The Role of Remote Sensing and Geographic Information System in Analyzing Climate Change in the Mesopotamian Marchlands, Iraq

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Research Article

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Abstract

The world's most essential natural environmental resources are the wetlands. Therefore, in Iraq, the Mesopotamia marshes are considered as the utmost significant swamplands worldwide. They are situated in the massive water meadow of Rivers Tigris and Euphrates in the lower basin of Mesopotamia. In this paper there will be a thoughtful study for the effect of climate and microclimate changing on these Marshes. Since, remote sensing tends to be the most effective approach as it is less costly and consumes fewer time, the Advanced, Very High-Resolution Radiometer is found in polar-orbiting ecological satellites to estimate NDVI the Normalized Difference Vegetation Index. Essentially, two ethereal stations located on sensor NOAA was conducted on three different marshes in the study area. A time-series observation of the AVHRR/NDVI for the period 1982-2017 of the three marshes enumerated the vagaries in the ecosystem to help determine hydrology and vegetation. The water system in Iraq is experiencing significant challenges, thus increasing concerns about the Mesopotamian marshes that have been sustaining the region for thousands of years that are likely to disappear soon.

Introduction

Wetlands are acknowledged as the world's most essential natural environmental resources. It is a critical ecosystem for animals and plant biodiversity, which provides revenue for indigenous economies through reed harvesting, nibbling for cattle, recreation and fishing. Mass aquatic plants cover the percentage of freshwater marshland surfaces. The most dominant community marshes are Phragmites australis. Most of the marshlands have vanished in many regions of the globe as a result of land use change, climate change, and human intervention (Albarakat et al., 2018). Similarly, swamps are being affected by local and regional changes in climate due to variations in hydrology, changes in land use and direct and indirect special effects in temperature fluctuations.

In Iraq, the Mesopotamia marshes are considered as the utmost significant swamplands worldwide. It is the biggest ecological unit of its kind in Western Asia and the Middle East and the home of the oldest world civilizations. Locally, the Mesopotamia marches are known as “Al-Ahwar”. They are packed within three provinces of Iraq Al-Basra, Dhiqar and Maysan, Figure (1). They are situated in the massive water meadow of Rivers Tigris and Euphrates in the lower basin of Mesopotamia. The floodplains are in a flat altitude area, created by the accretion of alluvial constituents deposited by external water from upstream (Hasab et al., 2020). Over the years, the marshland region has been experiencing variance between 20,000 km^2 and 10,500 km^2. The central marshes in the area include the Al-Huwaiza marsh, Al-Amarah or Central marshland and the Al-Hammar marsh. The Mesopotamia marshland hydrology is highly vital to the ecosystem of the whole of the upper Persian Gulf. These marshes act as natural wastewater treatment systems for the Tigris and Euphrates Rivers, which are considered a domineering part of keeping the biodiversity of the Middle East.

The rapid aridity of more than 10,000 km^2 of lakes and wetlands is bound to affect the region's microclimate significantly. With the decline in the moderation role played by the wetlands, the rates of

humidity and evapotranspiration are likely to decline considerably due to modification in the rainfall pattern (Kadhim, 2018). Furthermore, temperatures will surge invariably and notably during the hot summers. Dry and robust winds with temperatures of more than 40^0C have in the past broken the reed beds; thus, with the decline in the wetlands, they will not be hindered. With exposure to the dry marshland soil, salt crusts, and dusts, wind-blown containing impurities is likely to increase, thus affecting a vast region beyond Iraq (Lü et al., 2019). Ecological degradation on such a large scale could cause significant drawbacks to human health, such as pollution, water scarcity, exposure to extreme thermal, and possibly contaminated dust tempests carrying off dried marsh beds and saltpans. Moreover, the surrounding fragile land, initially marshlands, is probable to suffer from desertification and land dilapidation due to wind erosion as well as sand encroachment from dried marsh beds.

