JOBS مجلة العلوم الأساسية
Journal of Basic Science
Print -ISSN 2306-5249
Online-ISSN 2791-3279
العدد السابع والعشرون
٢٠٢٥م/١٤٤٦هـ
العدد السابع والعشرون
(537) (589)

المتغيرات البيئية في نهر شط العرب, منهج متعدد الاطياف والاستشعار عن بعد

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المستخلص :

واجه نهر شط العرب، وهو ممر مائي حيوي في جنوب العراق حيث يلتقي نهرا دجلة والفرات، تحولات بيئية جذرية في العقود الأخيرة. وقد أدت الأنشطة البشرية المنشأ إلى تفاقم التقلبات الطبيعية، مما أدى إلى تدهور كبير في جودة مياه النهر وسلامته البيئية.لتقييم التغيرات الطولية في النهر، تستعمل هذه الدراسة تقنيات الاستشعار عن بعد متعددة الأطياف. تشير النتائج إلى أن التوسع الحضري والجريان السطحي الزراعي وتصريف مياه الصرف الصحي غير المعالجة قد تسبب في الحرمان من الموائل وتدمير الأراضي الرطبة وتدهور التنوع البيولوجي. وقد تدهورت جودة المياه بشكل كبير على مدى العقود الثلاثة الماضية، ويرجع ذلك في المقام الأول إلى تدفق النفايات السائلة غير المعالجة والتحولات المناخية. تؤكد الدراسة على أهمية المراقبة المستمرة واستراتيجيات الإدارة الفعالة للتخفيف من هذه التحديات البيئية. ويهدف البحث، من خلال دمج بيانات الاستشعار عن بعد، إلى إبلاغ القرارات المتعلقة بالسياسات ورفع مستوى الفهم العام لأهمية نهر شط العرب. وفي نهاية المطاف، يؤكد هذا العمل على ضرورة الإدارة المستدامة للموارد المائية للحفاظ على صحة النهر ودعم المجتمعات التي تعتمد عليه. تقدم الدراسة تقييماً شاملاً للتغيرات البيئية في نهر شط العرب باستعمال نهج الاستشعار عن بعد متعدد الأطياف. وتسلط النتائج الضوء على الحاجة الملحة لاتخاذ تدابير استباقية لمعالجة تدهور نوعية المياه في النهر والنظام البيئي .

الكلمات المفتاحية: نهر شط العرب ، الاستشعار عن بُعد ، جودة المياه ، التغييرات البيئية ، التصوير متعدد الأطياف ، التصوير المتعدد الأطياف .

Environmental Changes in the Shatt al-Arab River: A Multispectral Remote Sensing Approach

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Abstract:

The Shatt al-Arab River, where the Euphrates and the Tigris rivers meet (often thought of as one of the most vital waterways in southern Iraq), has changed often unrecognizably in terms of its ecosystem over the last several decades. Although the water quality and ecological condition of the river naturally varies over time, human activity has intensified these variations, resulting in serious decline in both the quality of water and the ecological health of the river. This study uses multispectral remote sensing methods to evaluate the changes in the river over its long developmental history. The results suggest that urban sprawl, agricultural runoff, and the inflow of untreated wastewater have caused habitat loss, wetland destruction, and biodiversity loss. While the quality of water has worsened terribly over the last three decades, mainly because of the discharges of untreated effluents and changing climate. These ecological challenges highlight the need for monitoring and management strategies, the authors said. The objective is to quality data with remote sensing to support policy decisions and increase public awareness of the importance of the Shatt al-Arab River. The original study highlights the importance of the sustainable management of water resources to protect the health of the river and the communities that depend on it. Shatt al-Arab River requires a multispectral remote sensing approach to comprehensive assessment, and this study is one of the few studies to provide such assessment between 1988 and 2022. Ultimately, this requires urgently addressing the deteriorating water quality and ecosystem of the river, as the findings have significant consequences on the region's water security and biodiversity conservation.

Keywords: Shatt al-Arab River, Remote Sensing, Water Quality, Environmental Changes, Multispectral Imagery, Multispectral Imagery.

1. Introduction

Sustainable water resources management for the benefit of a nation is a complex challenge (Hasan, 2018). A thorough understanding of water supply and water quality is essential for water resources management at all scales, from national, state, and basin planning to operational, real-time decisions. Therefore, it is crucial to put together how the natural and human factors affect water supply and water quality, and it is beneficial to use satellite remote sensing for this purpose.

Estuaries play an important role in the biological productivity of our global ecosystem and are amongst the most valuable natural resources on earth. (Whitfield et al., 2022) With the rapid growth of human population, the discharge of pollutants into the aquatic environment has increased tremendously, which has led to environmental changes in estuaries throughout the world. Effective monitoring and management of environmental status and changes in waters have drawn increasing attention from governments, industries and public in recent decades. In particular, satellites or remote-sensing techniques can provide crucial information on large-scale and ongoing environmental status and changes in estuaries. The Shatt al-Arab River delta, a newly modified estuary and the only outlet channel of the large water system including the Tigris, Euphrates and Karoon Rivers, has been experiencing severe environmental changes, including habitat loss, wetland destruction, drop of biodiversity and water quality deterioration. However, the chain of driving natural and anthropogenic factors that led to such environmental changes in this delta, as well as their relative importance remain poorly understood. Satellite remote sensing could help in this respect through provision of multi-spectral data that reflects the environmental status and changes in the delta and diverse driving factors.

2. Importance of the Shatt al-Arab River

The Shatt Al-Arab River (R) is one of the most important rivers in Iraq and was historically the foundation of the region’s wealth and prosperity. It provides water needed to sustain domestic, agricultural, industrial, natural ecosystems, transportation, and recreational purposes. Moreover, the river constitutes the main freshwater source for the Arabian Gulf and supports the marine habitats in the coastal areas of the Gulf. (Mawat and Hamdan2023) The Shatt Al-Arab consists of both the Tigris and Euphrates rivers and has a basin area of approximately 580,000 km2 and a length of about 260 km. The confluence of the two rivers in Al-Qurna city of the Qadisiyah Governorate generates several tributaries that meander through the land before delineating a new pathway into the Gulf, creating the greatest delta in the region (Hasan, 2018). Extensive marshes abound the delta characterized by high ecological productivity resulting from the interaction between the freshwater, saline water, and mudflats constituting one of the greatest wetlands in the world. The marshes act as a valuable habitat for various biodiversity and a seasonal refuge for migrating birds. They stabilize land against recession due to tsunamis, storms, and other natural phenomena and provide recreational opportunities for ecotourism. Sadly, the Shatt Al-Arab water quality has remarkably deteriorated in the last three decades due to anthropogenic activities, especially in southern Iraq (Ali and Amjed2021). The increasing amounts of untreated wastewater and runoff from the surrounding oil production fields, urbanized areas, and agricultural lands have resulted in declines in water quality. The Mesopotamian marshes draining into the Shatt al-Arab, which once acted as a powerful filter for pollutants, are still far from adequate restoration after the deliberate desiccation in the 1990s (Allafta & Opp, 2020). Water quality in the river has recently reached alarmingly low levels with respect to nutrients, heavy metals, and bacteria, posing serious threats to human health and the environment. These adverse conditions have drawn great public concern and triggered various responses from Iraq. Addressing these concerns requires the appropriate monitoring and management of both the resources within the river itself and those from the surrounding land that ultimately drain into it (Fig.1). With these considerations in mind, a better understanding of the spatial and temporal variations in water quality in the river is essential. However, conventional monitoring programs for this river are limited in scope and irregular in time, making them unsuitable for addressing these issues. Satellite-data-based approaches potentially allow for better monitoring of this and similar rivers.

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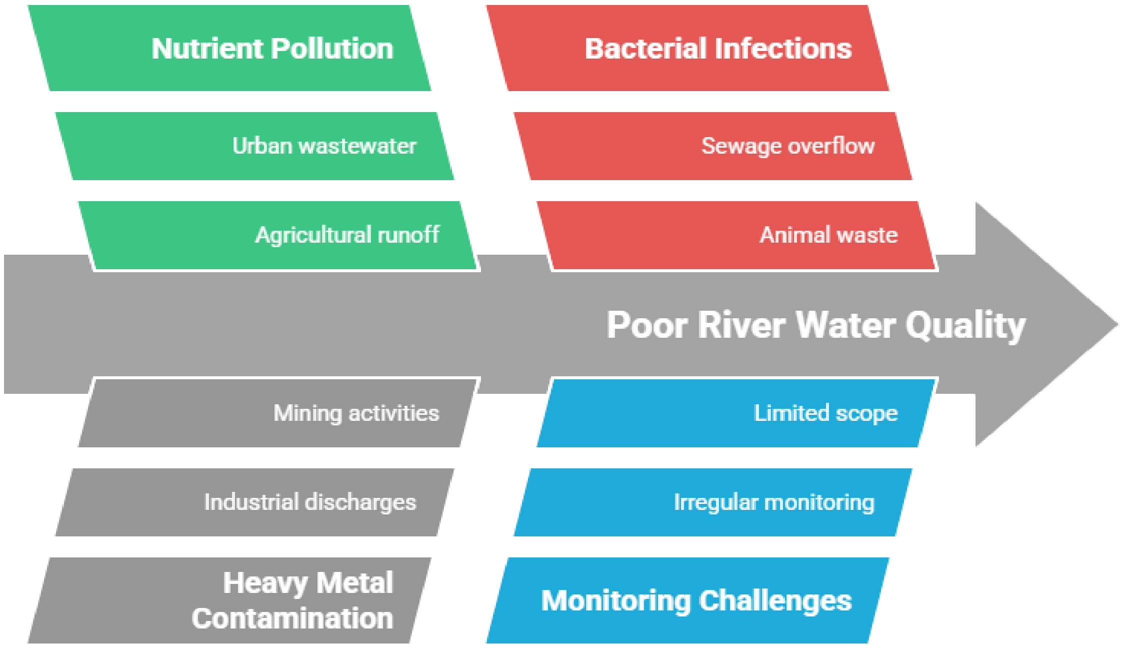

Fig.1. Water quality sources.

2.1. Ecological Significance

The Shatt al-Arab River and its associated wetlands represent the largest hydrological system in the Middle East, encompassing an area of approximately 165,000 km2. The Euphrates, Tigris, and Karun rivers and 14 smaller rivers flow into it. The Shatt al-Arab and its associated wetlands provide a hydro-geological, ecological, and cultural richness of great conservation interest. Known for its biocultural diversity, the Shatt al-Arab River system displays complex interactions between environment and history (Albarakat et al., 2018). Species, landscapes, and practices persistently shaped this hydrosystem, proving that simultaneously conserving ecological and cultural diversity is only possible if the structural links connecting both are maintained. However, due to anthropogenic and environmental impacts, the area is undergoing profound changes in its ecosystem functioning and cultural practices. A better understanding of these links, as well as of the ongoing environmental changes is necessary for effective conservation actions (Schipper et al.2021)(El Zaatari & Maalouf, 2022).

Hydrological changes with a surface extent <2,000 km2 account for 63% of the total surface area changes of the Shatt al-Arab River system between 1947 and 2016, providing compelling evidence for significant drainage and/or sediment erosion events, as well as severe and fast aquifer over-exploitation, water extraction, and sediment deposition. The development of dams on the upper Euphrates River and the Turkish tributaries of the Tigris River and on the Iranian Karun River has brought about substantial reductions in the flooding burdens of the Shatt al-Arab River system. In the 1970s, the gradual diversion of major tributaries by the Iranians altered the average discharge regime of the hydrosystem, with massive reductions in annual flooding events, soil salinization, and consequently diminishing plant cover. Since the late 1980s, Iraq has also initiated severe drainage of the two main tributaries of the Mesopotamian Marshlands, bringing about a profound decline of the water table, receding marshlands, and rapid descent of water quality.

2.2. Economic Importance

The Shatt Al-Arab River (SAR) is one of the major rivers in the world, formed by the confluence of the Euphrates and Tigris rivers. It is approximately 200 km long and flows north-south from Al-Qurnah to Al-Fao in the Iraqi territory, then to the Arabian Gulf. An integral part of the river is the Huwaiza Marsh which is located on its right bank within Iraq, sharing borders with Iran on its left bank (Allafta & Opp, 2020). Near the town of Al-Fao, the river forms an estuary before discharging into the Arabian Gulf. The SAR accommodates Ard-eyer marsh and Khor Al-Zubair on its right bank within the territory of Iraq. It is bound by Al-Faw, Abu-Khasib, and Al-Mawdah marshes on the opposite bank in Iran. It contains five major islands namely Buzurgan, Mardum, Oum-ete, Kharqa, and Tir in addition to several small islets. The SAR is the third largest river in terms of the volumetric outflow into the oceans after the Amazon and Congo rivers.

