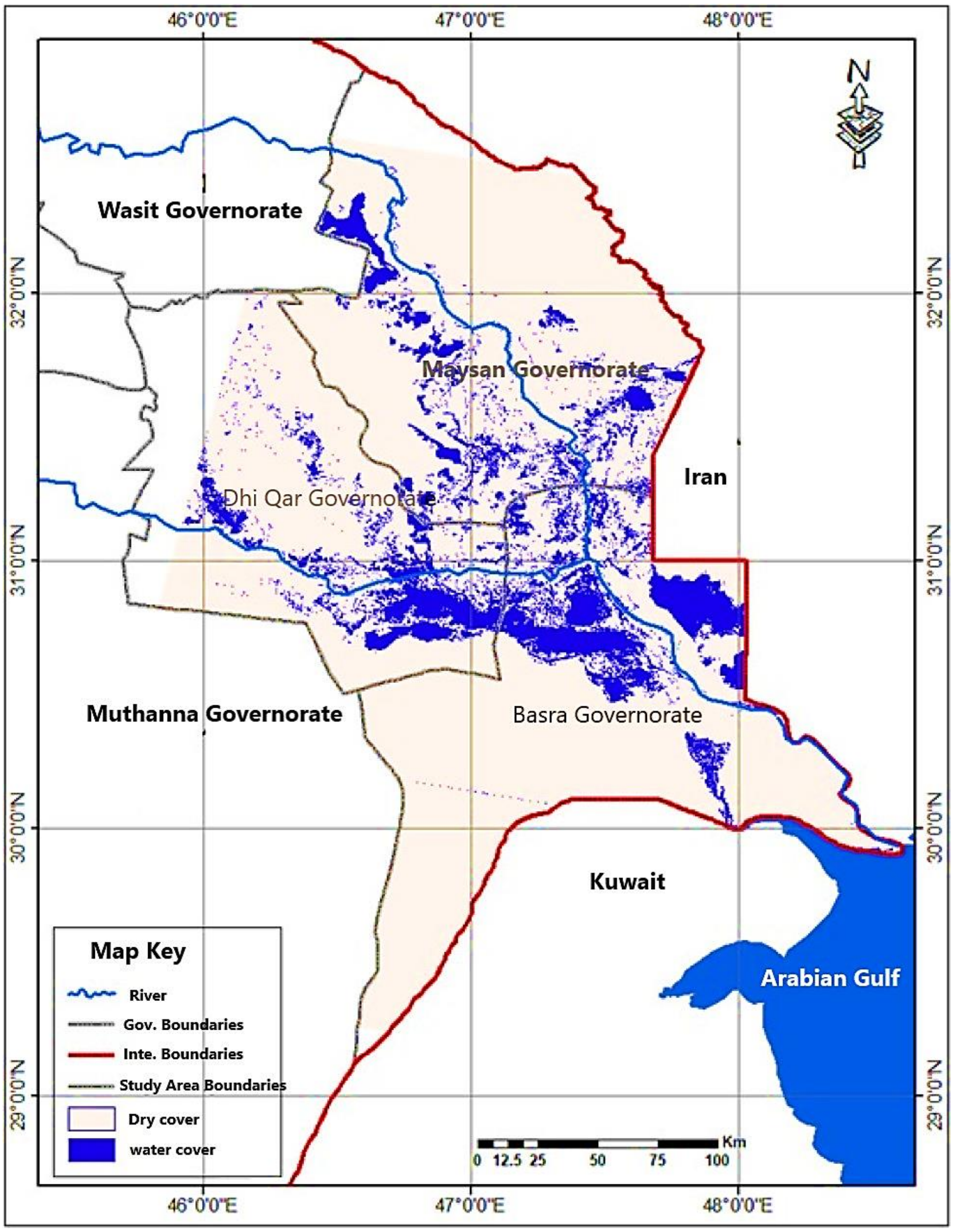
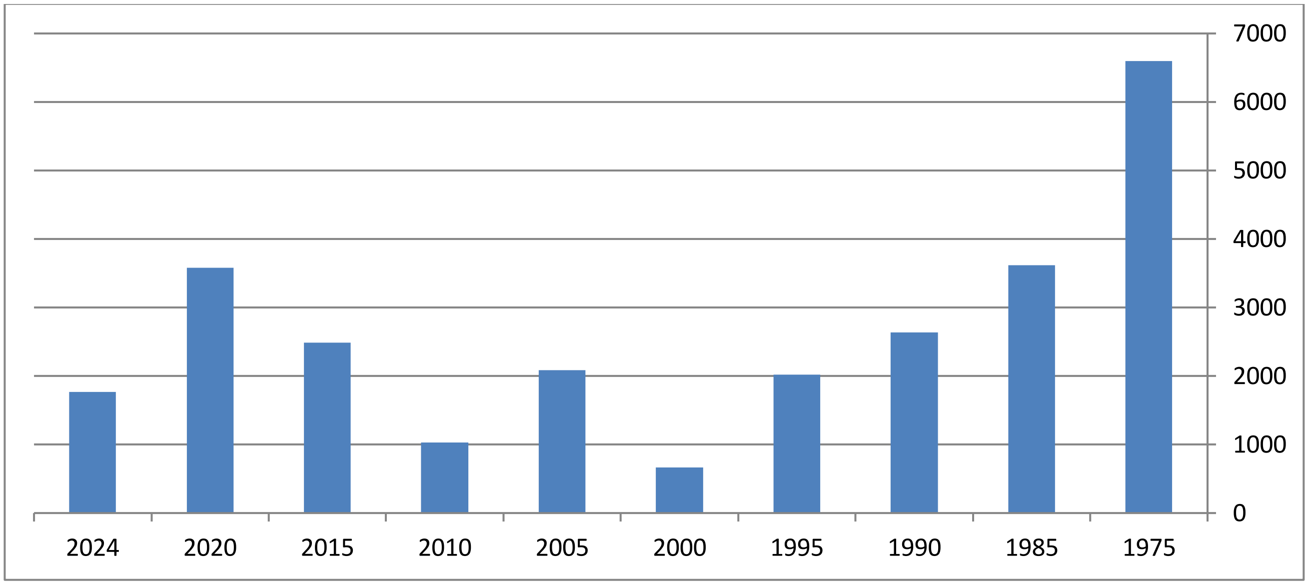
Figure (1) Area of the NDWI Water Cover Index in the study area for the period ((2024-1975 Area km2.