The marshlands have dried from anthropogenic river obstructing activities upstream and dehydrating acts influence by political interests of the 1980s and 1990s. Similarly, the construction of canals and dams on rivers Euphrates and Tigris. There has been a significant decline in vegetative cover in the three central marshes due to degradation leading to a dramatic rise in a barren land. The most damaged swamplands are the Central bogs and the Al-Hammar, where more than 90% of it is degraded (Mahmoudi et al., 2021). Only around 30% of the Al-Hamaar swamp remains intact due to the Karkha River from Iran, which continues to feed its northern parts (Albarakat et al., 2018). The massive operations have altered the drainage, considered the world's most extensive wetlands environmental adversities.

In the recent past, a number of scientific studies started to observe the bogs using Moderate Resolution Imaging Spectroradiometer (MODIS) images. This study aims to determine the relationship between vegetation indices and water cycle variables. The study displays alterations that are sign of ecological degradation. This paper targets to define the core human activities contributing to land humiliation in the Mesopotamia Marshlands, Iraq, using remote sensing and geographical information system (GIS) techniques. The study conducts a statistical analysis between the Normalized Difference Vegetation Index (NDVI) and climatological data in assessing the NDVI sensitivity and analysis of Advanced Very High-Resolution Radiometer (AVHRR) against NDVI and meteorological data to determine the trends and fluctuations in water bodies and vegetation cover.

Methods And Datasets

Area of Study

The Mesopotamian swamplands are situated in Southern Iraq between the latitude of 30.5 to 32.2N and the longitude of 46.3-47.00E. The marshlands comprise shallow freshwater lakes, some being permanent and seasonal. Therefore, the study locality is situated in a barren area resolute by mean yearly temperatures and rainfall. Figure:

Al-Hammar Marsh

The Al-Hammar is located in the southern part of the Euphrates River. The estimated area of Al-Hammar is about 2900 km2. It has permanent lakes, which are well-thought-out among the major lakes in the River Euphrates southern area, Figure (3).

The Central Swamplands

The Central swamps lie among the river Tigris and the Euphrates. They are referred to as 'Central' since they exist in the middle of marshes. It occupies an area of almost 3100 km2 and may increase to 3900km2 in flood times.

Al-Huwaiza Marsh

The Al-Huwaiza bog enlarges to Iran, wherever it links to the swamp of Al-Azim. Together, the Tigris River streams, namely Al-Kahla and Al-Mushrah canals, feed these marshes. The range of these marshes is approximately 2700 km2. Nevertheless, it can grow up to 3200km2 during periods of floods. The north portion of this marshland has huge enduring lakes having a typical deepness of about six meters.

Model Datasets and Satellite

AVHRR LTDR V5 Daily NDVI Product

The satellite concept remote sensing information has been extensively exploited to assess quantitative and qualitative changes in land cover. Over the previous two decades, distantly sensed information has been used to evaluate change recognition on a broader scale to monitor climate change (Azzawi & Abdulameer, 2022). Besides that, remote sensing also tends to be the most effective approach as it is less costly and consumes fewer time. The Advanced, Very High-Resolution Radiometer is found in polar-orbiting ecological satellites to estimate the Normalized Difference Vegetation Index. Essentially, two ethereal stations located on sensor NOAA AVHRR are recycled to compute the day-to-day value of NDVI. In this case, the NDVI is the different proportion between the red band and Near-Infrared Band alienated by the amount of the NIR and RED bands. For instance, this study used a subset of the area under study from the international dataset, ranging from 1982 to 2017. The values were extracted from these datasets and indicated the surface of the vegetation, hence neglecting the values that were less than 0.

GLDAS

The other datasets that this study uses are acquired from the GLDAS. These datasets can be accessed from NASA Goddard Earth Sciences. It integrates satellite and ground-based observational produces with the help of progressive land surface demonstrating and the adjustment of data procedures. The GLDAS is responsible for running the global exposure at perseverance of approximately 1^0.