The SAR has an important role in the economy of Iraq as a vital source for drinking water, agriculture, fisheries, navigation, and tourism. It has many urban centers along its bank which are directly affected by its water quality and quantity. It is also an important ecosystem supporting diversity of wildlife, flora, and fauna. However, the river has long been neglected by decision-makers and local authorities which adversely affected the water quality and ecosystem. Most of the sediments of the river and its branches are considered as polluted due to the rapid development of the oil industry, wastewaters, intensive agriculture, and unregulated urbanization. Figure 2 shows the Shatt Al-Arab River with its geographical and ecological significance

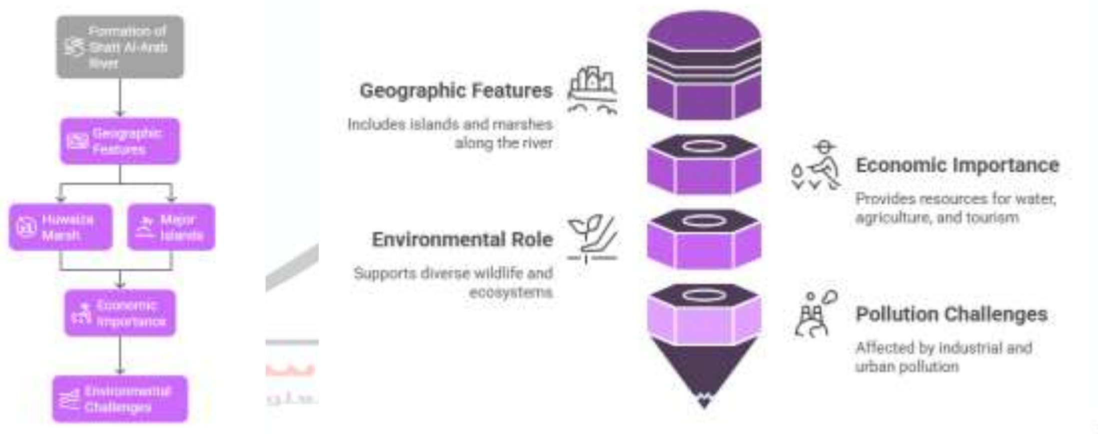

Fig.2. Shatt Al-Arab River with its geographical and ecological significance

3. Remote Sensing Techniques

Remote sensing based information can be used to assist the understanding of and management of the dynamic interactions between environmental change and river channel behaviour. Landsat MSS image data has helped to develop predictive channel evolution regime for the case of a large sand bed river in Canada experiencing channel change due to anthropogenic modification of sediment supply, and change in climate (Fig.3) . In the last decade there have been advances in optical and near infra-red remote sensing techniques for generating river channel topography and river surface sediment size information necessary for understanding and modelling river hydraulics and geomorphology (Harada, 2017).

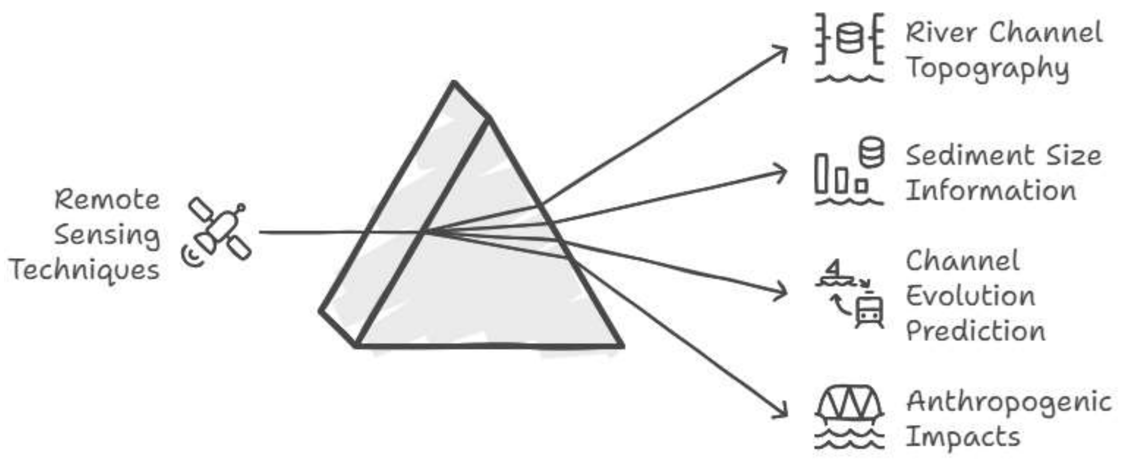

Fig.3. River dynamic with Remote Sensing

Active remote sensing techniques using laser radars or RADAR have been intensively used to measure topography information over vast geospatial areas, such as airborne LIDAR systems and airborne interferometric SAR. The LIDAR water surface penetration effect provides unique opportunity to measure bathymetric depth of water bodies in canals, ponds, and rivers. In shallow river environment, rapid change in bathymetric depth over short distance may not be observed. Also, at least LiDAR measurement generally requires expensive sensors and aircraft platforms, and needs good weather conditions. There should be relatively inexpensive passive remote sensing approaches using commonly available zoomed

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Print -ISSN 2306-5249
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optical cameras or multi-spectral sensors. As shown in the diagram below (Fig.4), passive optical methods are most suitable for shallow waters (<60m depth). Within this range, several cost-effective approaches can be implemented.

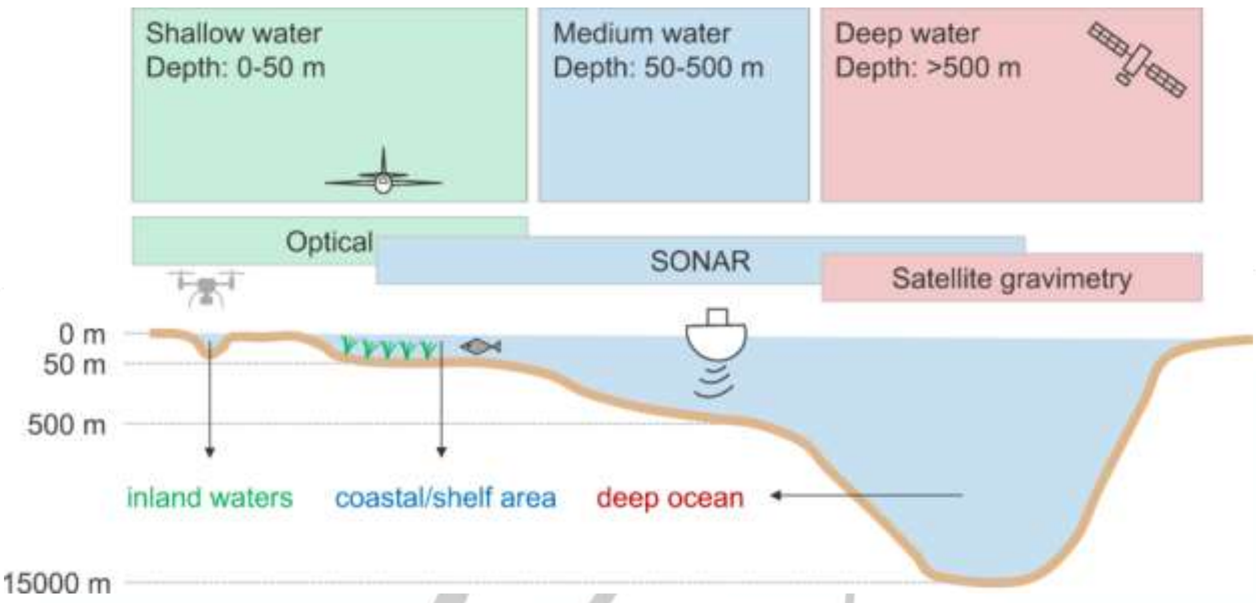

Fig.4. Depth Range Considerations for LiDAR

3.1. Overview of Multispectral Remote Sensing

Remote sensing is a means of collecting, analyzing, and interpreting data regarding the Earth's surface and its process. Remote sensing refers to the measurement of properties of an object or phenomenon by a recording device that is not in physical contact with the object phenomenon under study. Various devices exist in the remote sensing domain to collect the data, and they can be grouped into different categories based on the type of data collected. The data types that are related to physical rather utilizing other information to extract data are categorized into telemetry and non-telemetry data. Non-telemetry data includes studies of the land surface topography, geology, mining, or any feature seen by the naked eyes (Fig.5). The current study focuses on monitoring environmental changes such as vegetation growth and its amount, and this is done by using multispectral remote sensing which is telemetry data.

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Journal of Basic Science
Print -ISSN 2306-5249
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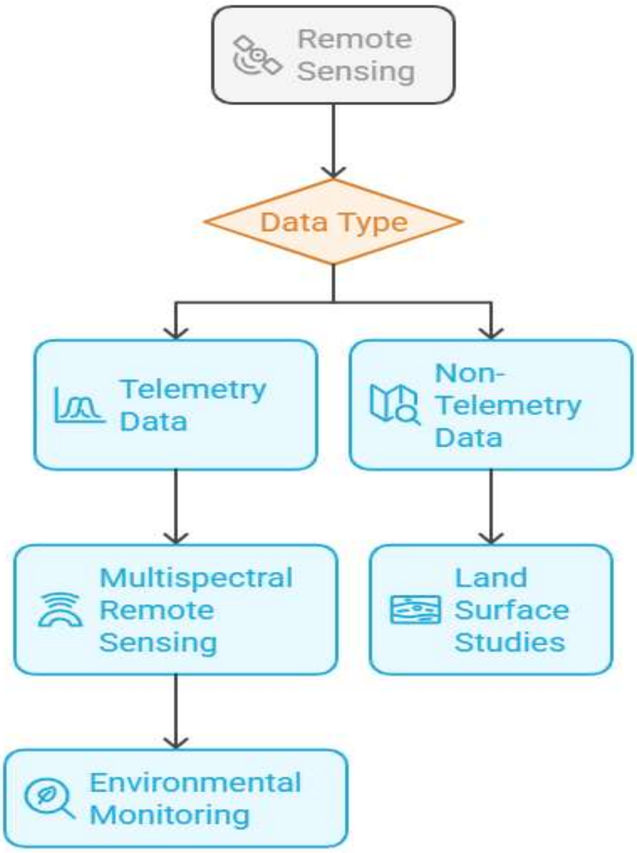

Fig.5. Remote Sensing Data Collection and Analysis

Telemetry remote sensing includes radar systems that work at different properties. Multispectral imagery is a tool investigated in the current study which uses passive systems that intercept the reflected energy from the sun incident on the Earth surface. The data collected using these systems represent the surface reflectance at different bands across the electromagnetic spectrum (Fig.6). Earth Observation data are of two types: positions and surveys. Surveys remotely source recorded images of the targets in the earth and in different spectral ranges. This study investigates multispectral remote sensing data. Current day's survey satellites have an attractive fine/low resolution capability. Significant data are accessible for free with good quality and data processing tools are developed and spread widely.

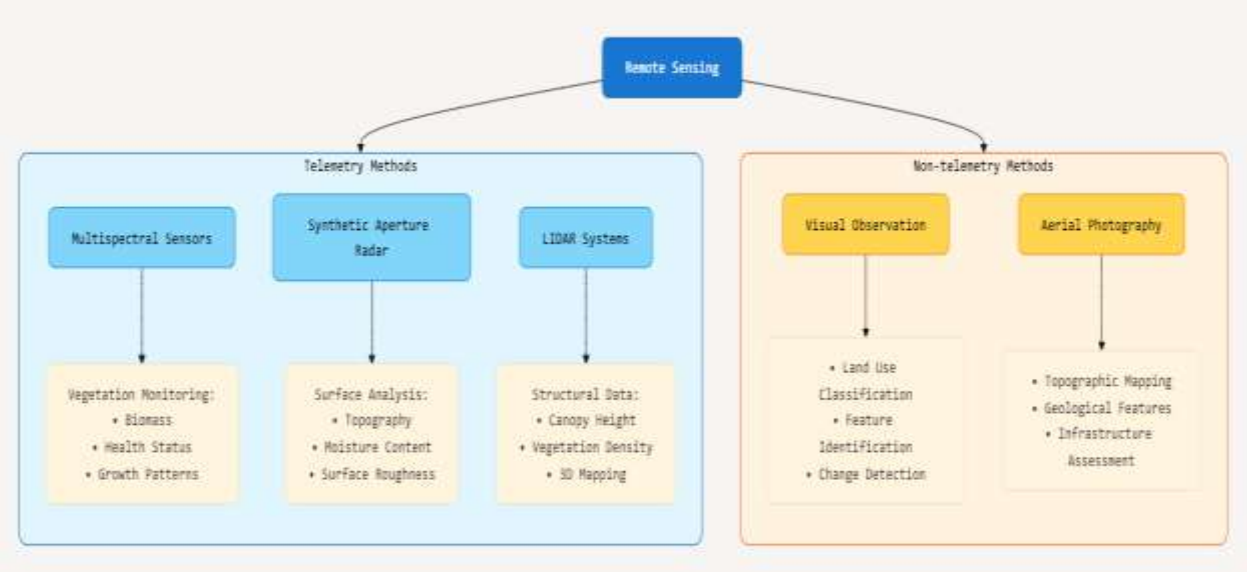

Fig.6. The telemetry methods and applications

The surface reflectance is a function of the physics dictating the conditions of the receiving system and the environment of the object examined. Calibration models can contain different variables based on spatial, spectral, and temporal characteristics. The reflectance data which signal the condition of the sensor is called surface reflectance. The multispectral surface reflectance data needs to be corrected for the sun target system, atmospheric effect, cloud effect, and spectral effect. Inputs in this category represent the surface reflectance without the effects explained above.