Source based on Table (1)

2. Hydrological change in southern Iraq in 1985

By analyzing the satellite visualization of the water cover in 1985, it became clear that its area was estimated (3619.97 km2) and (7.57%) of the area of the land cover class, which amounted to an area of (44144.65 km2) and (92.42%) See table (1), figure (1) and map (3), that is, there is a decline in area compared to 1975 and this decline is attributed to the amount of precipitation in 1985 decreased compared to 1975, as it amounted at the Amara Basra Nasiriyah station (1.60, 1.140, 1.83, 1.83 mm), respectively, after the amount of rainfall in 1975 was (1.188, 1.181, 1.155 mm) (60.1, 140.1, 140.1 and 83.1 mm), respectively, after the amount of rainfall in 1975 was (238, 181.8, 155.9 mm), in addition to the human factor represented by the foreign water policy and its implications on Iraq, as it constructed many dams, which reduced the water revenue reaching Iraq, including the study area .

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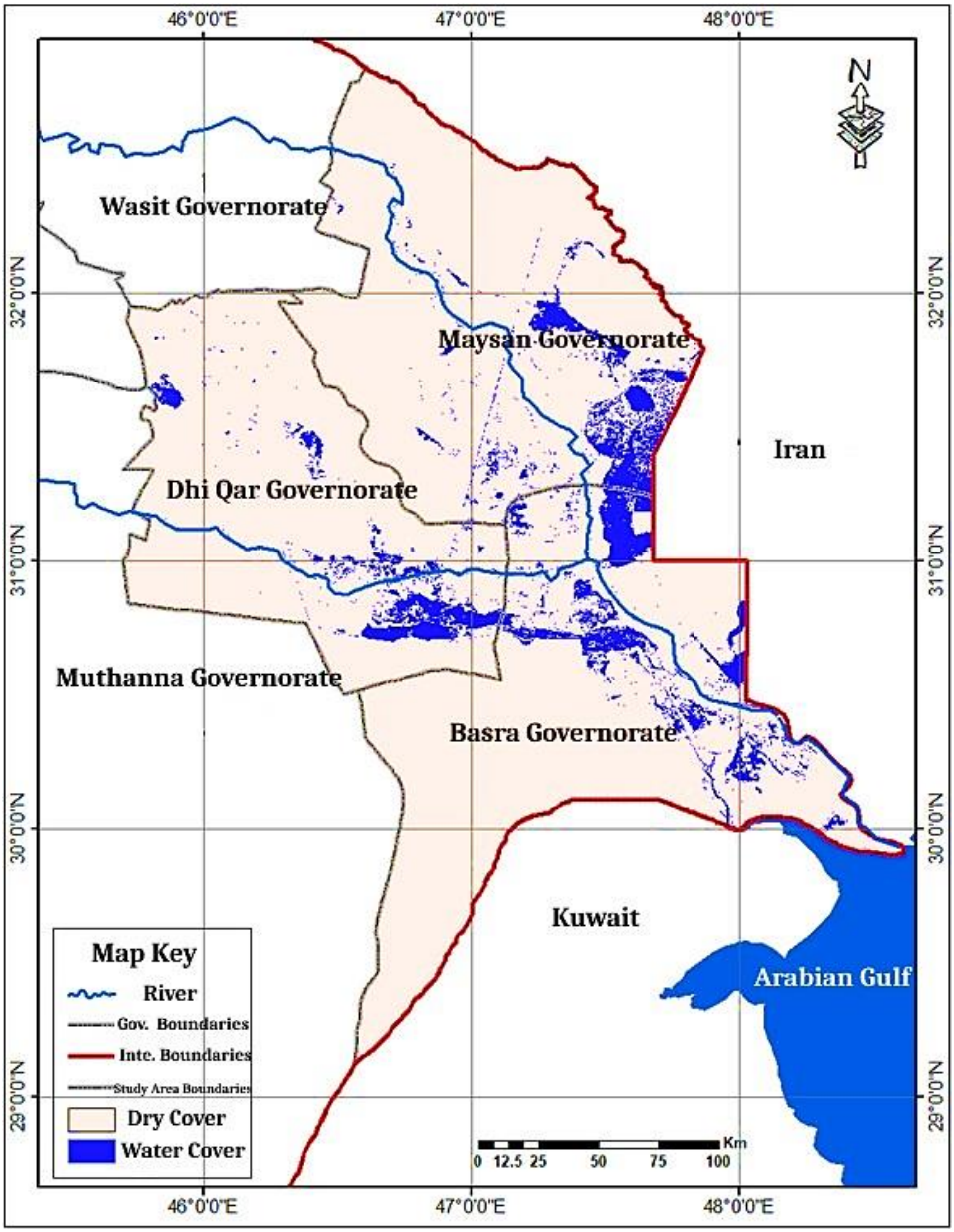
Map (3) NDWI Water Cover Index for the year 1985 in the study area

