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Extraction of Water Bodies Maps Using Remote Sensing Data and GIS Technique

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Abstract:

The extraction of water bodies maps using remote sensing and GIS is a crucial aspect of environmental monitoring and management. Remote sensing technology, such as satellite imagery and aerial photography, allows for the collection of data on water bodies from a large spatial scale, while GIS enables the analysis and visualization of this data in a spatial context. This combination of technologies has revolutionized how water bodies are mapped and monitored, providing valuable information for a wide range of applications, including water resource management, environmental impact assessment, and disaster management. By using several techniques, such as unsupervised classification and the water index methods like normalized difference water index and the modified normalized difference water index for the study area for the investigation of the most efficient approach for extracting water body maps, these water bodies have significant impacts on climate dynamics, biodiversity, and human welfare. In this study, we employ two Sentinel-2 satellite pictures to make high-resolution maps of the Darbandikhan Dam lake surface water using remote sensing techniques and GIS with a spatial resolution of 10 meters. for the years 2017 and 2023. After using the methods to extract the area of water bodies and present the results of these methods on field areas, it became clear that the modified normalised difference water index (MNDWI) method is the most accurate in extracting maps for water bodies.

Keywords: remote sensing; NDWI; water-body; Darbandikhan Dam Lake.

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استخراج خرائط المسطحات المائية باستخدام بيانات الاستشعار عن بعد وتقنية نظم المعلومات الجغرافية

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المستخلص

يُعدُّ استخراج خرائط المسطحات المائية باستعمال الاستشعار عن بعد ونظم المعلومات الجغرافية جانبا حاسما في المراقبة والإدارة البيئية. وتسمح تكنولوجيا الاستشعار عن بعد، مثل صور الأقمار الصناعية والتصوير الجوي، بجمع البيانات عن المسطحات المائية من نطاق مكاني كبير، في حين تتيح نظم المعلومات الجغرافية تحليل هذه البيانات وتصورها في سياق مكاني. وقد أحدث هذا المزيج من التقنيات ثورة في الطريقة التي يتم بها رسم خرائط المسطحات المائية ومراقبتها، مما يوفِّر معلومات قيمة لمجموعة واسعة من التطبيقات، بما في ذلك إدارة الموارد المائية، وتقييم الأثر البيئي، وإدارة الكوارث. باستعمال العديد من التقنيات، مثل التصنيف غير الخاضع للرقابة وطرق مؤشر المياه مثل مؤشر المياه الفرقية الطبيعية ومؤشر المياه الفرقية المعدلة لمنطقة الدراسة لدراسة النهج الأكثر كفاءة لاستخراج خرائط المسطحات المائية، كان لهذه المسطحات المائية تأثيرات كبيرة بشأن ديناميات المناخ والتنوع البيولوجي ورفاهية الإنسان. في هذه الدراسة، قمنا باستعمال صورتين من القمر الصناعي Sentinel-2 لعمل خرائط عالية الدقة للمياه السطحية لبحيرة سد دربندخان باستعمال تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية بدقة مكانية تبلغ 10 أمتار. لعامي 2017 و 2023. وبعد استعمال الطرق لغرض استخراج مساحة المسطحات المائية وعرض نتائج هذه الطرق على المساحات الحقلية، تبيَّن أن طريقة مؤشر المياه الفرقية المعيارية المعدلة (MNDWI) هي الأكثر دقة في استخراج الخرائط للمسطحات المائية.

الكلمات الافتتاحية

الاستشعار عن بعد، مؤشر نسبة المياه النسبية، الجسم المائي، بحيرة سد دربندخان

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1. INTRODUCTION

Water is a vital resource for all life on Earth, and the availability and distribution of surface water play a crucial role in various ecological and socio-economic processes. Accurate mapping and monitoring of surface water bodies are essential for effective water resource management and environmental planning. The recent progress in remote sensing technology has been significant in urban land/cover mapping, planning, tourism, and environmental management. High-resolution images are commonly utilised for urban classification. (Mahmoud et al., 2022)Furthermore, remote sensing and GIS provide a cost-effective and efficient means of mapping water bodies, particularly in remote or inaccessible areas.Nevertheless, a significant drawback of field mapping is the challenge of conducting comprehensive observations, particularly in densely vegetated regions (Mezaal et al., 2017). This essay explores the application of RS and GIS in mapping surface water bodies and their long-term changes, highlighting their significance and potential future developments.