Land Cover Classifications and Landsat Images

Since the NDVI spatial resolution is approximately 5km, the study uses a Landsat 30km thematic mapper information to define alterations in the Mesopotamian marshlands at this three-dimensional tenacity. In essence, remote sensing technology has been applied increasingly as a primary foundation of Geographic Information Systems at local, provincial, and international scales. Satellite information is extensively used to forecast ungauged basins, catchments, and groundwater (Abid et al., 2022). The study also uses ArcMap GIS to evaluate the distantly detected information by incorporating various investigative measures such as data acquirement, data dispensation and analysis, data alteration, valuation of mistakes and errors, and concluding product exhibition (Aboelnour & Engel, 2018). For instance, the supervised classification technique is essential in the ArcMap GIS software. This method is grounded on the idea of arithmetical design acknowledgment methods used for multispectral remote data sensors. Equally important, the land cover organization signifies the primary structures present on the landscape, like crops, water bodies, and forests.

In Situ Data

The meteorological information used in this study is essential in determining the relationship between rainfall and NDVI, temperature, and evaporation. The study integrates three areas: Al-Basra, Al-Nasiriyah, and Al-Amarah.

Biomass Dynamics Long-Term Trends

After that, the time successions of the NDVI were statistically assessed based on linear regression. This was essential to determine the areas that displayed a tremendous drop or a rise in the rate of NDVI.

Results

Monthly Time-Series Patterns from 1980-2017

The modification in land usage is one of the significant aspects that is dealt with in this paper. The paper uses Landsat data to display changes that have been taking place in relation to land usage over time. The mosaic output images are shown in Figure 3, for the area under study in different years between 1985 and 2009. The vegetation presented in blue-turquoise, black and red colors symbolize water bodies, and gray and yellowish-grey color represents barren areas.

The main water source for River Euphrates feeds the Al-Hammar marsh, which has less release compared to River Tigris, which provides the Al-Huwaiza and the Central wetlands. The Tigris River's high discharge rate is due to the numerous tributaries supplying it with water from the north convergence with River Euphrates in Southern Iraq (Albarakat et al., 2018). Figure 4 indicates a statistically important negative drift between 1982-2017 on both Rivers Euphrates and Tigris, which means a drop in the yearly discharge (Ziboon et al., 2022). The considerable reduction is due to construction of a vast dam in Turkey and a chain of dams in Syria and downstream Iraq. Despite a good river flow from 1990-2003, it hardly aided the marshlands (Abdollahi et al., 2021). The Euphrates and Tigris rivers that used to support the swamp

had their water sidetracked away from the swamplands, resulting in a drying operation. A report by the Iraqi Water Resources Ministry indicates that there has been a constant decline in water inflow at the Iraqi-Syria and Turkey border.

During the first phase all the swamps demonstrated high NDVI values apart from 1988-1989 because the dying operations started in the late 1980s when Sadam Hussein was in power. Throughout the entire period, the period from 1993-2003 demonstrated the least NDVI values as a result of upstream weirs and parching operations downstream across the swamplands. 1994 represents the least values of NDVI for the Mesopotamian marshes (Ziboon et al., 2022). At the time of canal and dam construction on Rivers Euphrates and Tigris, small cans from these rivers were used to feed the marshes during the diversion time. Hence the slight increase in the behavior of NDVI from 1996-1999 owing to the surge in upstream nation's precipitation and the rise in the water discharge to the marshlands through the small diversion channels. The vegetation growth in the wetlands was not affected by the precipitation because of the absence of rain in Southern Iraq. Rainfall in parched regions is scarce; hence its efficiency is minimal because of the high evaporation rate leading to nearly 80% loss of the average rainfall (Al-Quraishi & Negm, 2020). The NDVI increased from 2004-2007 due to improved human practices such as dam constructions, diversion of water supply and local and regional precipitations. The increase in the discharge rate and decline results in a drought catastrophe. After the fall of Sadam's administration, high snow and heavy precipitation were witnessed in the Anatolian Zagros highlands and Iran. The melting of the snow resulted in the increased water volume in the Euphrates and Tigris, the primary water sources for the marshlands from 2004-2008. Approximately 85% of River Euphrates flows through swamplands prior to reaching Shatt Al-Arab. Conversely, the small NDVI values from 2009 to 2017 indicate that most swampland regions have received little water because of heightened drought and the low flow of upstream water nations.