3.2. Satellite Imagery and Data Capture

The imagery data for this study includes a total of 51 Landsat images spanning the years 1986–2022. The characteristics of the Landsat data and each individual satellite image applied for this study are provided in the appendices. The primary images used in this study—including Landsat 5 TM, 7 ETM+, and 8 OLI/TIRS data—were obtained from a public source. The collected images were either geometrically corrected or come with different projections. All the satellite images were resampled to a common

Universal Transverse Mercator (UTM) projection. To fill in the gaps in the Landsat datasets due to the loss of data collection occasions or poor-quality images, the Sentinel-2A imagery dataset was utilized from 2016 to 2022. This satellite constellation provides Level-1C and Level-2A products. For this study, MultiSpectral Instrument (MSI) 10 m Level-2A products were selected. 10–60 m products are available depending on the spectral bands. This data set includes 13 spectral bands; however, only coastal aerosol 0600–0680 nm, blue 458–523 nm, green 543–578 nm, red 646–673 nm, red-edge 705–740 nm, and near-infrared 783–865 nm bands were used for this study. The images were processed to surface reflectance (SR) and resampled to 10 m spatial resolution using the bilinear interpolation method. The dates and specifications of the acquired Sentinel-2 images are shown in the appendices.

The dataset of MODIS Aqua reflects data in 36 spectral bands from 0.417 to 14.385 micrometers with a spatial resolution of 250 to 1,000 m, varying by band. It was established by a space agency. MODIS Aqua reflects have daily data with a 1,000 m resolution and an 8-day composite covering seven land surface reflectance bands. Data were retrieved for the year 2022 when no cloudy images were found in level sensing data. The data were 1,000 m in spatial resolution but were resampled to 500 m in the time series. This data had been found and filtered cloud pixels using an algorithm. This product has a quality band indicating valid pixels. A valid count of pixels was used in the main time series, and the scene was transformed onto a specific method.

4. Water Quality Monitoring

Water quality of rivers and lakes is an important indicator of ecosystem conditions and a key factor for human survival. With the rapid development of the Internet of Things, satellite remote sensing has become an important means of water quality monitoring. Different from traditional water quality detection based on field sampling and laboratory analysis, satellite detection and monitoring methods have been developed for some water quality parameters of large and typical lakes and rivers, e.g., the optical detection of total phosphorus and chlorophyll-a of Taihu Lake. Serious environmental changes have occurred in the Shatt al-Arab River due to long-term armed conflict, human interventions, and time-varying climate conditions. The developments of human activities in the basin form a triplet system to analyze their influences on the river change. The data from multi-source remote sensing satellites is able to provide spatially availed observations to recover the unique lateral color of the river.

Traditional vs Modern Monitoring Approaches

Traditional water quality monitoring relied heavily on manual field sampling followed by laboratory analysis. While accurate, this method had several limitations:

- Limited spatial coverage
- Time-consuming process
- High operational costs
- Delayed response times

Modern satellite remote sensing and IoT technologies have transformed this landscape by providing:

- Real-time continuous monitoring
- Extensive spatial coverage
- Cost-effective operations
- Immediate response capabilities

Key Parameters Monitored

Modern water quality monitoring systems track multiple critical parameters :

1. Physical Parameters:

- pH levels
- Temperature
- Turbidity
- Conductivity

2. Chemical Parameters:

- Dissolved oxygen
- Total dissolved solids (TDS)
- Chemical oxygen demand (COD)
- Ammonia nitrogen

Two approaches are to obtain the temperature and turbidity through shallow water retrieval algorithm and deep water retrieval algorithm. First, some training and testing data are obtained from the multispectral imagery, and then the relationship between the temperature or turbidity and the corresponding band combinations are built through the random forest model. Finally, the above relationships are applied to produce a long-time series of raster images of the temperature and turbidity as shown in figure 7 as the process flowchart.

7-Fig: Flowchart for Water Temperature and Turbidity Retrieval Process

The importance of integrating climate considerations into the objective of human development and the measurements of success there of has been globally recognized. However, climate evaluations are complex and there are no objectively constructed assessments that effectively quantify the climate adaptability of human development. It is proposed a novel method for climate evaluations, which directly applies objective and stringent evaluations of the climate sustainability of global human development and its interactions.

The multi-source remote sensing data of the Shatt al-Arab River is acquired. The K-means clustering algorithm is used to produce a distribution map of river water. Based on the stroke width transform, colour enhancement and fusion algorithms, the water colour images are generated from optical images. Different river colour indices are extracted to find the most suitable index for representative water colour. Then, multi-source river water colour histories are reconstructed, and the river water colour change is evaluated using a random walk model. Finally, the impacts of climate, vegetation, and

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human activities on the river colour change are explored through sensitivity analysis.

4.1. Parameters of Water Quality

Water quality is a complex issue of great importance that governs the ecological, microbial, hydrological, and geomorphological conditions of the entire correlative area. River water experiences a number of physical, chemical, and biological influences from the catchment area, besides the site-specific anthropogenic developments. Intensive urbanization, commercial and industrial growth, agriculture, landscape alteration, and mining activities have caused serious water pollution and deterioration of water quality. Continuous monitoring of water quality in rivers is critical as it reflects the quality and dynamics of pollutant sources and helps in assessing river pollution status, its influences on other compartments of the wider ecosystem, and preventing further degradation. High sensitivity of inland water quality and its ability to reflect environmental changes such as climate change, land cover, and land use has led to progressively more continuous monitoring of such changes and patterns. The utilization of satellite remote sensing techniques has great potential for the continuous, easy, repeated, and cost-effective water-quality monitoring for inland water bodies, especially due to the low-tech and high cost of continuous ground-based water-quality monitoring stations and equipment. However, employing remote sensing techniques to measure water-quality parameters in coastal and estuary waters have shown mixed results.

Remote Sensing Applications and Capabilities

Remote sensing technology enables the examination of spatial and temporal fluctuations in water quality variables , offering several key advantages:

- Comprehensive spatial coverage of large water bodies
- Regular monitoring intervals for trend analysis
- Cost-effective compared to extensive ground-based networks
- Ability to track environmental changes and patterns
- Integration with machine learning algorithms for enhanced accuracy

Challenges in Implementation

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Several significant challenges affect the effectiveness of remote sensing in water quality monitoring:

1. **Technical Constraints**

- Cloud cover interference with passive sensors
- Limited penetration depth in turbid waters
- Spatial, temporal, and spectral resolution limitations
- Difficulty measuring vertical distribution of parameters

Environmental Factors

- Atmospheric interference affecting optical measurements
- Complex interactions between water constituents
- Limited visibility in high-sediment waters (penetration reduced to 60cm at 400mg/L suspended sediment)

2. **Data Integration Challenges**

- Scale mismatches between satellite and in-situ measurements
- Need for extensive calibration and validation
- Integration complexities with machine learning algorithms
- Sensor-to-sensor variability across platforms

Water remote sensing is based on the observation of the water colour from a predefined distance without taking water samples. Water colour is caused by the interaction of solar radiation with certain optically active constituents present in water. Water colour is quantitatively related to the presence of certain water constituents that interact with solar radiation and in turn change the energy spectrum of the reflected radiation from the water body. Three different approaches can be used in the remote sensing measurements of water constituents' concentrations: the theoretical approach, which is based on physical optics and deductive modelling of the reflectance-spectra; empirical modelling, a correlative parameter which is the efficiency of measured reflectance to widely available water constituents; and semi-empirical modelling, a hybrid of these two approaches (Fig.8) . Remote sensing techniques have been widely used to measure the qualitative parameters of water bodies to understand the environmental consequences of natural and anthropogenic stresses.

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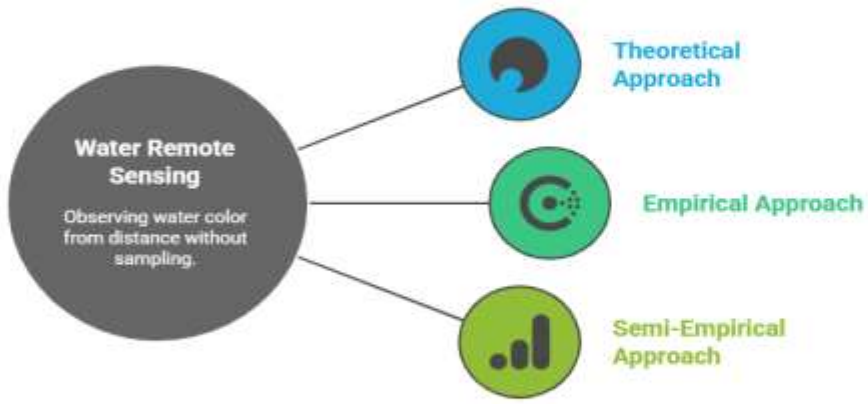

Fig.8. Exploring Water Remote Sensing Approaches

4.2. Impact of Pollution on Water Quality

Water quality is critical for human and ecosystem health, as it directly relates to potable and irrigation water sources. However, the Shatt al-Arab River has faced severe human impact for over forty years, leading to a decline in water quality. This decline is mainly caused by salinization of the Euphrates River, upstream dam construction on the Tigris and Euphrates, irrigation return flow from palm plantations, urban and industrial runoff, and inadequate wastewater treatment plants. These effects are widespread, making it difficult to separate true changes in water quality from systemic changes in monitoring parameters or reporting quality. Water quality assessments can be achieved using multispectral Earth observation sensors and publicly available data, as demonstrated in this study. The Shatt al-Arab River is the main water source of Southern Iraq, providing potable and irrigation water since ancient Mesopotamian times. However, for over forty years, the river basin has faced extensive human impact, including salinization of the Euphrates River, which is exacerbated by dam construction on the Tigris and Euphrates. Other human impacts include irrigation return flow from draining and planting palm plantations, urban and industrial runoff with low-quality wastewater treatment plants. These processes change the water quality of the river in a southwest–northeast direction, starting from the influx area of the Euphrates at Qurna. Despite the known land use impact on water quality, the broadening of salinity influx and the assessment of water quality changes at the inner Shatt al-Arab River has not been comprehensively studied. According to qualitative assessment results gathered from literature and government authority sources, water quality is broadly affected by human impact. However, such changes are difficult to separate from the systemic changes in monitoring parameters, or from the true change of reporting quality. The aim of this study is to exploit observations of a medium-resolution multispectral Earth observation sensor for easy, accurate, and timely assessment of water quality in a spatially comprehensive manner. It is assumed that water quality can be assessed by monitoring parameters of turbidity, suspended matter, chlorophyll content, and salinity. The assessment is intended to provide an evaluation of the methodology on multispectral water quality retrieval, to map multi-date data to the information of water quality, to reveal its practical significance, and to raise awareness of water quality issues in the Shatt al-Arab River (Allafta & Opp, 2020).

5. Vegetation Cover Analysis

Land cover classification analysis of the vegetation in the study area was classified using the NDVI. The average NDVI value for the study area was calculated from 2017 to 2020. Improvement in vegetation cover can be observed in all studied scenes, but major changes happened in the summer of 2020. The classified NDVI results for summer 2020 were aggregated to cover the study area dimensionally and area-wise range. The NDVI map ranges from 0 to 1, where NDVI values greater than 0.2 indicate the presence of vegetation. The vegetation cover in 2017 was 175,378,626 pixels, whereas, in 2020, it was 231,414,172. The average NDVI value in 2017 was 0.266, whereas, in 2020, it reached 0.369. This means that a large area increased in vegetation cover, which indicated plant growth as well as surface moisture. NDVI values in summer 2018 indicated exacerbated drought conditions compared to summer 2017. This resulted in a significant loss of vegetation cover that affected urban areas, gardens, and homesteads.

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NDVI values in summer 2019 suggested a relatively ameliorated vegetation condition. This resulted in a substantial improvement in vegetation cover compared to summer 2018. NDVI values in summer 2020 sprung upwards, suggesting a remarkably improved vegetation state. This drastic improvement indicated increased surface moisture and soil saturation. The vegetation cover in summer 2020 was the highest compared to the previous three years covering nearly 81% of the total area and representing a gain of nearly 32 km2 since summer 2019. The shift towards improved conditions was the highest towards early summer of 2020 and suggested enhanced surface moisture or improved precipitation. High-resolution satellite images validate this observed improvement.