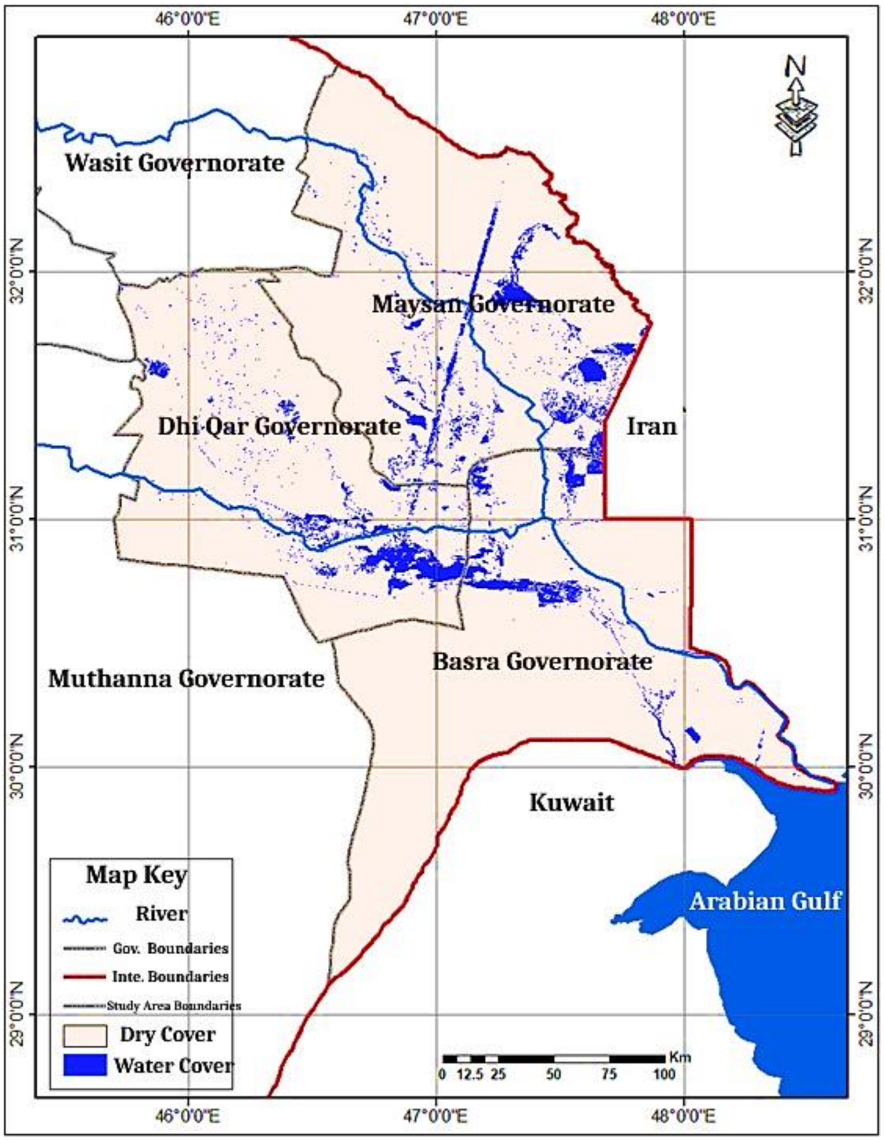


Source: The Author is based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 5 satellite, the MSS sensor, and ArcMap 10.4.2 software technologies .

Hydrological change in 1990

The area of water cover in 1990 was estimated at (2638.96 km2) and (5.52%) of the land cover class, which occupied an area of (45125.66 km2) and (94.47%), which decreased compared to 1975 and 1985, see Table (1), Figure (1) and Map (4), and this decrease is due to the decrease in the amount of precipitation, which amounted to (113.1, 48.3 and 64.1 mm) for the station of Amara, Basra and Nasiriyah, respectively Amara Basra Nasiriyah station, respectively, and the decrease in the amount of water discharges to Iraq during the 1990s, especially from the Turkish side, which stated that the waters of the Tigris and Euphrates rivers are transient Turkish waters, as the implementation of many water projects was entered, which worked to reduce the water coming to Iraq .