Due to the extensive and consistent coverage provided by satellite remote sensing, the rapid and precise extraction of water information has become a crucial technological tool in various applications such as water resource surveying, monitoring, wetlands preservation, and disaster prevention and mitigation. Simultaneously, other water information extraction techniques, including the threshold approach. The categorization of satellite images and other images is divided into two techniques: supervised and unsupervised. The primary distinction between the two lies in the method by which the spectral signatures are produced. In a supervised technique, the operator manually identifies the places where a given class of land cover exists, and then the

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computer calculates the spectral signatures. Contrarily, in the unsupervised approach, the computer employs mathematical data clustering in the multi-dimensional feature space to construct the spectral signatures. (Mezaal et al., 2022). The ratio-based index, commonly referred to as the normalized index, incorporates the Difference Normalized Water Index(MNDWI). (Mc Feeters S K.2016).

2- Study Area

Darbandikhan Lake is situated in the southeastern section of Sleimani City, at a distance of around 60 kilometers. The geographical coordinates of the location are latitude 35.112011°N and longitude 45.685272°E. The lakeside and riverfront sections showcase awe-inspiring natural scenery. The southern part of Iraq is a popular destination for those who are drawn to its scenic landscapes and revitalising ambiance. The region is widely recognized for its significant tourist prospects, captivating visual allure, and abundant biodiversity(Husain Y. 2016). The prominent feature of Darbandikhan is its noteworthy freshwater reservoir, which was created by the construction of the Darbandikhan Dam. The reservoir receives its water supply from two prominent rivers, specifically the Tanjero in the northern area and the Sirwan in the eastern vicinity, both of which possess historical importance. The lake functions as a popular destination for recreational pursuits, such as picnics, while simultaneously serving as a crucial habitat for the native fauna in the vicinity. Figure 1 displays a map depicting the research region.