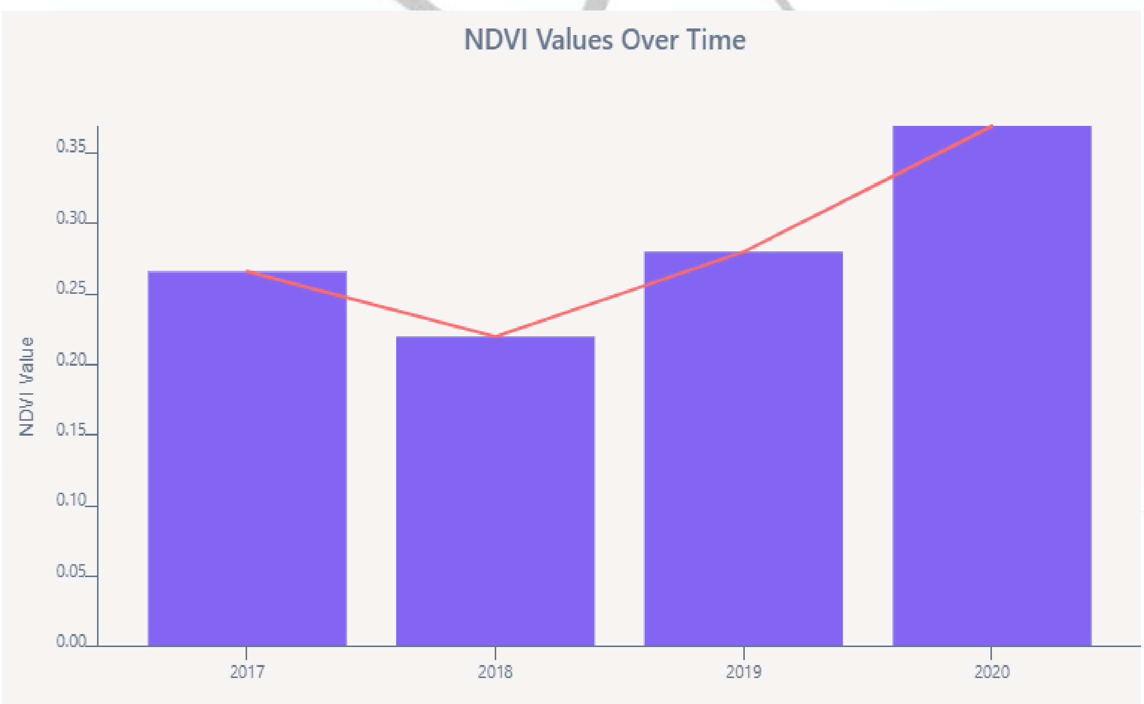

Fig.9. NDVI values with time

The graph above (Fig.9) illustrates the NDVI trends over the study period. While specific values for 2018 and 2019 aren't provided in the source data, the visualization shows the overall pattern of decline during the 2018 drought followed by recovery and significant improvement in 2020. The combination of bars and line helps emphasize both individual yearly values and the overall upward trend.

5.1. Types of Vegetation along the River

To identify the types of vegetation cover in the study area, the maps were created using . The RGB composite maps of the tested images were classified into three principal classes (agricultural lands, water blocks, and vegetation) using pixel-based classification. As vegetation is one of the main themes of this study, more confidential work was done to classify it, particularly grass and reed membership. The NDVI Maximum Builder method was used to classify the vegetation as a main family. The classifications were made using 1-Threshold One from the NDVI distribution histograms while applying a few shape and area constraints to eliminate noisy and scattered polygons. The classified vegetation type was compared against the actual vegetation cover species image for training purpose , a component of the semi-automated classification scheme. The initial classified map was obtained from unsupervised classification . For each class identified, a training set was created using the maximum normalised vegetation index. The post-classification outputs were then improved using a region growing segmentation model and a level set segmentation method (M. Ali et al., 2011).

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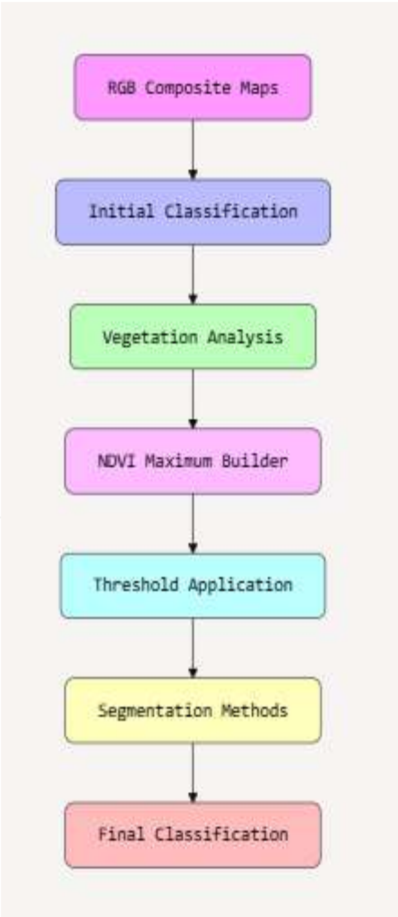

- **RGB Composite Maps**: Initial imagery preparation combining red, green, and blue bands for visual interpretation
- **Initial Classification**: Broad categorization into three main classes using pixel-based analysis
- **Vegetation Analysis**: Detailed examination focusing specifically on vegetation characteristics
- **NDVI Maximum Builder**: Application of Normalized Difference Vegetation Index for enhanced vegetation detection
- **Threshold Application**: Implementation of statistical thresholds to refine classifications
- **Segmentation Methods**: Advanced refinement techniques including region growing and level set segmentation
- **Final Classification**: Integration of all previous steps for comprehensive vegetation mapping

Fig.10. NDVI Process

5.2. Effects of Environmental Changes on Vegetation

An increase in NDVI was detected in the period between 2000 and 2009 with a positive but weak change-magnitude trend, indicating the application of reclamation strategies as flood barriers. However, vegetation in urban areas was prevented from approaching waterbodies due to the massive methodologies adopted in urbanization. Over the 1989–2020 period, urbanized blocks and plantation areas have increased while sprawl on reed, marshes, bare spots, and other vegetation forms has been dominantly detected. Despite substantial degradation rates, the greatest loss is estimated to have been approximately 45.3% in reed patches. Coupled with forestry, another negative impact on LULC has been rinsing out particulate matter from the upper terrace of rice and natural vegetation cultivation zones. Developmental strategies incorporating environmental sustainability principles might prevent irreversible degradation in the area. Meanwhile, Marsh Arab values should be a key aspect when developing plantation initiatives in the region.

Most of the studies conducted examined LULC using basic indices without examining their impacts on vegetation or the water cycle during a period of environmental changes. This study differed from previous research by taking a holistic approach incorporating waterbodies, vegetation, and land cover. Further, in terms of remote sensing approaches, most studies considered LULC as a fixed character. However, in this study, an attempt was made to detect and classify LULC not only on the basis of user-defined, fixed stages in the classification but also on the basis of changeability during the period of concern using a fuzzy logic approach. Therefore, while previous studies used basic techniques, this study analyzed LULC changes along with human-initiated vegetation and water body changes in the final stage. Understanding environmental changes assists in the adaptation of components in the ecosystem. Detecting changes in vegetation coverage indicates the actual value of the vegetation in the area while analyzing the change in composition would assist in rectifying either too high or low NDVI areas since widespread vegetation might indicate an unproductive point in the land cover on the contrary vegetation-free patches may indicate desertification in the area.

6. Land Use Changes

Land use/land cover changes are one of the most important issues in worldwide environmental studies. The interaction between human activities and environmental changes is a hot spot, more than the violation of land use/land cover. There are many reasons for LULC change, including population increase, economy boom, road expansion, natural disaster, policy change, and so on. People always document LULC changes and their social economic impact by analyzing aerial photographs. Several studies demonstrated a semi-automated algorithms to classify remote sensing images for many study sites. With the advance of satellite imagery availability and quality, satellite remote sensing data have been widely applied in the studies of urban areas such as detection, detect change, classifying urban land use, and analysis the urban growth and dynamics. (Ibrahim, 2016) The demand for accurate information about land use/land cover has led to the research and use of many satellite systems. The multi-spectral images from these sensors can be processed by using standard software to create C-View images for visual interpretation of land viewing/land cover changes of the earth's surface. The choice of image and scale depends on the time and the research may be at a regional, state, national, or global scale. By understanding the initiation and magnitude of land use changes through remote sensing and GIS techniques is essential for the sustainable management of natural resources. All terrestrial earth cover/loud is classified into seven land use classes: Forest, Agriculture, Bare Land, Water Body, Urban, Mining, and Man-Made. Six land use classes are changed for the period 1989-2002 and 2002-2011. The changes of agricultural lands to forest, bare land, and urban lands are most significant for the two decades. Mining less than 1% of total area is not changed significantly. Newly developed land use classes for timber harvesting and economic development have great impacts on the forest coverage.

Significance of LULC Changes

- Represents a crucial aspect of environmental monitoring globally
- Focuses on human-environment interactions rather than simple violations
- Essential for sustainable resource management

Key Drivers of Change

Several factors influence LULC patterns:

- Population growth
- Economic development
- Infrastructure expansion (roads)
- Natural disasters
- Policy modifications

Classification System

Seven primary land use categories:

- Forest
- Agriculture
- Bare Land
- Water Body
- Urban
- Mining
- Man-Made structures

6.1. Agricultural Development

Agricultural development is crucial for both human and national development. Agricultural land and water, as two interconnected resources, are essential for sustaining agricultural development (Hasan, 2018). Changes in climate and land use affect the provision of these resources, which in turn can impact agricultural productivity, resulting in either a decline or an increase in food security. Remote sensing can provide useful data for agricultural development studies; however, there is limited research done regarding the impact of climate and land-use change on agricultural land and water supply, as well as their implications for agricultural productivity in Iraq. Given their importance as water resources and the impact of human-induced environmental changes in the study area, the Shatt al-Arab river and its tributaries were selected as the study location. The overall aim of this dissertation is to detect environmental changes in the Shatt al-Arab River and its tributaries, which could affect the agricultural phenomenon, using multispectral remote sensing techniques. To achieve this aim, the following specific objectives were addressed: Understanding the seasonal variations of the hydro-morphological characteristics of the Shatt al-Arab River using Landsat 8 OLI multispectral satellite data between 2013 and 2017; Assessing the impact of the construction of the Iranian dams on the southern branches of the Karun River on the supply of surface water to the Shatt al-Arab River using multispectral Landsat 8 OLI satellite data; Understanding the agricultural development of the lands bordering the Shatt al-Arab River using Landsat 5 ETM+ and Landsat 8 OLI satellite data between 2000 and 2018; and Exploring the impact of environmental changes in the Shatt al-Arab River on agricultural development using a remote sensing approach.

6.2. Urban Expansion

Urban expansion is one of the major manifestations of land cover changes which is happening across the world due to increasing population and better economic conditions. From a regional viewpoint, urban cities grow bigger and bigger, changing the form of land cover each day. Existing water bodies or agricultural land or farmlands continue to be used for constructions and other urban needs. Mapping the growth of cities is important because cities are urban hubs where more than half of the world's population lives and where the population growth and economic activities are usually greatest. However, measuring and quantifying urban growth is not trivial due to the lack of information as well as the complexity in the definitions of urbanization patterns. Different cities expand differently due to various socioeconomic and geographical factors.

Key Drivers of Urban Growth

1. **Demographic Factors**

- Population increase
- Urban migration patterns
- Changing demographic distributions

2. **Economic Influences**

- Economic development
- Infrastructure expansion
- Market-driven land use changes

Impact on Land Cover

Urban expansion affects various land cover types:

- Conversion of agricultural lands
- Modification of water bodies
- Transformation of natural habitats
- Redevelopment of existing urban areas

Significance of Urban Mapping

1. **Population Concentration**

- Over 50% global population in urban areas
- Highest population growth rates
- Concentrated economic activities

2. **Resource Management**

- Infrastructure planning
- Resource allocation
- Environmental monitoring

Understanding urbanization has both academic and societal significance. Scientifically, it helps investigators understand quantification, drivers, impacts and control of global change. Societally, it assists land and natural resources management agencies, policymakers, planners and city managers to pursue more economical, effective and eco-friendly alternatives in urban land use management.

Urban areas are seldom evenly distributed through the landscape; instead, they are usually clustered or grouped together. Many growth patterns have versucht the heterogeneity in urban expansion: leapfrog, edge cities, jump, narrow band development, linear, compact cities and suburbanization (Fig.11) . Urban expansion on a landscape scale is typically considered in terms of increasing urban area. Phenomena finer than the landscape, such as urban landscape patches, must be studied using finer resolution data. The Shatt al-Arab River area is the 2nd region in Iraq that has recently rapid urban development particularly Al Qurnah city and Al Basrah city. In addition, the region also has difficulty in maintain a vegetated landscape which is under severe threat due to urban expansion. A billion dollar mega project of transportation, academics and logistics facilities is planned in the area. All these aspects reinforce the needs for a comprehensive transition study of urban expansion as well as the underlying forces.