Map (4) NDWI Water Cover Index in 1990 in the study area

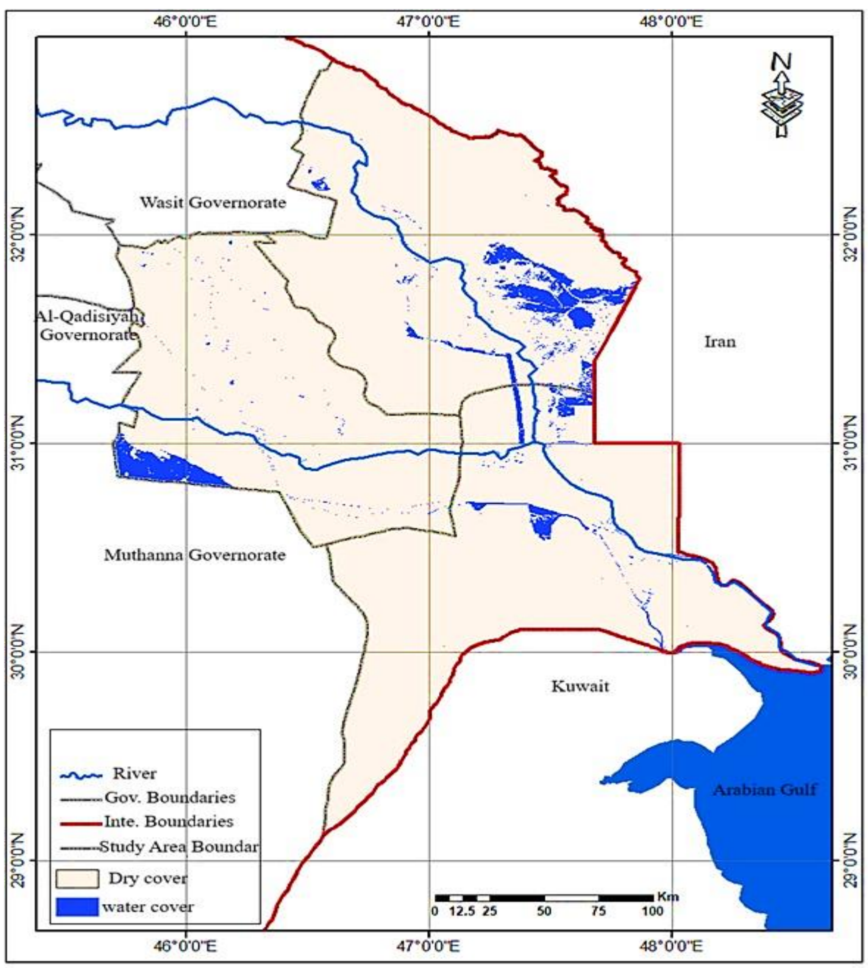


Source: Author based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 5 satellite, for the ETM sensor, and ArcMap 10.4.2 software technologies.

Hydrological change in 1995

The area of water cover for the wet season in 1995 was estimated at (2020.06 km2) and a percentage (4.22%) of the area of the land cover class, which was estimated at (45,744.56 km2) and a percentage (95.77%), which is also in a state of decline if compared to the years prior to the study, see Table (1), Figure (1) and Map (5), and the reasons for the decline in this year are due to the operations of draining the marshes. which was carried out by the former regime in a systematic engineering campaign since 1991, which affected the water cover of the study area in the decline of its area, especially for the marshes, in addition to the decrease in the amount of precipitation, which amounted to (124, 8, 132, 3, 112 mm) for the Amara Basra Nasiriyah station, respectively, as well as the decrease in water revenue .

Map (5) NDWI Water Cover Index for the year 1995 in the study area

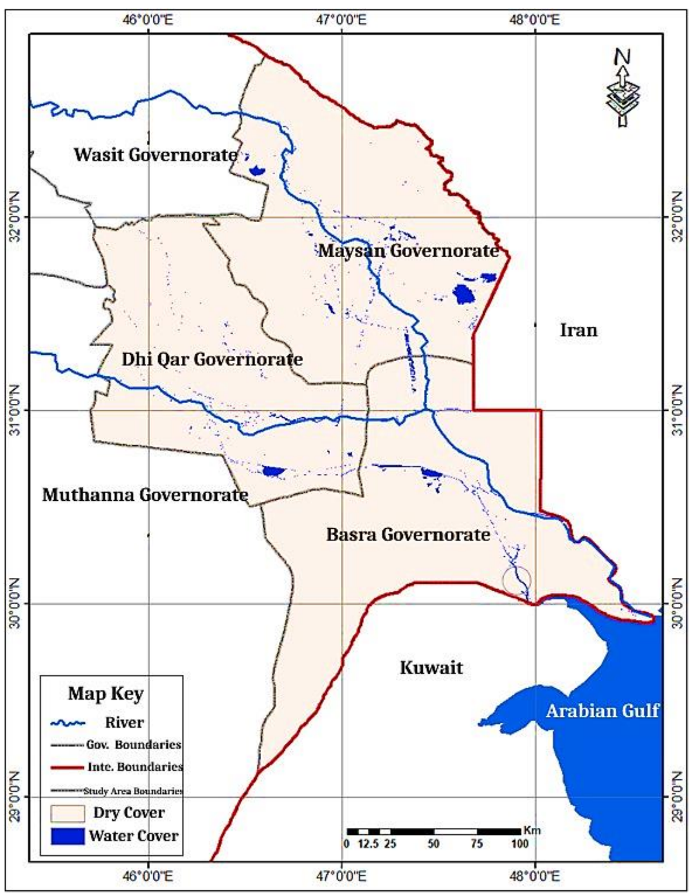


Source: Author based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 5 satellite, for the ETM sensor, and ArcMap 10.4.2 software technologies.