To identify variations in vegetation from 1982-2017, a long-term AVHRR/NDVI was used in each swampland. The study was grouped into three phases, the first ten years referred to as "pre-diversion", the second ten years as "diversion", and the third fourteen years "post-diversion." Figure 3 represents the NDVI monthly series from 1982-2017 in Mesopotamia, Iraq.

Validation of Areas of Vegetation Productivity for Every Marsh

Figure 4 displays the statistical test outcomes of a significant geographical vegetation cover degradation level. As a result of the dynamic nature of degradation induced by human activities like the building of weirs on the main rivers that feed the marshlands has led to a drastic decline in green biomass (NDVI). The Al-Hammar marsh green biomass for nearly four decades increased by about 13% and decreased by more than 85% (Al-Quraishi & Negm, 2020). The Central wetlands increased in vegetation cover by about 1% while demonstrating a massive vegetation degradation of around 99%. For the Al-Huwaiza marsh, the vegetation cover increased by about 16% and declined by more than 80%. The Al-Huwaiza marsh has had an increase in green biomass compared to the other wetlands since the central area of the swamp has been experiencing consistent water flow from the Karkha River from Iran during the drying operations.

Discussion And Conclusions

A time-series observation of the AVHRR/NDVI for the period 1982-2017 of the three marshes enumerated the vagaries in the ecosystem to help determine hydrology and vegetation. The observation for the three periods characterizes the effects of the anthropogenic and environmental conditions on the marshes. The Landsat images classify every marsh's temporal and spatial changes in vegetative areas and barren and water extent regions. The wetlands experienced a severe negative change in 2009 because of intense drought in the upstream countries like Syria and Turkey, in addition to a drop in water flow from Iran (Ziboon et al., 2022). Consequently, this has led to a decline in all the marshes. The region with barren land is continuously increasing, evidenced by the significant deterioration experienced by the distinct wetlands for about four decades analyzed by this research study. The statistical analyses indicate the increase and decrease in percentages of NDVI for the three marshlands, demonstrating a significant decline in vegetation cover in the area for the past forty years (Al-Quraishi et al., 2020). The vegetation degradation results from negative statistical trends in the yearly discharge of rivers Euphrates and Tigris. The dominant cause of the worsening state of the Mesopotamian marshes has been contributed to by human activities and the decline in the supply of water taken by Iraq's neighbours like Iran, Syria and Turkey (Al-Quraishi & Negm, 2020). The water system in Iraq is experiencing significant challenges, thus increasing concerns about the Mesopotamian marshes that have been sustaining the region for thousands of years that are likely to disappear soon.

Declarations

- Author Declarations:

I, the undersigned, hereby declare that this research is my own work entirely, with my own words, and that all sources used in researching it are totally acknowledged and all quotations was identified properly.

- Please make sure that all of the figures are cited/mentioned within your manuscript text.

All the figures are cited/mentioned.

- Funding:

It’s a totally self-fund.

-Conflicts of interest/Competing interests (include appropriate disclosures):

Not required for my study.

- Ethics approval/declarations (include appropriate approvals or waivers):

Also not required in my study.

- Consent to participate (include appropriate statements)

- Nazar Jameel Khalid

- Manuchehr Farajzadeh:

I agree voluntarily to take part in this study. I understand I received a copy of this consent form. I understand that photographs (audio/video recordings) taken during the study. I consent to use of my photograph (audio/video) in presentations related to this research.

Consent for publication (include appropriate statements):

I, the undersigned, give my consent for the publication of identifiable details, it can include photograph(s) and/or videos and/or case history and/or details within the text ("Material") to be published I springer.

Nazar Jameel Khalid.