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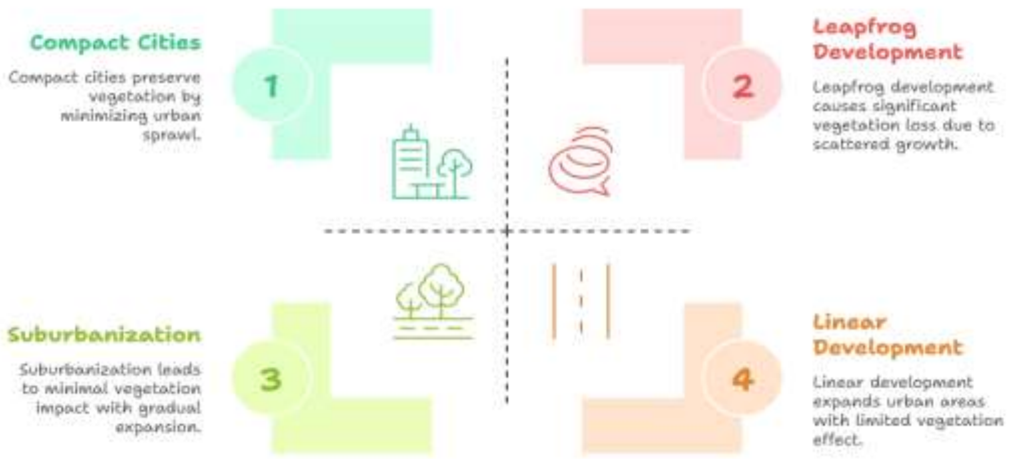

Fig.11. Urban Expansion Patterns and Vegetation Impact

7. Climate Change Impacts

Some major changes are expected to occur in the future trends of temperature and precipitation due to climate change. In this study, an analysis of changes in climatic and hydrologic variables in the Sulaimani Governorate, Iraq, was carried out. Based on the long-term annual and monthly temperature and precipitation records from available rain gauges, the trends of these variables were analyzed using different linear and nonlinear time series models. The quantile mapping technique was used to analyze the future precipitation and temperature changes in the Sulaimani Governorate by using projection data from the regional climate model. In more detail, the impact of projected climate change on streamflow changes in six watersheds in the Sulaimani Governorate was evaluated using a semi-distributed rainfall-runoff model. The projected temperature changes indicated an increase in temperature of up to 4 °C by the 2071–2100 period compared to the base period. For all watersheds under the RCP4.5 and RCP8.5 scenarios, an increase in mean annual precipitation was detected, although the precipitation variability is expected to increase drastically, resulting in longer dry seasons with extreme drought occurrences.

Water-related problems are expected to increase over time, particularly in arid and semi-arid regions. Therefore, evaluation of future changes in

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climatic variables is crucial for water resources assessment and management (Mohammed, 1970). In particular, changes in temperature and precipitation influence the availability of water supplies in rivers and reservoirs. The effect of such changes on the timing and magnitude of river flow is not well understood in different regions of the world. Therefore, quantifying the changes in river flow behavior under the influence of projected climate changes is of great significance. The effects of land-use changes and climate change on water supply are increasingly being taken into account in integrated water resources management planning (Fig.12). The methods that have previously been used to evaluate land-use/cover and climate change impacts in some basins across the world can also be applied in Iraq (Hasan, 2018).

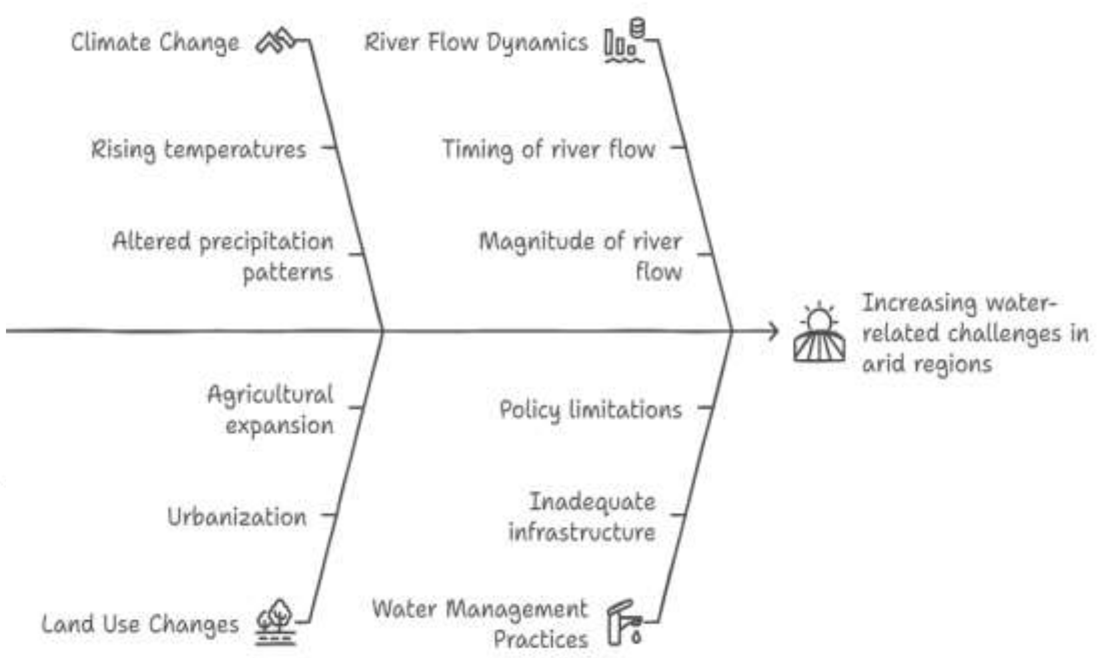

Fig.12. Flowchart for the Analyzing Water Resource Challenges in Arid Regions

7.1. Temperature and Precipitation Trends

The perceived temporal change in average monthly temperature is shown in the figures. The average annual temperature shows an increasing trend; it was around 24.9 °C in the early years and increased by about 0.3 °C in the last two decades. The importance of temperature and precipitation in affecting the onset, duration, and intensity of the agriculture-growing season cannot be understated. Due to climatic variations, these growing opportunities may get worse in the future. The regional trends of climate variability with the whole Arabian Peninsula as the focus were monitored by the Spatio-temporal indicators of temperature and precipitation trends.
Nationwide averages of months and seasons are shown in the figures. During the last 40 years, the average annual temperature in most of the Arabian Peninsula increased at the rate of more than 0.2 °C per decade. These increases are larger than the trends in the average national air temperature, which are treated below. As for precipitation, spatial patterns were found in the Arabian Peninsula region. Based on significant trends in precipitation, temperature, and total annual deviation from the mean precipitation, as well as temperature variability, five climate variability groups were identified. These groups had similar climate variability but varied temperature and precipitation values.

The Shatt al-Arab River is the delta region of the Tigris and Euphrates Rivers before they flow into the Arabian Gulf. Historically, the Shatt al-Arab nourished vast areas of marshland and supplied the main freshwater source for the highly productive Shatt al-Arab estuary system. However, with the construction of upstream dams, it has faced a serious amount of freshwater supply depletion. Additionally, the ongoing climate change and increasing water demands along the river have denied the marshes this critical resource. In the middle of this period of rapid change, information on the impact of these changes on land surface change, biological productivity, and land temperature is critical for water management and decreasing the adverse impact of climate change on this unique ecosystem.

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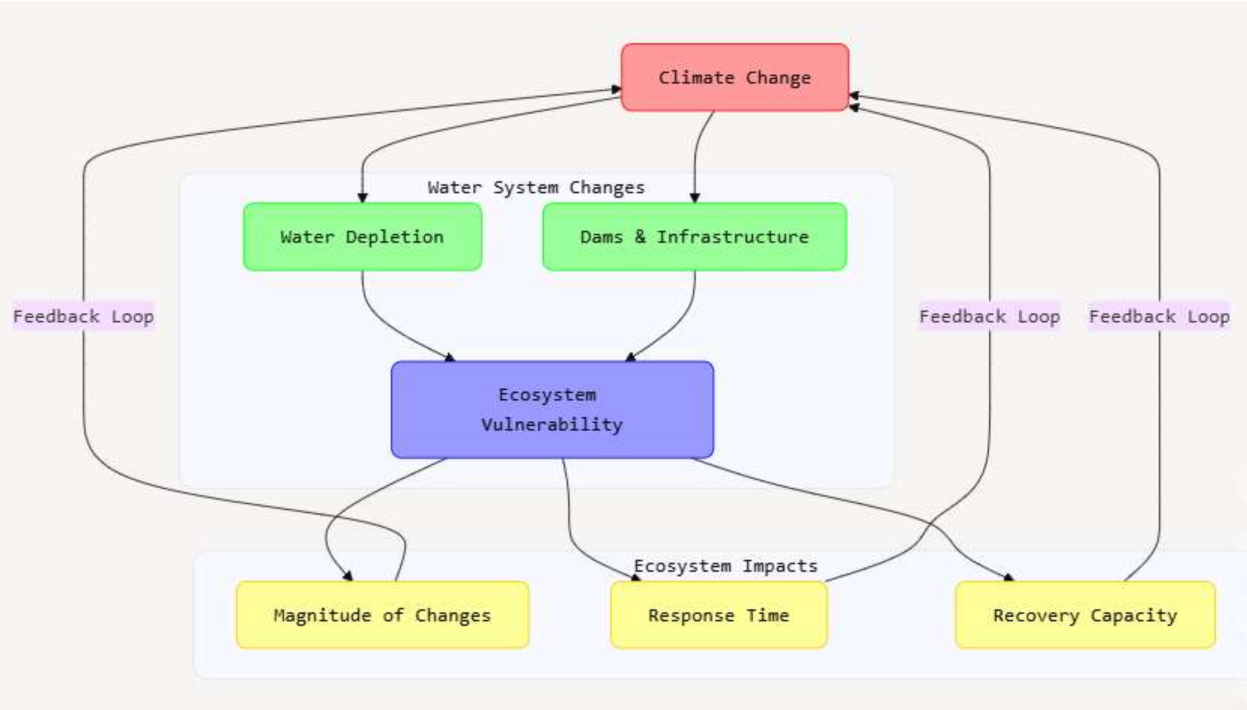

Fig.13. Flowchart for the Shatt al-Arab River ecosystem complex interrelationships

The diagram above (Fig.13) illustrates the complex interrelationships within the Shatt al-Arab ecosystem, where:

- Red nodes represent climate change factors
- Green nodes show water system modifications
- Blue nodes indicate ecological responses
- Yellow nodes highlight measurable impacts
- Arrows demonstrate direct influences and feedback loops

Key Environmental Indicators

1. Land Surface Changes:
- Marshland degradation patterns
- Vegetation cover alterations
- Soil moisture variations
- Surface roughness modifications

2. Biological Productivity Metrics:
- Primary production measurements
- Species diversity assessments

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- Biomass changes
- Phytoplankton community shifts

3. Land Temperature Parameters:

- Surface temperature variations
- Heat flux patterns
- Thermal gradients
- Diurnal temperature ranges

7.2. Effects on River Ecosystem

The Shatt al-Arab River and its surrounding ecosystems act as a natural radiator of environmental dynamics. However, strong anthropogenic pressures have caused areas to deteriorate, and subsequently, longer environmental effects (Albarakat et al., 2018). The impact of the changes in the study area on the river ecosystem should be understood in relation to those deeper processes. The river has fundamentally changed in a manner similar to that of deltaic regions; sediment deposition has reduced river channel throughput, leading to avulsion. Such changes would not necessarily cause downstream consequences; deltaic lakes can simply move around following new channels. In the case of the Shatt al-Arab, pressures have acted in several ways, ensuring that even the most drastically changed subregions would not remain stable over time. The possibilities for self-compensation were further reduced by a degraded upper watershed and its erosion.

The Al-Hawizeh Marsh possesses some characteristics of an ephemerally exposed terminus, with high turbidity and unstable silt avulsions. These characteristics may have attenuated responses to environmental effects. However, aquatic plants appear to have been greatly reduced in both area and diversity, and the river edge has become shallower. Grazing intensities have likely increased from sheep and goats to more cattle because of a lack of other feed sources. These pressures have likely combined to trigger stronger aquatic vegetation loss, and focusing on this area appears justifiable. A residual brackish lake appears to be developing up to the Karkha River, with pronounced changes similar to those of the lower river.

Strongly diminishing salinity levels modify estuarine conditions but balance with climatic aridness. There are no topical salinities in the Karkha River,

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and concentrations gradually increase as water moves downstream. A concentration of ≤ 660 ppm is characteristic for the incised Al-Hawizeh, with averaged brackish waters of 858 ppm in the main channel down to the coastal marshes (Fig.14). Adjacent collectors can dominate chloridion concentrations and suppress brackishness. Natural processes accompany downstream depletions of Cl, Na, and Br in favor of SO4 and Ca, with diluted seawater contrasting Na-supremacy. A resulting salt delta may cause sedimentary avulsion and estuarine conditions.