Hydrological change in 2000

This year is the most variable year in the area of water cover and this is shown by analyzing the satellite visualization that the area of water cover in 2000 was estimated (662,75 km2) and a percentage of (1.38%) of the land cover class, which constituted (47101,87 km2) and a percentage of (98.61%), thus the percentage of water decline is large compared to the previous study years as shown in Table (1) and Map (6) due to the decrease in river discharges, in conjunction with the drainage of the marshes carried out by the former regime, which culminated in this year, represented by the construction of artificial rivers and canals, which led to the drainage of the Hawr al-Hovaiza, and the disappearance of a very large area of the Hawr al-Hammar. This process was represented by the construction of artificial rivers and canals, which led to the drying of Hawr al-Huwayzah, and the disappearance of a very large area of Hawr al-Hammar, especially after controlling the branches of the Euphrates River that supply water to Hawr al-Hammar south of Nasiriyah (Suq al-Shuyukh) and the aim of this drying was to convert these areas into agricultural projects, but the opposite happened, as these operations had multiple environmental disasters.

Map (6) NDWI Water Cover Index for the year 2000 in the study area

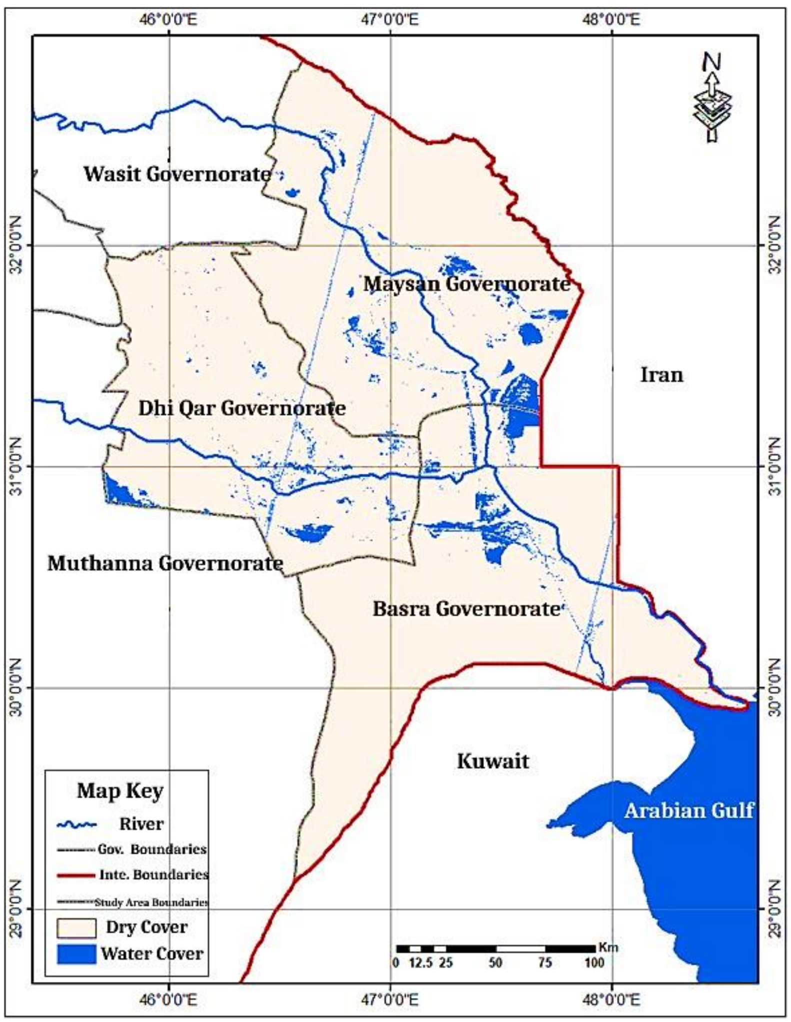


Source: Author work based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 7 satellite, for the ETM sensor, and ArcMap 10.4.2 software technologies.

Hydrological change in 2005

The area of water cover for this year was estimated (2085.14 km2) and (4.36%), of the land cover class, which was estimated (45679.48 km2) and (95.63%), which is also in a significant decline from the area of water cover from 1975 and 1985 due to different climatic conditions and increased demand for water as a result of the increase in population, but when compared with 2000 it is clear that the area in this year is higher than the year 2000 is seen Table (1) and map (7) and this is due to the revitalization of the marshes carried out by the Ministry of Water Resources that occurred after 2003, as the water was restored to flow again to the marshes and as a result of the people breaking the dams, which led to the flow of water and flooded large areas, that is, the return of part of the marshes after it was agricultural lands and turned into marshes again, which worked to increase the area of water cover .