-Availability of data and material/ Data availability & Code availability (software application or custom code):

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions:

Manuchehr Farajzadeh analyzed and interpreted the resulted figure and study scientific writing.

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Figures

Figure 1

Map of the Mesopotamian Marshes South of Iraq. Blue circles indicate the Marshes locations.

Remapped from the (Al-Zahery et al., 2011)

Figure 2

Image of the Mesopotamian Marshes South of Iraq. Taken from Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite, http://earthobservatory.nasa.gov/IOTD/view.php?id=38409

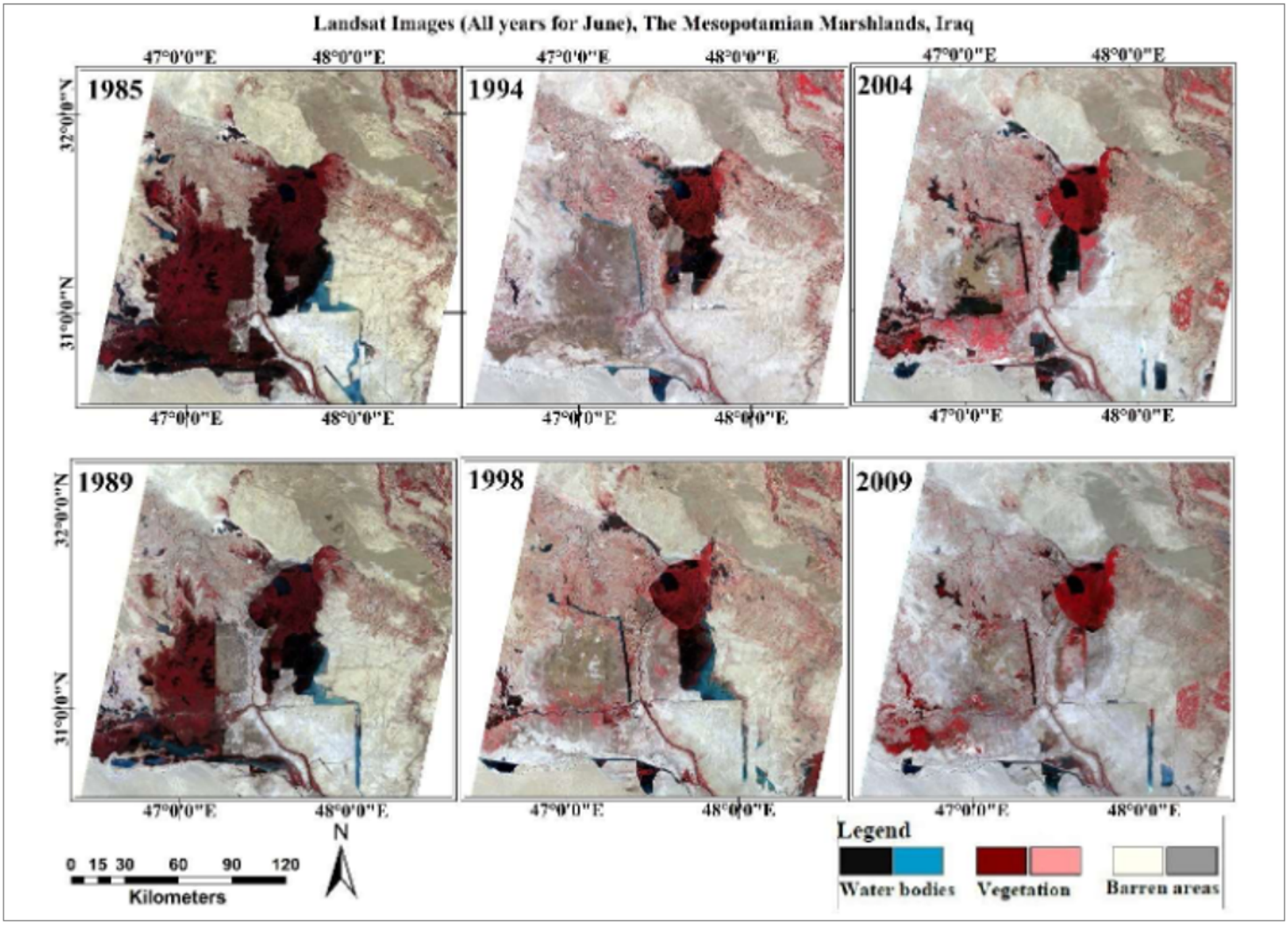

Figure 3

Mosaicked Landsat images of the areas of study between 1985-2009.