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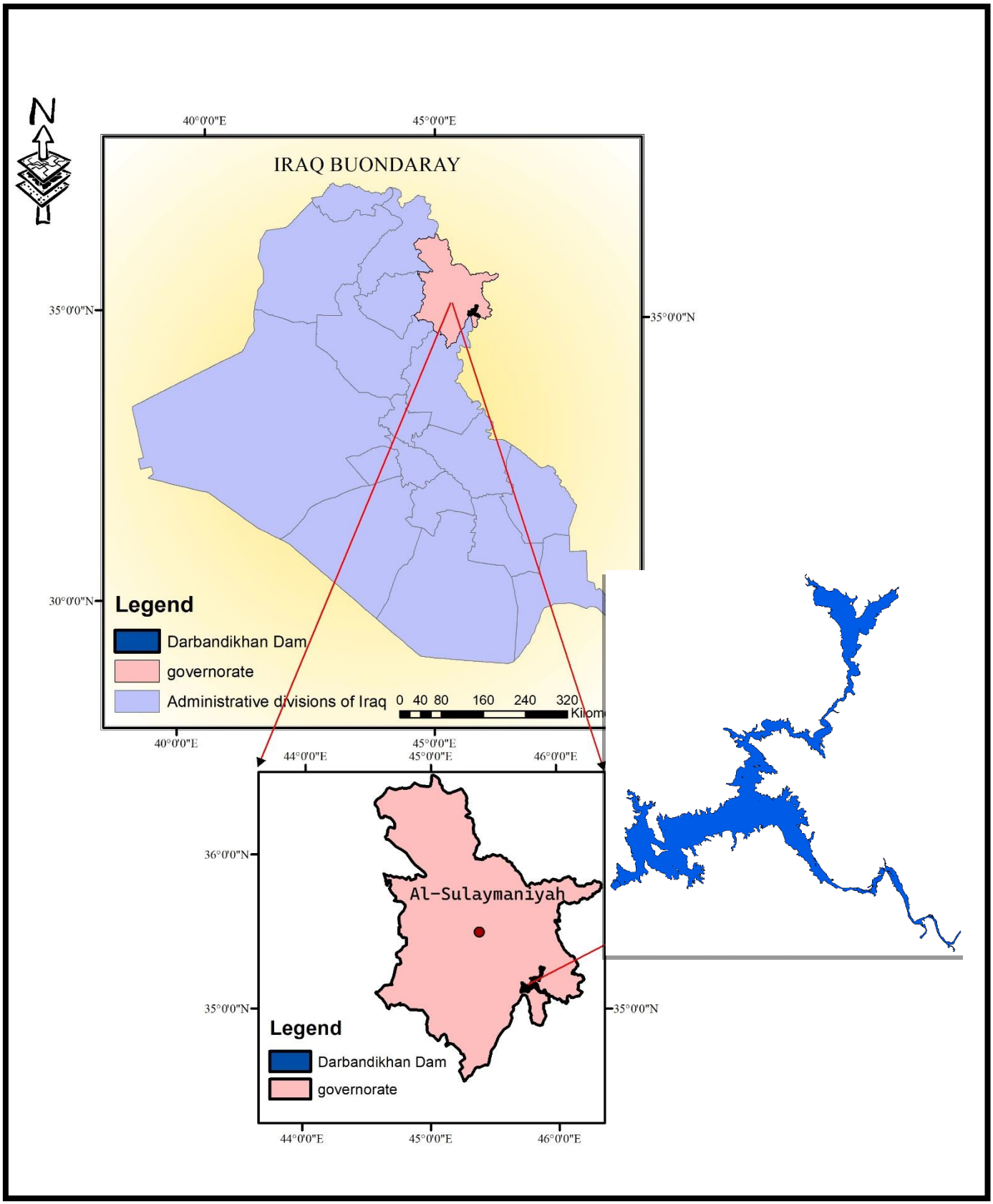

Figure -1: Study area maps by Author

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3. DATA USED AND METHODOLOGY

3.1 Data Used

two Sentinel 2 satellite images, were used for this research. from a Sentinel 2A image that was acquired on December 2017, 2023. The Sentinel 2 images were selected and downloaded from the platform(https://dataspace.copernicus.eu/) **(**Maarez, H. G. et al.,2022**)** for the purposes of this research. “The sentinel-2 images contain 13 bands. The interval between revisits has increased to ten days at the equator when using only one satellite, and fife days while using two satellites in clear weather circumstances. This translates to 2-3 days at mid-latitudes, allowing for effective monitoring of changes on the Earth's surface **(**Wadeea K.et al.,. 2023)

The utilisation of RS applications and (GIS) tools has been employed for the assessment and administration of water resources, as well as the management of coastal regions. These technologies facilitate the monitoring and delineation of open water areas, quantification of water body extents and depths, examination of beach and island alterations, and extraction of water areas using various indicators derived from judicial opinion data, thereby distinguishing them from other species **(Fahad, et al . 2020).** The study utilised the Sentinel-2 satellite, which possesses a spatial resolution of 10 meters, to collect data for the study area throughout the years 2017, 2023. The software utilised includes Snap Desktop 9.0 and ArcGIS 10.8.

3- 2 Software

SNAP 9.0 and ArcGIS V.10.8 software have been used. SNAP 8.0 Image processing was conducted using software. The data analysis and map building tasks were performed using Arc GIS 10.8 software.

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SNAPDesktop

Is a freely available software package that offers a comprehensive set of tools for the processing of satellite data outputs. It supports a wide range of satellite missions, including The Copernicus Sentinel-1, Sentinel-2, and Sentinel-3 satellites, along with the European Space Agency's Soil Moisture and Ocean Salinity (SMOS) program and missions conducted by third parties. The development of the technology was undertaken by Brockmann Consult, Skywatch, Sensar, and C-S.