Map (7) NDWI Water Cover Index for the year 2005 in the study area

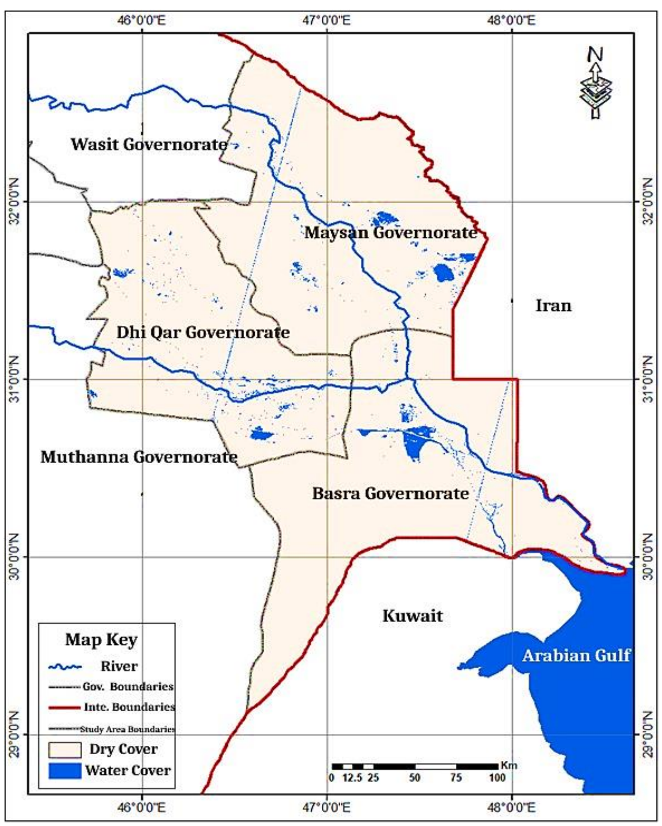


Source: Author based on data from the US Geological Survey earthexplorer.usgs.gov, Land Sat 7 satellite data, ETM sensor and ArcMap 10.4.2 software technologies.

Hydrological change in 2010

The year (2010) is considered one of the dry years that the study area witnessed, especially from the successive drought that occurred in 2008 and 2009, which led to a significant decrease in the flow of water from the Tigris and Euphrates rivers and thus the impact was reflected on the shrinking of the water areas for this year, and this is evident through the analysis of satellite visualizations for the year 2010, as the area of (1029.04 km2) and (2.15%) of the land cover class (46735.58 km2) and (97.84%) as shown in Table (1), Figure (1) and Map (8) as a result of the lack and fluctuation of rainfall, which totaled (128.3, 31.9, 57.6 mm) for the stations of Amara, Basra and Nasiriyah in addition to the low water discharges of the Tigris and Euphrates rivers in the study area. This led to a disparity in the area of water cover in the study area according to the size of the nutrition reaching it, which is subject to human control more effectively than the nature of the water year through the completion of most of the dams built on the rivers, as well as Iran's diversion of river paths into its territory, including cutting off the waters of the Karun River from feeding Sharm el-Sheikh. the Karun River from feeding the Shatt al-Arab, which affected the water level, the construction of the Ghatis Dam (west of Qurna) in 2009, which completely cut off the Euphrates River from the Shatt al-Arab, as well as the construction of an earthen dam to impound the Euphrates River between Nasiriyah and Qurna from Hawr al-Hammar, thus causing changes in surface water hydrology.

Map (8) NDWI Water Cover Index for the year 2010 in the study area

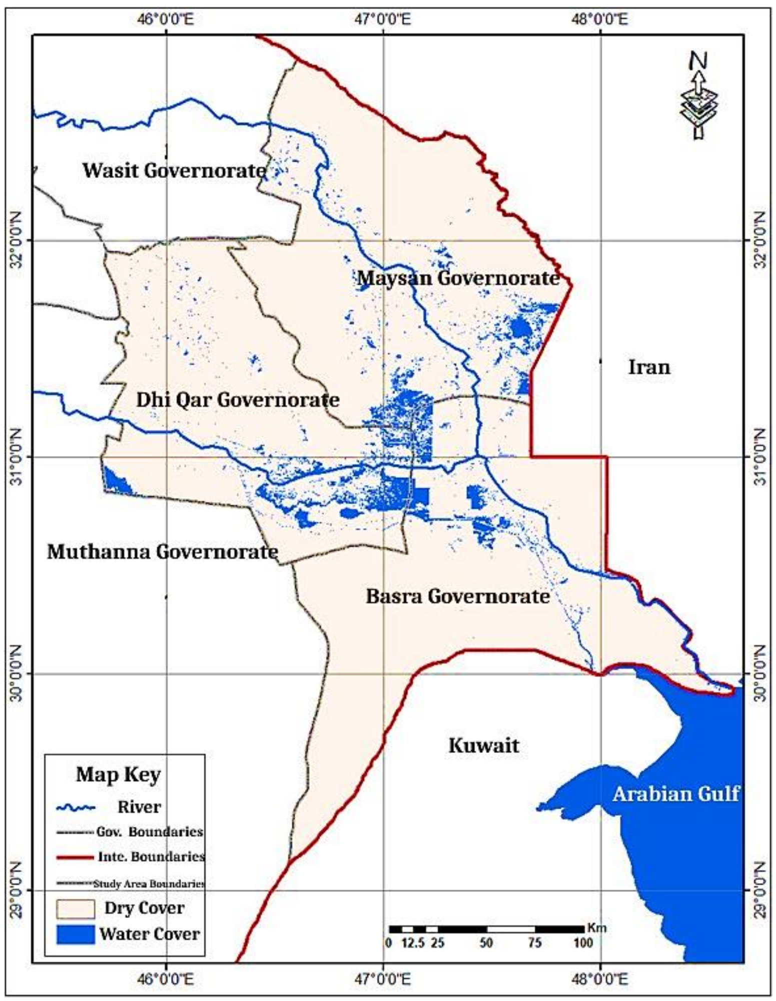


Source: Author based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 7 satellite, for the ETM sensor, and ArcMap 10.4.2 software technologies.

Hydrological change in 2015

When analyzing the satellite visualization for the year 2015 and the wet season, it became clear that the water cover class was estimated (2491.02 km2) and (5.21%) of the land cover class, which constituted an area of (45273.60 km2) and (94.78%), which is in decline compared to the previous years of the study represented in 1975, 1985 and 1990, and this is due to the different natural and human conditions occurring between them, and despite this decline, despite this decline. However, this year witnessed an improvement and increase in the water situation compared to 1995, 2000 and 2010, see map (9), table (1) and figure (1) as a result of rainfall and melting snow, which increased the flow of water to the rivers and then to the marshes, and some local efforts contributed to improving water management by reclaiming some of the water networks and working to re-submerge and revitalize the marshes with water .