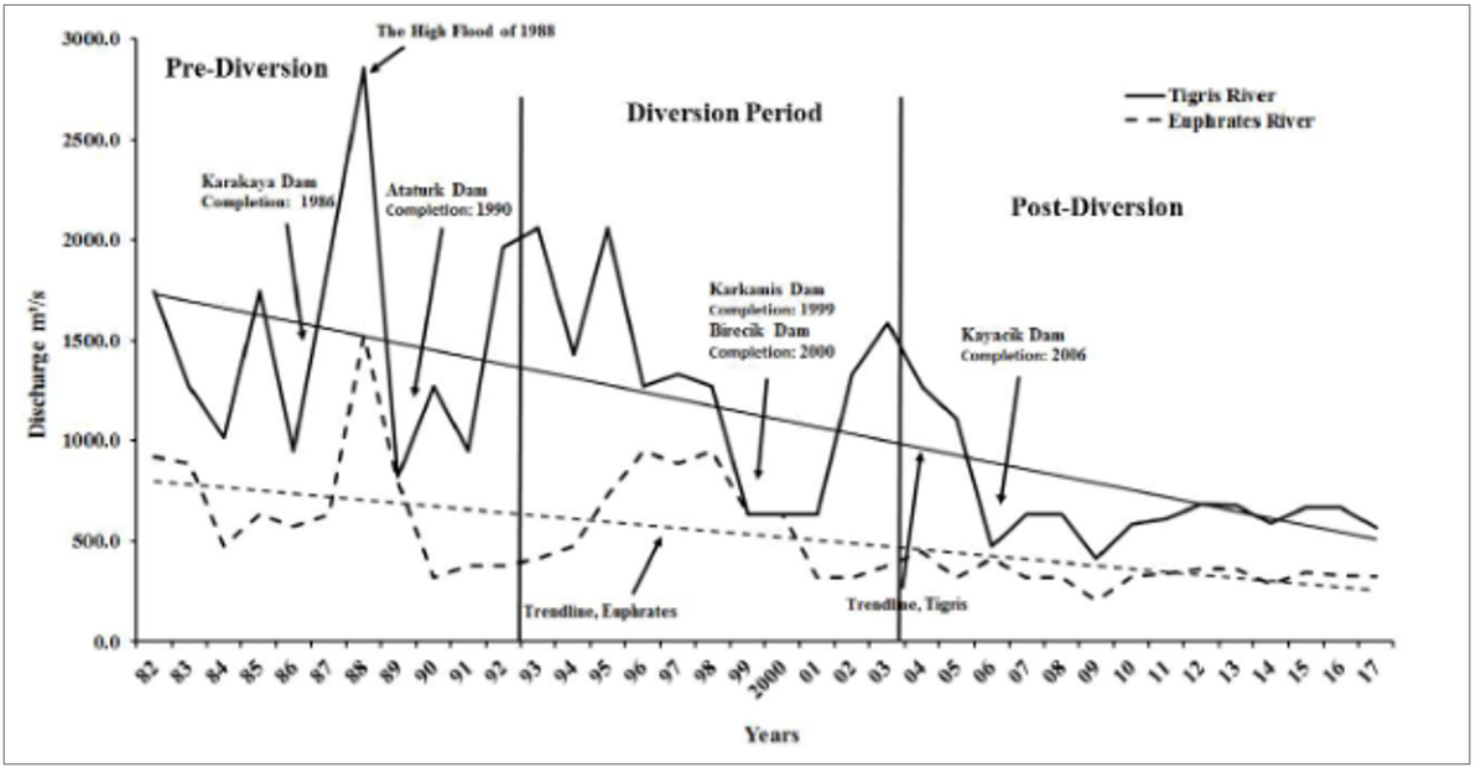

Figure 4

The Euphrates and Tigris yearly discharge (m^3/s) (The Mistry of Water Resources, Iraq).