ArcGIS

Is a software application developed by Esri that provides a comprehensive suite of tools for geographic information system (GIS) analysis and mapping .The software program produced by "Esri" is known as a comprehensive toolset that enables users to generate, examine, and administer geographic data. The software in question is a geographic information system (GIS) that provides users with the capability to generate maps, conduct spatial analysis, and effectively handle data in diverse formats.

3-3 Research method

This study includes an initial phase known as "pre-processing," which involves radiometric and atmospheric corrections, as well as subsetting. After the pre-processing stage, the photographs were classified into groups using unsupervised classification algorithms that rely on the natural water difference and Indice. The aim was to ascertain the magnitude of the Darbandikhan Dam reservoir. This study utilised the Modified Normalised Difference Water Index (MNDWI) and Normalised Difference Water Index (NDWI) to Extraction Maps of the surface the Darbandikhan Dam Lake. This examination is depicted

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in Figure 2 The previous steps utilised the Geographic Information System/Remote Sensing (GIS/RS) technique.

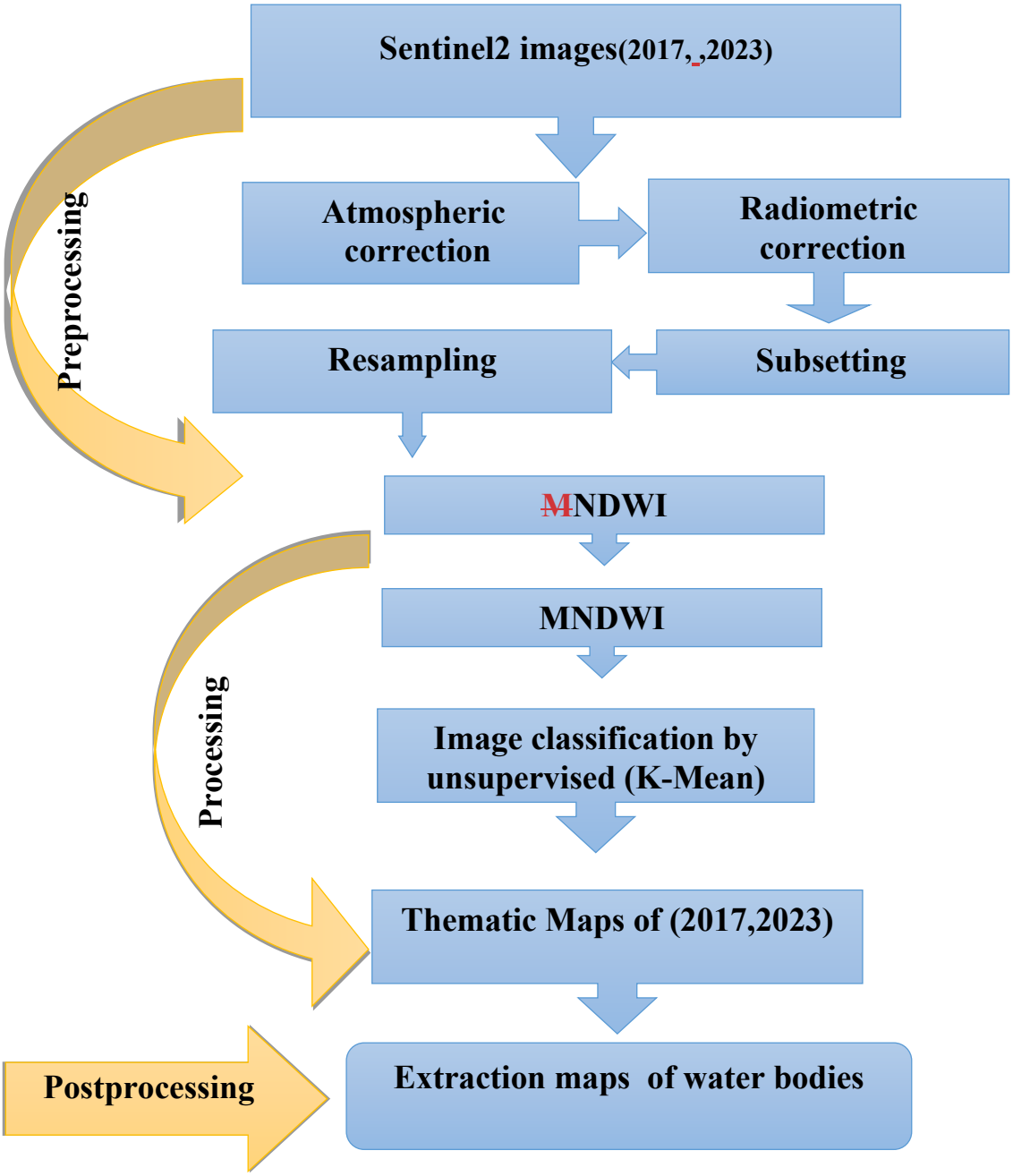

Figure-2: Schematic of the research methodology

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3-4 Remote Sensing Techniques:

Remote sensing is the process of gathering data about an object or event without making direct physical contact. In the context of surface water mapping, remote sensing techniques such as satellite imagery, aerial photography, and LiDAR (Light Detection and Ranging) are widely used. Satellite imagery provides a comprehensive view of large areas, enabling the identification and mapping of water bodies. Aerial photography offers higher spatial resolution, allowing for detailed mapping of smaller water bodies. LiDAR technology, on the other hand, provides accurate elevation data, facilitating the identification of water bodies and their topographic characteristics. Remote sensing techniques have proven to be effective in providing timely and accurate information about surface water dynamics(Hashim F., et al., 2021). One widely used remote sensing index for surface water mapping is the MNDWI Index. Below are the concepts, applications, and advantages of MNDWI in surface water mapping.