Map (9) NDWI Water Cover Index for the year 2015 in the study area

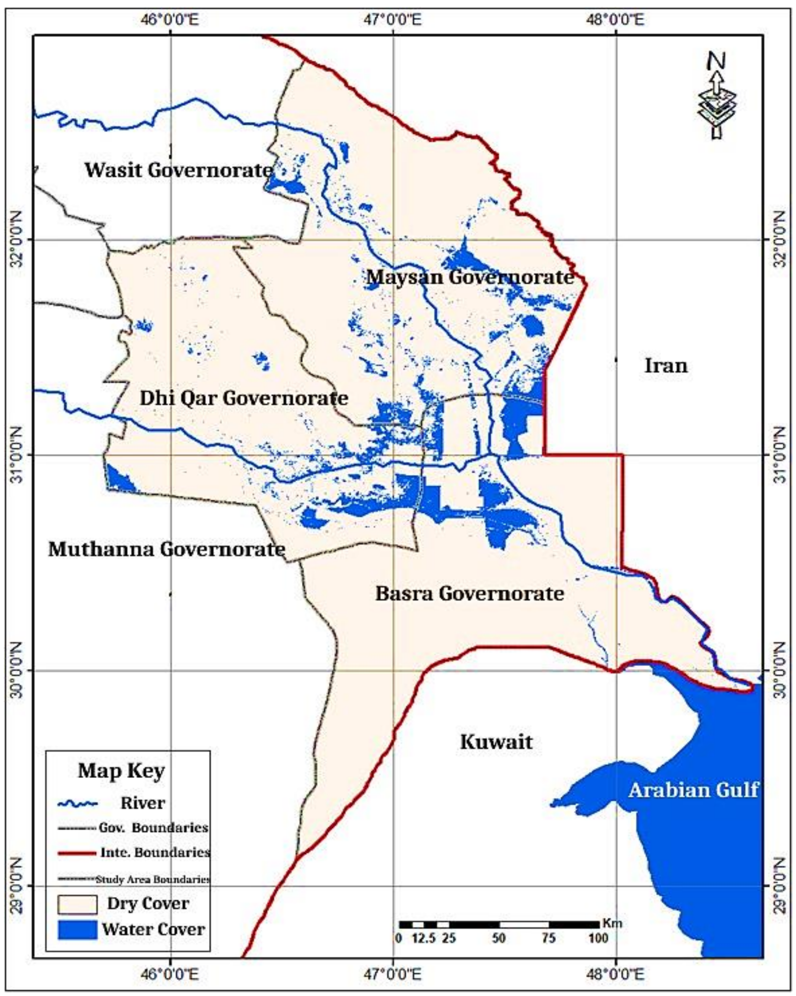


Source: Author based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 8 satellite, and ArcMap 10.4.2 software technologies

Hydrological change in 2020

It is clear from the analysis of satellite visualizations in 2020 that the area of water cover was estimated at (3577.08 km2) and a percentage (7.48%) of the land cover class of (44187.54 km2) and a percentage (92.51%) See map (10), table (1) and figure (1), which is also less than the water cover in 1975, but when compared with previous years (1995 - 2015), it is clear that there is a significant positive change in the water cover from this season. 2015), it is clear that there is a significant positive change in the water cover from this season, and the reason for this is due to the sudden climatic changes represented by the large amounts of precipitation that occurred in 2019, whether in the upstream countries or in Iraq (as it was an exceptional flood year), which led to an increase in water discharges in rivers above the absorptive capacity (i.e. there is water storage) reflected on the increase in water areas for 2020, as well as the government agencies to increase the water quotas of the marshes, especially after their inclusion on the World Heritage List in 2016.

Map (10) NDWI Water Cover Index for the year 2020 in the study area



Source: Author based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 9 satellite, for the TIRS sensor, and ArcMap 10.4.2 software technologies.