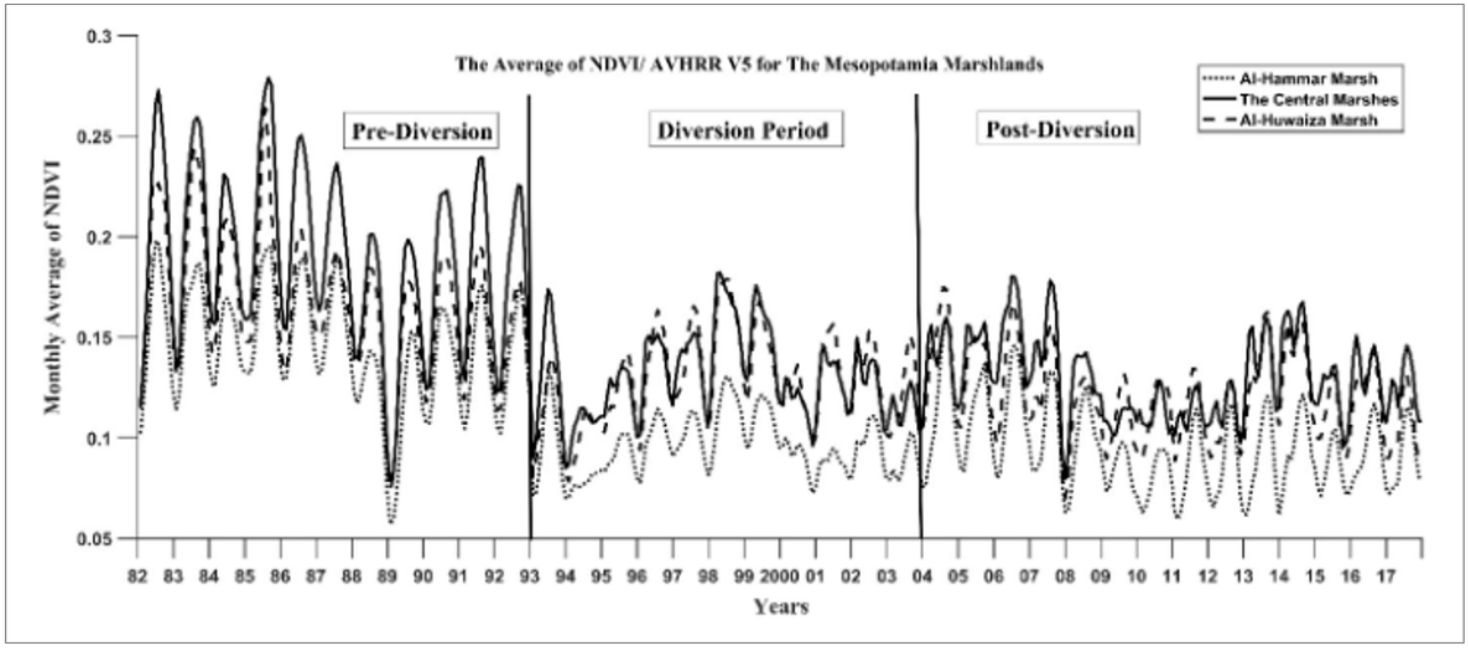

Figure 5

Monthly averages of AVHRR/NDVI daily data for the three marshes.