3.4.1 Modified Normalized Difference Water Indices (MNDWI) :

Is a widely used remote sensing technique for water detection and monitoring. It is derived from multispectral satellite imagery and provides a quantitative measure of water presence in a given area. MNDWI is particularly effective in distinguishing water bodies from other land cover types, such as vegetation and bare soil. The index is calculated by utilizing the green and short-infrared bands of the imagery, which are sensitive to water absorption and reflection properties. MNDWI values can be derived by performing subtraction between the green band and the mid-infrared band and then dividing the result by their sum. These values range between -1 and 1. Positive MNDWI values

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indicate the presence of water, while negative values indicate the absence of water**(Xu, H.Q 2006)**. The index has proven to be useful in various applications, including hydrological studies, urban planning, and environmental monitoring. Its ability to accurately identify water bodies makes it an invaluable tool for assessing water resources, monitoring changes in water bodies over time, and aiding in the management of water-related issues.

$$MNDWI = \left(\frac{Green - Nir}{Green + Nir}\right) \quad (1)$$

3.4.2 The Normalized Difference Water Index (NDWI)

Is a remote sensing-derived index that estimates the water or moisture content of a surface. It is computed with the near-infrared (NIR) and green bands of a satellite image. NDWI can be used to delineate and monitor changes in surface water, leaf water content, and fire risk. NDWI values range from -1 to +1, with higher values indicating more water or moisture5.

$$NDWI = \left(\frac{Green - Nir}{Green + Nir}\right) \quad (2)$$

3.5 Geographic Information System (GIS)

GIS, or Geographic Information System, is a computer-based tool used for the creation, management, analysis, and mapping of various data sets. GIS facilitates the connection between data and a map by incorporating spatial data (the geographical coordinates of objects) with other forms of explanatory data (the characteristics of the location) (Habeeb, et al., 2022). Mapping and analysis are essential elements employed in research and virtually every