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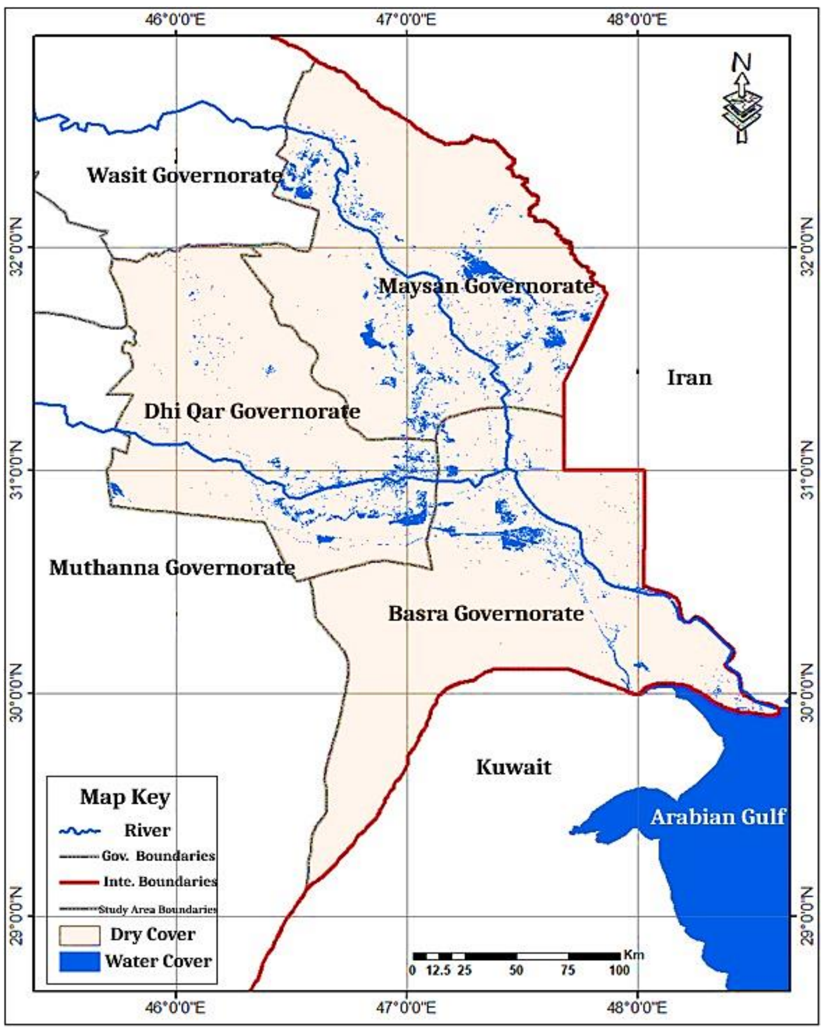
Hydrological change in 2024

The year 2024 witnessed a significant hydrological change compared to 1975 and 1985, as evidenced by Table (1), Figure (1) and Map (11), as the area of water cover decreased to (1763.92 km2) and by (3.69%) of the land cover class, which formed an area of (46000.70 km2) and by (96.30%), and this decline is due to what the region suffers from repeated drought waves from (2021 - 2024), which increased the pressure on water resources and the level of water storage decreased to 7 billion / m3 after it reached 55 billion / m3 in 2020, and as a result of the increase in water demand, if the population growth and expansion. 2024), which increased the pressure on water resources, and the level of water storage decreased to 7 billion / m3 after it reached 55 billion / m3 in 2020, and as a result of the increase in demand for water, the population growth and expansion of some uses led to increased water consumption .

Map (11) NDWI Water Cover Index for the year 2024 in the study area



Source: Author based on data from the US Geological Survey earthexplorer.usgs.gov, data from the Land Sat 8 satellite, for the TIRS sensor, and ArcMap 10.4.2 software technologies.

Conclusions

1- The natural factors represented by geology, rock quality and permeability, climate, soil and natural vegetation are factors that have a direct impact on the amount of water collected and spilled on the surface as well as control the speed of flow in the rivers and marshes of the study area and thus control the hydrological changes in southern Iraq.
2- The human factor represented by the control and storage projects and water projects established on the Tigris and Euphrates basins represented by the Turkish, Syrian, and Iranian sides, as well as those established inside Iraq, affects the amount of water reaching the study area, and due to the location of the study area in the southeastern part of Iraq, it led to the lack of water income reaching it.
3- The state's policy of draining the marshes and poor planning and management had a major role in the hydrological changes occurring in the study area.
4- Remote sensing technologies and GIS had a major role in monitoring and detecting hydrological changes during the period (1975-2024) as it was an effective and rapid tool in obtaining the best results with the least time and effort and the cheapest costs .
5- Analyzing the hydrological change maps produced for the region based on satellite visualization, which represented different hydrological years, revealed that there is a change in the water area at the annual level (6596.45 km2, 3619.97 km2, 2638.96 km2, 2020.06 km2, 662.75 km2, 2085.14 km2, 1029.14 km2, 2491.02 km2, 3577.08 km2, 1763.92 km2) for 1975, 1985, 1990, 1995, 2000, 2005, 2010, 2010, 2015, 2020 and 2024 respectively
6- The largest decline in water areas during the period (1975-2024) was in 2000, 2010, 2015, and 2024 .

Suggestions

1 -The necessity of adopting remote sensing techniques and geographic information systems in monitoring changes in the study area because it provides accurate and comprehensive information about the areas to be studied, and provides analysis, calculating areas and producing high-precision maps of the study area, which helps in making the appropriate decision to solve emergency issues, and this method is one of the least expensive and time-consuming means of studies, especially in large areas .

2 -To ensure the water quota for the study area, the study recommends the need to organize the water flow along the areas through which the rivers pass, negotiate with the Upper Basin countries (Syria, Turkey, Iran) and use international support, especially the United Nations organizations, which indicated that the drying up of the marshes is the loss of one of the lungs of the world, which must provide support for the purpose of reaching a fair and permanent agreement for the division of water that guarantees Iraq its water requirements, including the study area and the Ministry of Water Resources to organize water quotas between the governorates and work to increase water releases to the marshes and not compromise the share of the marshes.

3 -The study recommends installing modern and high-tech hydrological stations to accurately record the readings of discharges and water levels.

4 -Emphasizing coordination between research centers, universities and concerned departments in order to create a comprehensive database of water resources in Iraq and the study area, identify water issues and develop solutions to them.

9 -Work on rationalizing water in all fields.

10 -To avoid excessive water consumption, it is necessary to resort to increasing water pricing by considering water as an economic commodity.

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