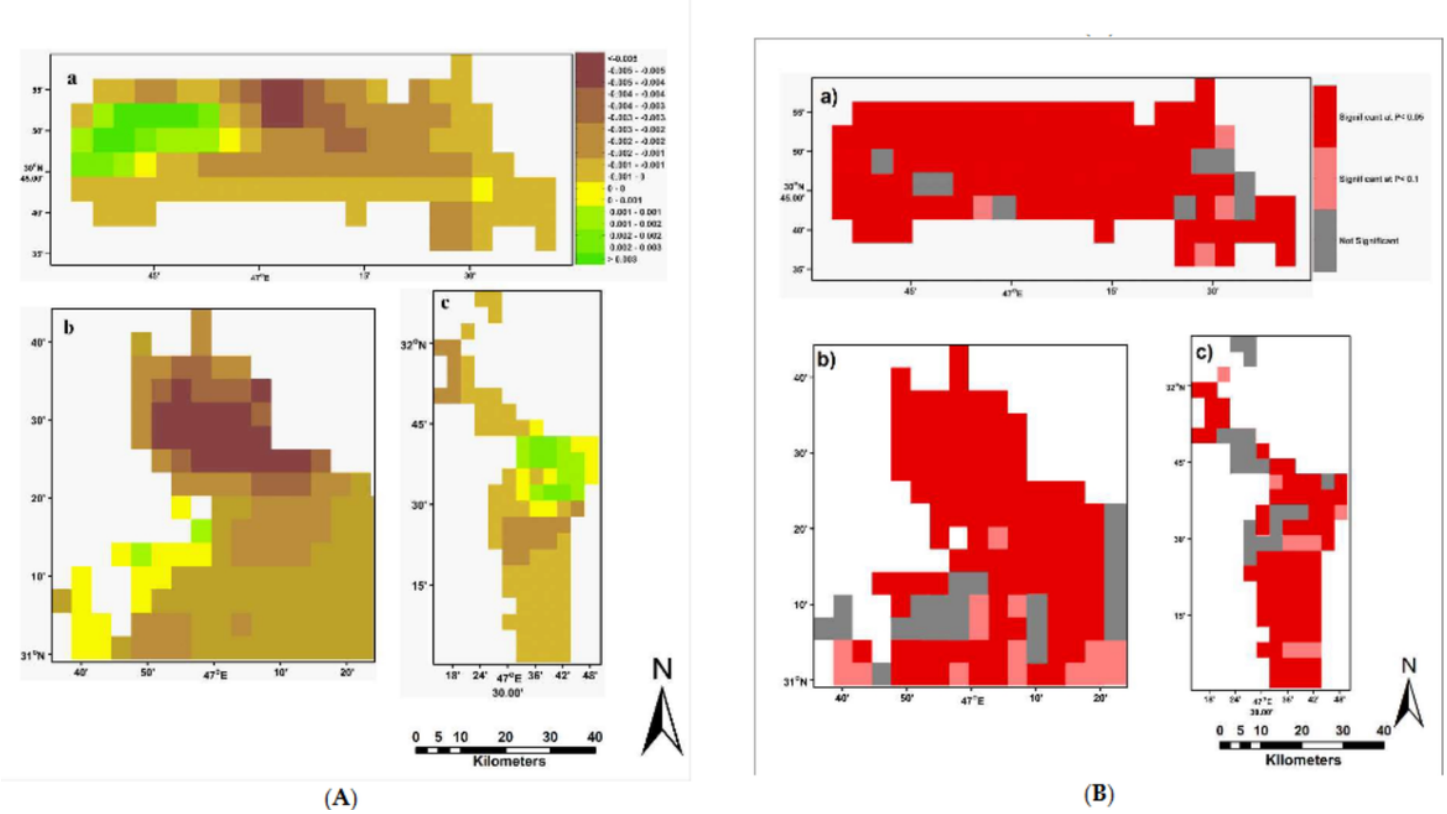

Figure 6

(A): The linear gradient of the yearly NDVI for the time 1982-2017 represents the long-term change in tendencies of green biomass in the three Mesopotamian bogs. (B) Linear slope of pixel-based significance over the age for the three Mesopotamian marshes.