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business. GIS enables users to understand patterns, relationships, and spatial context. Advantages of this include increased productivity, as well as more effective administration and decision-making. GIS provides a spatial representation of water resource systems. A GIS may add geographical dimensions to a typical water resource database and offer an integrated perspective of the world. This is accomplished by integrating various social, economic, and environmental factors related to geographical entities of a water resources issue and making them accessible for utilization in a decision-making procedure. (Habeeb, et al., 2022)

3.5.1 Unsupervised Classification:

The process of establishing, recognizing, labeling, and mapping spectrally homogenous classes is known as unsupervised categorization. It's a method for categorizing the pixels in an image without the employer being aware of the underlying ground properties. This method aids in determining the quantity and locations of the spectral categories into which the data is divided, as well as the spectral category of each individual pixel. The analyst then links a sample of pixels from each spectral category to readily available reference material, which can include maps and details from field trips. Many methods have been created, The methods employed include cluster analysis with movement, iterative self-organizing data analysis, and agglomerative hierarchical clustering. **(**Wadeea**, et al.,2023).**

4. RESULTS AND DISCUSSION

The application of technological tools in the analysis and processing of satellite imagery, along with the use of geographic information systems,

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facilitates the extraction of maps depicting water bodies. The ability to carry out research on water bodies throughout the year is made possible by the use of a comprehensive database that contains relevant information regarding the water surface.To undertake a thorough examination of the water surface area of a contemporary reservoir, numerous categorization maps were developed. In this study, two Sentinel-2 images captured in 2017 and 2023 were utilised for the purpose of categorization. This categorization process involved the application of natural water difference indices and unsupervised classification approaches.

The rapid development of remote sensing technology has had a substantial impact on the facilitation of various strategies focused on the extraction of water bodies maps, such as the Darbandekhan Dam Lake.

The application of remote sensing techniques has led to the identification of the Modified Normalised Difference Water Index (MNDWI) method as the most effective strategy for reliably extracting water body maps of the Darbandekhan Dam Lake. The proposed approach is predicated on the computation of spectral reflections at the green wavelength and the medium red wavelength, wherein the ratio between these reflections is utilised to deduce the intended measurements. Moreover, it is important to acknowledge that this approach holds promise for future refinement and augmentation. Figure 2- illustrates the Difference in maps extracted for the lake by the employed methodologies for yares 2017and 2023.

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Table 1. The table compares the water area of the Miyun reservoir extracted using various methods.

Method for extracting bodies of water	Water surface area for lake 2017(km^2)	Water surface area for lake 2023(km^2)
Unsupervised classification	40.02	31.15
NDWI	44.07	33.25
MNDWI	44.19	33.65

Provide a concise overview of the impact of water body extraction. Utilize the SNAP Desktop software for Remote Sensing image processing to superimpose the extracted water body onto the image of Darbandikhan Dam Lake's water area.

(1) unsupervised classification

Unsupervised classification is a rapid and straightforward method that does not require modeling. It achieves high accuracy in various types of classification and produces effective results.

(2) Normalized Difference Water Index

It is proficient in water extraction. The impact of water extraction on the Darbandikhan Dam Lake and city is generally positive, yet it is nonetheless accompanied by a mixture of unrelated non-water information. The NDWI approach, which is a reference to NDVI, involves determining a threshold and extracting water body information quickly after doing band math. However, buildings and water can be readily mistaken for soil in NDWI, resulting in noise. The model employed in this method is complex (Maarez, et al., 2022).