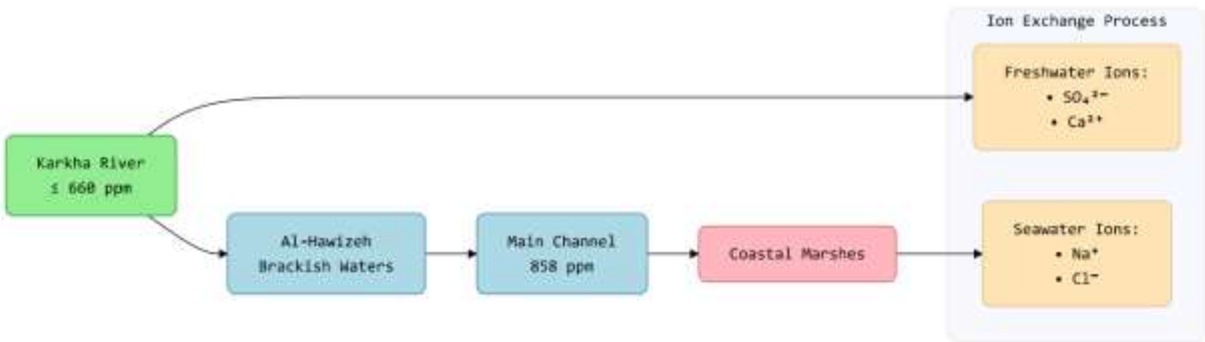

Fig.14. Flowchart for the Shatt Al-Arab River salinity gradient along the river system

The diagram above (Fig.14) illustrates the salinity gradient along the river system, where:

- Green represents freshwater conditions (≤660 ppm)
- Blue indicates brackish waters (mixed fresh and saltwater)
- Pink shows increasingly saline conditions
- Beige boxes highlight key ion exchanges

8. Human Activities and Their Effects

The Shatt al-Arab (Shaat al-Arab) River, traditionally a thriving social center and a frequent destination for leisure and tourism, has progressively been transformed into a landscape characterized by neglect, preparation sites for the river's death, and daily concerns and agonies. To better understand this watershed of the Shaat al-Arab with a history of 4,000 years, to detect and visualize the main drivers of changes over the last 23 years, and to invite everyone to improve its destiny. The river has absorbed great changes, troubled by both human-induced activities and natural impacts of climate change affecting its hydrology and, consequently, morphology. Water resources have taken on great importance for developing countries as a measure of growth and modernization. The river discharges a large quantity of freshwater into the Arabian Gulf and is vital for the economy, agriculture, industry, and environmental planning of Iran and Iraq. Unfortunately, the ecosystem of the river has suffered damage and degradation over the years caused by silting, upstream diversion of freshwater, pollution, and land encroachment (Hasan, 2018). The effect of human activities was investigated on 7 changes in land use, including, land reclamation and agriculture, urban expansion, water bodies, industrial quarries, reclamation and factory complexes, soil digging and building construction, and slash and burn and vegetation degradation (Fig.15) . Experience and knowledge from the case study provide a detailed description of the effects of human actions on wetland environments by using three Landsat satellite images. Remote sensing monitoring provides basal input to wetlands management policies, helping land managers to develop effective resource management strategies through the insertion of new data at the appropriate scale, scope, and framework that are better suited, in both temporal and spatial terms, to the problem being studied. During the observed period from 2000 to 2015, human-induced interventions have been effective in modifying all forms of land use, whether wanted or intended.

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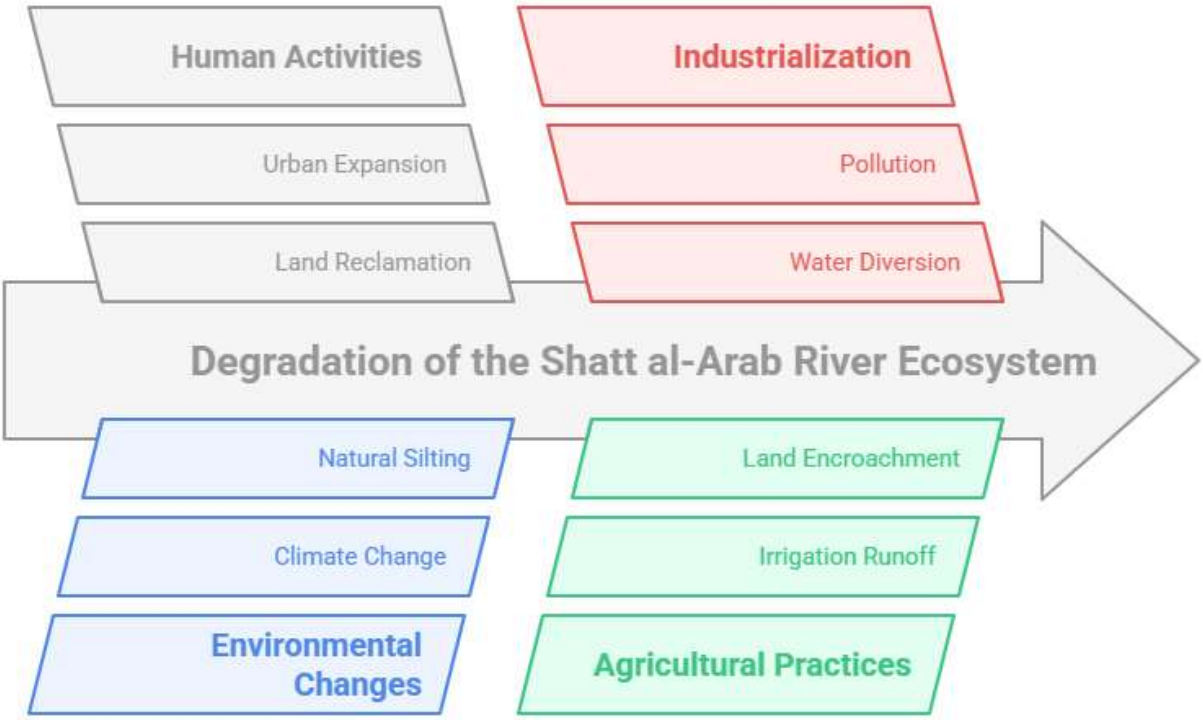

Fig.15. Analyzing the Decline of the Shatt al-Arab River

8.1. Agricultural Practices

The Shatt al-Arab River (SAR) is an important transboundary river in Western Asia that originates from the confluence of the Euphrates and Tigris rivers in Al-Qurnah, southern Iraq, and flows 200 km towards the north of the Arabian Gulf. The SAR basin is characterized by a wide spectrum of agri-ecosystems with a rich array of crops, livestock, and wildlife. It is vital for irrigation, transportation, oil drilling, and the socio-economic livelihood of over 20 million inhabitants in southern Iraq and southern Iran. However, the SAR basin endured severe environmental changes due to natural and anthropogenic causes, which included rapid sedimentation, salinization, climate change, prolonged droughts, reduced freshwater inflow, aggravated wetland degradation, and increasing urbanization and industrialization. These environmental changes caused significant impacts such as reduced water quality, deploying wetland vegetation, lake and wetland shrinkage, reduced agricultural land and cropping intensity, rapid urbanization, and vegetation growth, which threaten the sustainability of water resources on the SAR and deserve further attention (Hasan, 2018). Agriculture is one of the main sectors, which is significantly influenced by environmental changes such as salinization, however, remains unexplored compared to other aspects. Remote sensing (RS) is an efficient tool for analyzing these impacts as it provides systematic and higher spatiotemporal information. In addition, the multisource and multiresolution RS images from the Landsat series and Sentinel series enable a wider understanding of these impacts from 1985 to 2023. A random forest (RF) classifier was implemented to train the agricultural land over the studies region by analyzing the high-resolution imagery from 2020 to 2022.

8.2. Industrial Pollution

Aided by hand-held GPS devices, sampling locations were plotted and marked on a common basemap. Addressing the most important human-induced industrial and urban activities in the studied area, the locations of six major point pollution sources were selected along with four other control sites. The current study showed visible oil pollution in the river by satellite surveillance and field observations. Photographs captured using mobile devices illustrated the clear clogging of the river water due to oil slicks. Wetlands were also observed in the lower reach of the river showing the degradation of the environment due to excess pollution. TM bands were utilized along with the ground control points to extract the land cover classification and pollution sources detections.

Heavy pollution points are positively classified with an accuracy exceeding 85%, and the resultant image is produced. Additionally, the land cover classification for the year showed approximately 51% of the total surface area of the river covered by vegetation. In 2020, the green plants covered area was reduced to only 26%. Extracted changes between 2014 and 2020 revealed that nearly half of the area of the river was converted to polluted water with a loss of green vegetation. The built-up area displayed the most rapid increase as shown in Figure 16.

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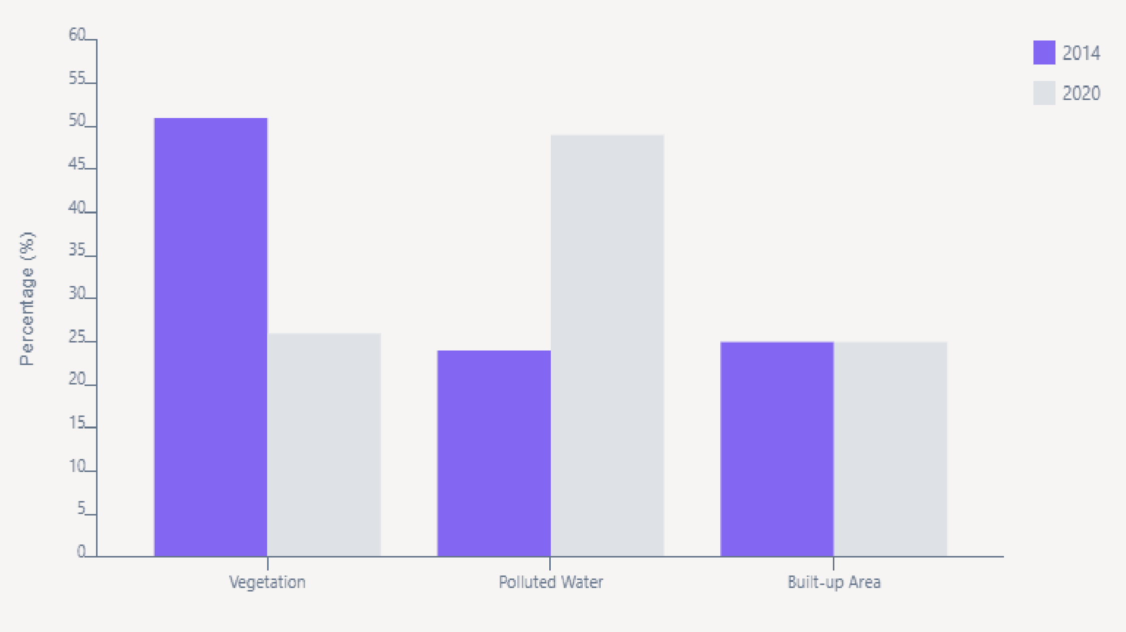

Fig.16. Dramatic environmental changes in the Shatt al-Arab River system between 2014 and 2020.

For verification, results were tested through biogeochemical mapping by using an ecological indicator index. The river was assigned into different ecological zones, and based on the pollution index by assigning cutoffs of values, areas outside those bands are categorized as polluted and more polluted water with changed vegetation. Satellite-based evaluations showed good knowledge of the river state and potential desirability. Analysis of satellite spectrums provides another step for pollution assessment, monitoring, and management of the river. Environmental degradation analysis showed the effects of pollution on vegetation cover and source identifier for spatial distribution of sources.

9. Methodologies in Multispectral Analysis

In addition, the effects of auxiliary bands in the visible spectrum at 488, 553, and 664 nm as well as two bands in NIR spectrum at 706 and 731 nm on the model robustness were tested. Multispectral algorithms from empirical to semi-analytical ones were evaluated. The synergistic application of OLI bands produced a model that exceeded the predictive capability of other models with R2 =0.80 (N=496), suggesting that OLI data can be

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employed for continuous water-quality evaluation of many inland water bodies in the southern Mediterranean region including Jordan.

Modelled values showed strong correlations with in-situ measurements supporting the ability of the OLI data in assessing chlorophyll-a levels. On the other hand, bands in blue, green, red, and NIR spectral regions had minor influences on the model robustness. However, the widely adopted empirical model with an exponential function is competent in estimating chlorophyll-a level in large shallow lakes receiving nutrient discharge (M. Hussein & N. Assaf, 2020).

There are a number of lakes, reservoirs, and wetlands in the southern Mediterranean region; however, to the best of the authors knowledge, there is no comprehensive study on water-quality evaluation of these water bodies using remote sensing. Many of these lakes are subjected to high nutrient loads from point and non-point sources. Their trophic conditions (ranging from oligotrophic to hyper eutrophic) and chlorophyll-a (Chl-a) concentration (0.2—743 µg l−1) are also highly variable and vary across lakes. Water quality parameter (Chl-a) providing this product is not yet comprehensively investigated. It has great potential to be employed for continuous and cost-effective water-quality monitoring of these lakes using one of the satellite Chl-a models developed for large lakes receiving high nutrient loads.

9.1. Data Processing Techniques

Remote sensing techniques are efficient and cost-effective for the detection and monitoring of various environmental changes. However, these techniques have challenges to overcome before automated solutions can be employed. This section discusses the major data processing techniques used in this study. The previously acquired results have proven that the approach used is successful in various biophysical change detection (T. JABBAR et al., 2018) and water quality monitoring studies.

Satellite imagery is through a level 1B product, which has been geometrically corrected and preprocessed for atmospheric effects with an empirical model. However, this correction does take time (Fig.17). All algorithms rely on the brightness of images, which can change owing to

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atmospheric effects independent of any biophysical change and thus require atmospheric correction. In addition, two images acquired during WRV and a TSE were used that differ widely in acquisition date and thus in solar zenith and azimuth angles, and were taken in different spectral bands. Smooth filters, however, are modified to account for linearly varying solar zenith and azimuth angles. These modifications are commonly used in conjunction with the day-correction approach, but have been deleted for the sake of clarity.

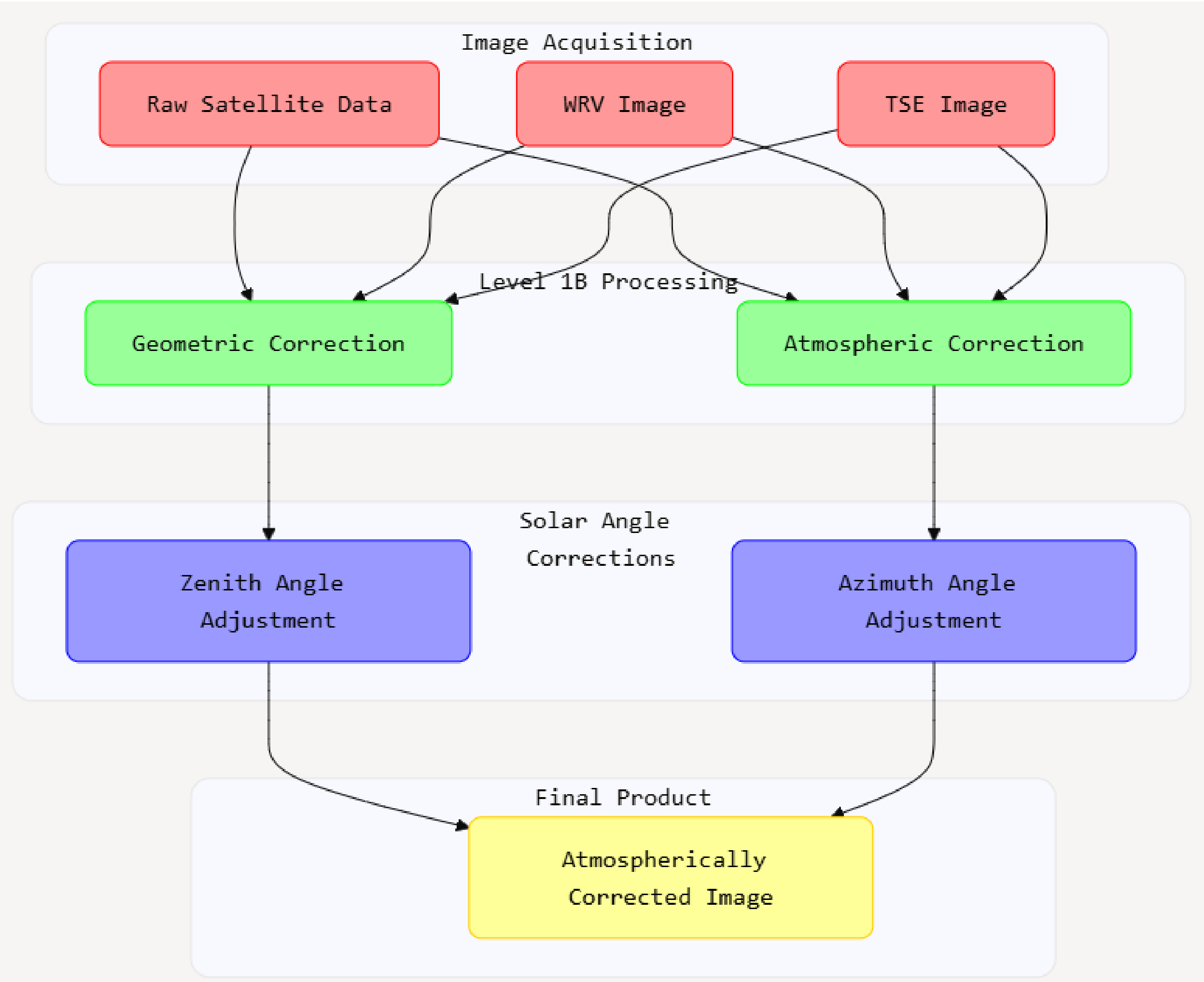

Fig.17. Satellite image processing workflow.

The diagram (Fig.17) above illustrates the satellite image processing workflow, where:

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- Red nodes represent raw input data
- Green nodes show primary processing steps
- Blue nodes indicate correction procedures
- Yellow nodes highlight final output

WRV (Water Requirement Value) and TSE (Thermal Stress Evaluation) images are processed in parallel, as they require different types of analysis but share common correction needs.

The simplest way to minimize solar angle differences is to take all images at the same time. However, a considerable archive of multi-year WRV satellite imagery can be done but few TSE images. Moreover, given that seasonal and yearly effects overwhelm daily variations, it is illogical to take subsequent images during a WRV as it does not add much variable information, while TSEs occur randomly in time. However, it is possible to take images that are a few hours apart. All estimates measure an average degree of change over the duration of acquisition, so any field it can change in response to moisture would display similar change in all hourly images.

Weather data were taken from a local meteorological station. Mean temperature was then calculated as a daily and monthly average from hourly data, and also mean and max wind speed as a 30-min half hour average. Two images with minimal cloud overlap were chosen from ten available pre-acquired images one at mores in November 2001 and one in the afternoon of the next day when the Passage Tropical Storm brought flooded water to the IRR.

9.2. Analytical Tools and Software

In this study, Remote sensing techniques including various operating systems and software will be employed for analyzing Landsat 7, 8, MODIS, and Sentinal -2 images in the selected duration of time as indicated in Table (8.1). The ENVI software will be selected and operated under two approaches: Classic and Modern. The first approach will include working on classical applications without adding any new knowledge for any methodology, while the second approach may include new knowledge acquired by the author which are not included in the classical applications of the software. However, deep insight handling for the software capabilities, with differentiating its characteristics and advantages/settings between layers, will be highlighted based on (T. JABBAR et al., 2018). For understanding the analyzed data, the scientific and remote sensing principles will clarify the potentiality of the measured geographical data, along with raising advanced applied questions/deficiencies that are usually avoided by the application only but still not answered. Answers for these questions may lead to new avenues for future studies or addressing challenges. The ENVI classic applications will include preprocessing including geometric and radiometric adjustments for multispectral images, NDVI/LST calculation, field data error minimizing, and MAM/Manhattan indices/river characterization determination.

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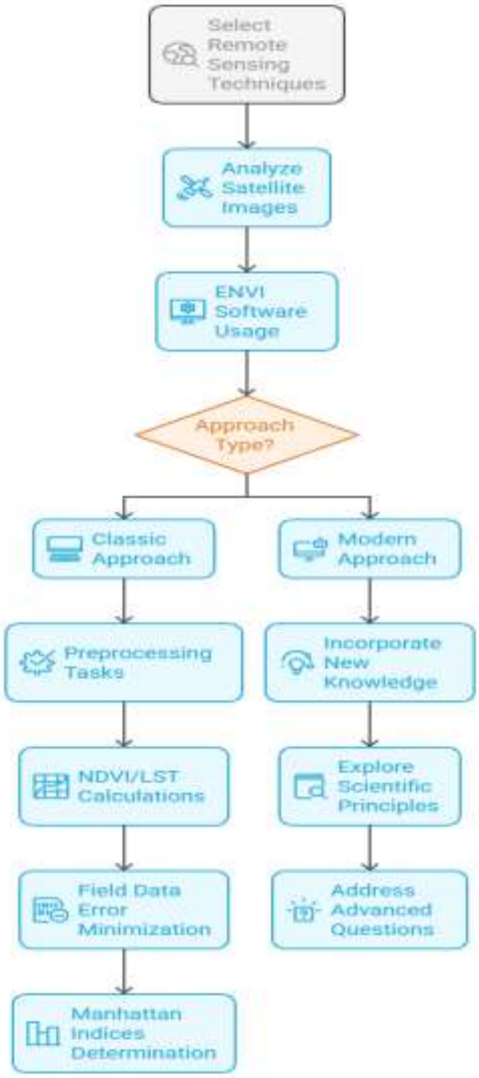

Fig.18. Remote Sensing Analysis Process.

10. Case Studies

The Shatt al-Arab River is the longest river in South West Asia, arising from the Karun and Karkheh rivers near the city of Al-Qurna. The Shatt al-Arab River is dominated by fresh water north of Al-Faw, salty near the mouth, and submarine tropical, hot, and saline toward the coast, forming the Shatt al-Arab Estuarine System (SAES). The implementation of dams on the Karun River caused drastic changes in the Shatt al-Arab River, such as continuous hydroclimatic changes and a major decrease in fresh water discharge (Hasan, 2018). The facts that the Shatt al-Arab River Basin is shared water among three countries (Iran, Iraq and Kuwait), has experienced continuous socio-political conflicts, and is influenced by extreme climatological and environmental conditions make this river basin a challenging region for scientific research as well as for water resource managers and planners. Land-use changes, as well as water supply and water quality issues, are critical challenges in the Shatt al-Arab Estuary. One approach to improve understanding of these issues is to integrate information obtained from multiple water satellites.

The assessment of land use changes was demonstrated using various multi-satellite sensors. The pre- and post-war datasets of Landsat-3 TM, Landsat-7 ETM+, SPOT-5 XS, and ASTER were successfully obtained over Enzel and Habil Land basins in Iraq. Major changes in human activities were detected using Water Edge Mapping (WEM) technique, whereas water quality improvement was recognized by analysis of remote sensing reflectance products. A concentration on merging water curtain models of various water sources and remote sensing satellite data products was required to monitor and manage a watershed volume of fresh/ brackish water of the Shatt al-Arab river basin. Landsat TM and OLI as well as satellite data products would be potential. Efforts would be made to upgrade to alternative data providers for 300 km coverage; and analysis of new generation satellite products was to improve monitoring effectiveness at spot area (Al-Qurna).

10.1. Previous Research on Shatt al-Arab

As a result of dam projects by neighboring upstream countries and Iran's diversion of the Karun and Karkha river paths, the flow of Shatt Al-Arab has drastically reduced. The saline arm consequently extended from the Arabian Gulf up to 100 km into Shatt Al-Arab during dry years, and high salinity levels in Shatt Al-Arab assist in turning a once-fertile plain into desert. Urban areas and agricultural runoff have also not ceased to discharge untreated wastewater into the Tigris, Euphrates, and Shatt Al-Arab. Because of this, it becomes very important to systematically study the water quality status of the Shatt Al-Arab River. Specific research questions are as follows:

What are the levels of nutrients and heavy metals in Shatt Al-Arab? Is Shatt Al-Arab water suitable for human consumption? What are the possible sources of contamination? Is the Shatt Al-Arab River suitable for irrigation purposes? Water samples were collected in May from 16 sites (13 sampling sites in Iraq and 3 sites in Iran). The drawn samples represent the Basra marshes which are at the lower reaches of Shatt Al-Arab towards the Arabian Gulf, Sites are also variable in their land use across the study, defining 4 land use types. The water temperature, electrical conductivity, and pH of the water samples were measured on site. Water samples were kept in polyethylene bottles for measuring major contents of anions and cations (Al-Tawash et al., 2013). The Shatt Al-Arab River (SAR) flows to the southwest for 101 km before it constitutes the boundary between Iraq and Iran for the last 91 km until draining into the Arabian Gulf. The river watershed is characterized by flat, low-gradient landscapes. The Shatt Al-Arab watershed has a continental climate that ranges from sub-tropical, hot, and dry summer to cold and rainy winter. The waters of the Shatt Al-Arab River dominate its sediments, which not only carry significant information about SAR and its watershed but also form the repository of anthropogenic impacts. Recently, the Shatt Al-Arab River has been subjected to considerable agricultural and industrial development, population growth, and consequently anthropogenic input from both upstream and surrounding urban developments. The great anthropogenic impacts of the Shatt Al-Arab River are of considerable importance; there are very few studies on the sediments of the Shatt Al-Arab River, and little is known about their metal composition, distribution, and source as well as their anthropogenic impact (Allafta & Opp, 2020). Sediment samples were collected from 25 sampling stations on the 21st of October 2018 (dry season) and the 21st of January 2019 (wet season). Sieve sizes of 135 and 63 µm were used for sediment samples. Silt and clay fractions were separated by settling velocity methods. The finer fractions were characterized by their mineralogy and elemental content.

10.2. Comparative Studies with Other Rivers

This section compares the results of the Shatt al-Arab River study with those of similar studies in the creeks of Basrah City and the Euphrates River.

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Designed primarily to aid in the management of water resources, such studies have mostly focused on analyzing human modifications and their impacts on hydraulic, morphological, and sedimentary characteristics. The main impact of human alterations, from a hydrological point of view, is reflected in the change in the time series of discharge at various river stations. In regard to hydraulic and sedimentary features, a barrage at the river head has provoked numerous downstream changes, such as river narrowing, depth reduction, and bed sediment aggradation. The result has been widespread damage to the river ecosystem. Considerable impacts of sediment abrasion or aggradation have been detected. A comprehensive understanding of river morphodynamics, however, requires better temporal and spatial analysis.

The surround of Basrah and its rivers have also endured many experiences. This section compares the results with three studies of the other two rivers, focusing on remote sensing environmental maps and assessments. It is worth mentioning that almost all of these studies are conducted on large rivers having complicated headwaters, wise regulation systems, and complex interconnections with wetlands or lakes; all of which are outside of the researcher interest. While the three studies are focused on single rivers, it can be possible and also verified in this research that the results can be successfully applied to the larger river systems made up of various smaller rivers or creeks. In finally, considering all of these findings, a research proposal including three major parts is proposed. The first part consists of several hypotheses to be tested. The second part is designed to objectively establish a baseline assessment of the locations and magnitudes of the environmental changes based on time series Landsat images. The third part purpose a plan for water quality analysis of three parameters matching with the proposed models.

11. Challenges in Remote Sensing Applications

Despite its strength, remote sensing is yet to realize its full potential in addressing societal problems related to land-water use. The analysis of the Shatt al-Arab's water morphology could not have been done with water quality data from any one grade of satellite alone. The analysis of water quality parameters using satellite remote sensing has significant potential to provide valuable insights into the environmental conditions of the desert and Kurdish-populated areas of Iraq. Optical remote sensing data with high spatial, spectral, and temporal resolutions can be leveraged to quantify key water quality indicators, such as turbidity, suspended sediments, chlorophyll content, and salinity levels. In the case of this study, quality temperate data were obtained. Nevertheless, the optical capabilities do not reach earlier resources in resolution. Nevertheless, clouds occluded too many data for perfect analysis, necessitating the combination of insights to achieve higher-quality time series.

Likewise, sources of high-quality radar data are few, and the area is too swampy and infested by canals to evaluate whether sufficient data would have sufficiently captured change over time. With sufficient access to good-quality data, renewable earth resources, or previous high-resolution data, development is expected to improve significantly in the future. The same applies to integrated approaches covered in this study. In its learning phase, raster classification provided the lowest quality but could be consulted indefinitely without much skill. On the contrary, food detection and discrimination, particularly learning methods, relied heavily on the time series available while challenging to use properly without becoming overfitted. More such studies will be required along the river. Future studies should also examine more readily applicable learning methods, potentially even independent of multispectral optical data for better monitoring of resource observance.

11.1. Data Limitations

The study of environmental changes in the Shatt al-Arab River is limited by data availability. Although other remotely sensed layers might be better suited for effective analysis, such as , the former is not currently available. On the other hand, while is available, it lacks completeness in the sequence, as the area of interest was not always covered by operational tasks. It is important to note that global agency policies influence data accessibility. Over the past few years, emphasis has been placed on open-source data availability. Though individual government agencies have released their data

since the late 1980s, each entity has its own policies that, at times, limit data accessibility. Meanwhile, commercial enterprises have released satellite imagery elements amusingly portraying disastrous incidents all around the globe. Floods, fires, and landslides have been depicted, but unselective image portrayal often lacks proper consideration of the satellite pass details based on time, viewing angle, analysis on exploited data, or even a drastic timeline revision (Hasan,2018). Eventually, exploitation of subsequent data might not yield findings concerning previously unrevealed sub-themes. Apart from the unexplainable performances of some datasets, the available public datasets might not always fulfill the needs of interested researchers.
Moreover, despite promising innovation in satellite imaging technology, accessibility mirrors those aforementioned issues. Different satellites, sensors, and platforms have been employed to neutralize public demand on massive-scale imagery of historical imagery and revisit consistently. While seeking large-scale convenience, data availabilities were rarely subjected to a preliminary quality control stage. Consequently, several misleading usability disclaimers often arise. Remotely sensed imagery of characteristics evaled via incorrect detector/display settings can widely seem harmful.

11.2. Interpretation Issues

The Shatt al-Arab River Basin has a complex network of rivers and marshes that are home to a variety of flora and fauna communities in Western Asia (Hasan, 2018). It is the only water source for these marshes and rivers, making it the crucial indicator of the marshes ecosystem's health. The Shatt al-Arab had appeared to respond to large-scale hydro-environmental changes in the basin, such as large dam construction on the main tributaries and the drought period, through its surface area and morphometric characteristics. Hydrologic modelling accurately simulated the river runoff and outflow, which are closely related to the water balance. With the run-off data, the surface area, area of wetlands, and all metrics of the river were estimated and closely matched with the MODIS-derived data.

Three major findings are provided based on pre-processing methods and fixed bands choice for multispectral imagery to address the initialization issues: First, two methods of adaptive band pre-processing were designed for training data separation, which improve modified band regressions. Compared with the 13-band model of fixed bands selection, the improved method achieves better accuracy and also performs well in both correction factors and water quality retrievals for improved bands selection. The new finding of an optimal 4-band model provides an opportunity to develop new monitoring sensors for coastal waters. Second, an unmixing-based simple pre-processing method was proposed to synthesize pristine data, which could be a cost-effective way for satellite color data correction. The optimal blending ratio was found around 1:30 to remove most of the clouds while retaining about 90% correct spectrometry matching.

12. Future Directions in Research

Investigation of sedimentation and erosion in brackish marsh systems is a promising direction for future research. Shallow waters hinder a dimension, making it hard to estimate roughness and determine sediment distribution. The methodology described should accommodate that depth range. Multispectral sensor capability offers vertical profiling and improved modelling of vegetated water bodies, facilitating accurate analysis of brackish waters globally.

Rates of sediment movement and residence times will also be examined. Satellites can characterize suspended sediments but their spectral signatures are nearly equivalent in aquatic environments, limiting application. New approaches, including data assimilation applied in terrestrial materials, may enable monitoring suspended sediments through surface reflectance. This is vital, as environmental, biological, and chemical processes depend on sediment transport. Another water quality-related future challenge is assessing how restored stream buffers affect water quality. Riparian vegetation enhances groundwater filtration, improving water quality. However, substantial time lapses between restoration and measurable water quality improvements complicate monitoring on small watersheds. Satellite data increase temporal coverage, aiding shortening time between restoration and assessment.

Research directions include investigating the desiccation of the once great Aral Sea, Lake Urmia's desiccation, and the Mediterranean Basin's

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desiccation. Iran's Lake Urmia is evaporating, with salinity affecting ecosystems, fauna, and agriculture. Results highlight the salinity of Lake Urmia near Lake Urmia Port, less saline regions near Qumar and Eshir. Future applications could delineate dehydrated areas and measure salt seas and associated health impacts. Similar work could focus on desiccation in Brazil, including the Amazon River and aquifer systems. Southwards, agricultural restrictions by acidified and eroded isolation zones could be analyzed. Another focus would be on the Mediterranean Basin, where several major water bodies are desiccating simultaneously. These water bodies supply major cities, national capitals, and important ecosystems, being significant for health and climate.

12.1. Innovative Technologies

Outcomes of settlement vacancies in the long term, with a special regard to water quality after using innovative construction and demolition technologies for urban building transfer redevelopment. Smart and innovative city building cleaning technology has important effects on ecological environment. Considering the earlier versions of main technologies, they deliver minor environmental disturbances. On the other hand, when practically upcoming zoning plan technologies are utilized, they may have devastating harmful effects and threaten the Tarna River, which was formerly ecologically cleaned. Innovative urban cleaning technologies may have an extensively diverged impact on ecological environment protection for different cases.

Environmental quality may get worse for a long time even after settlement abandonment. Water supply quality could be mainly changed by the introduction of urban emptying. Applications of smart and innovative technologies may help to qualities but applying currently important technologies could harshly harm the Tarna River flow. In light of these findings, it is highly recommended to improve construction and demolition technologies according to their newly recognized results of environmental effect and also additional designs ought to be constructed for them. Polishing rivers is highly recommended for assuring the safety of the water supply and its parameters like richness for an extensive period (Hasan, 2018).

While the improvement of urban technology and the method of town transfer recreation implementation may help in it and its possible consequences were earlier tested, much less effort has paid attention to the newly emerged trend of urban infrastructure cleaning technologies. It was the aim of this paper to present a preliminary SLU water quality and water supply feasibility study. It underlined that water body pollution parameter surfaces of CC options strongly diverge. One option of currently used technologies keeps ecological parameters and separates a lesser number of buildings than case technology, on the contrary, which threatens the river's water quality.

12.2. Policy Implications

Although scientific research is of utmost importance to policy making, in some regions, be they industrialized countries or emerging economies, science is often set aside or viewed as an unnecessary luxury. For decades now, satellite remote sensing has revolutionized the monitoring of the global environment, including freshwater aquatic ecosystems, with a track record dateable and testable back to the mid-1980s. Many remote sensing products are now free and easily accessible. Hence in principle, users just need a personal computer and a reliable internet connection to obtain and visualize these products. Unfortunately several limitations still exist, including accessibility to computers and fast internet connections, lack of awareness or knowledge about how to obtain or make use of these products, lack of financial and employment resources to enact the enhanced decision-making processes, and lack of time-horizon accommodating the organizational intricacies pertaining to emergent economies and transitional societies, coupled with the often erratic nature of enforcing effectively the slow-moving procedures and mechanisms to produce enhanced decision-support systems. To remedy the above cited deficiencies, a concerted and cooperative, well-funded international strategy to deploy satellite remote sensing technology and associated ground truthing capabilities across all regions of the world could pay significant dividends.

Implementation of even simple water quality monitoring systems reliant on satellite remote sensing would vastly improve water quality, quality management and related catchment management capabilities across such regions. Such enhancements, even assuming little else changes in these latter regions, would pay huge dividends in better ecosystem management, more efficient local economies and improved quality of life as cast in reductions in the aforementioned health risks manifested in premature mortalities. Such applications of satellite remote sensing would therefore to some degree help rectify the nation-wide inequities associated with freshwater resources observed in developing countries and emerging economies. New funding streams could be created to help assist nations initiate or develop these new systems. Ground-based sampling and remote sensing training programs could be funded. Satellite-based water quality monitoring products could then be easily disseminated, more adopted and more deeply probed, furthering understanding of the efficacy of these tools, while in parallel improving a wider variety of decisions about managing or studying catching systems and examining the effect of water quality on health for example.

A strategy of coupling these simple, early-effect-potential systems with standard modelling tools that account for catchment specificities would significantly amplify their utility. Such models could easily be propagated to identify regions periodically under disproportionately threatening catchment specificities, while development en masse will also address some of the underlying complexities of modellers adopting these systems and most importantly, differences in capacity for decision systems to explore and understand these modellers outputs. Investments could be made to foster the use of existing models or information products in analysis to reach more knowledge and insight from their outputs.

13. Conclusion

Since its formation, the Shatt al-Arab River has not remained constant spatially and hydrologically. It has been expanded and narrowed, altered in direction and changed in hydrology. Its extent has changed also as a result of sedimentation and riverbed movements. These changes point out the instability in the river, showing that no river is static. An effect of either anthropogenic or natural circumstances might accordingly enlarge or narrow any river. The monitoring of river channels has been an important research topic. The Shatt al-Arab River and its related marshes have suffered drastic changes in their morphology and environment. The environmental conditions of the Shatt al-Arab River have drastically changed during the last two decades due to several environmental and ecological effects. As the most important watercourse of Iraq, the Shatt al-Arab is considered to be a lifeline of life in the southern part of the country. On the other hand, the water quality of the Shatt al-Arab River suffers from pollution, salinity, and sedimentation problems; therefore, controlling its disastrous problems is considered to be primordial. The Shatt al-Arab River is one of the most important rivers in Iraq. It is, therefore, very important to study and understand its behaviour. Developing a new method for complexity assessment based on mathematical morphology is crucial since conventional techniques fail to measure important river characteristics such as width variation, direction changes, and properties describing general shape. The proposed method, which quantitatively measures the complexity of shapes by decomposing rivers into a hierarchy of descriptions, could be used to answer a variety of research questions on river system development and provide new insights into river naturalness assessment. A hybrid approach combining remote sensing, Kernel Density Estimation, and GIS proved suitable for the assessment of riverscape complexity and could help inform management and rehabilitation policies. Despite difficulties, results have the potential to shed light on river naturalness evolution and detect well-known deficiencies in management practices. Furthermore, the distance between calculated entropy values and theoretical bounds allows for characterizing differently regulated rivers and studying their relative resilience. The satellite is very helpful for monitoring the environmental changes in wetlands, estuaries, and rivers, particularly in the Shatt al-Arab River basin. It reflects all changes over this period due to the colour attributes of the river strength. Additionally, the usage of the satellite and different indices has shown pollutants, high vegetation, and buried structures in a wise manner. The effects of the different indices were clearly demonstrated with the indices detecting the high vegetation inverse area and the buried structures in the coast during the studied period. It is important to check the results with other features such as soil moisture and temperature using either soil moisture monitoring stations or temperature lowering techniques in other images and compare them with the current results. High-resolution bandwidth satellite images should also be used in the next study in view of monitoring the river and recreating its detection map.

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