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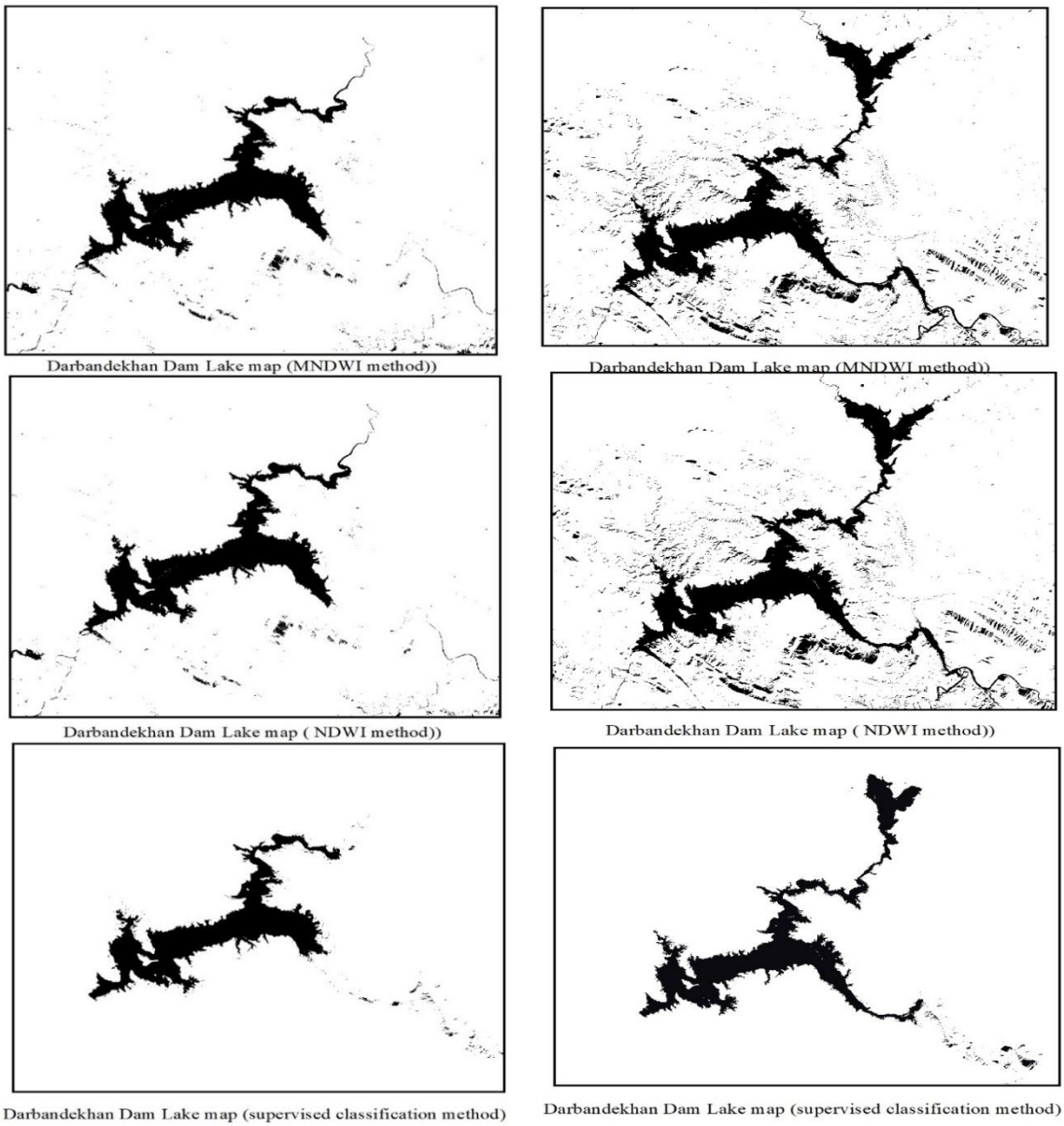
(3) Modified Normalized Difference Water Index

The MNDWI index effectively removes the influence of shadow wells. The MNDWI image contains more comprehensive data compared to the NDWI image and other visible bands. Additionally, the MNDWI index demonstrates superior accuracy in extracting small water bodies. The citation (Maarez, et al., 2022) refers to a publication by Maarez and colleagues in the year 2022. Water Index Update



5. C

Figure 3 . Darbandikhan Dam Lake maps (a)2017, (b)2023 (MNDWI, NDWI, and Unsupervised classification method)

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The extraction of water bodies maps using remote sensing and GIS is a powerful tool for monitoring and managing water resources. The combination of remote sensing technology and GIS allows for the collection, analysis, and visualization of data on water bodies, providing valuable insights for a wide range of applications. While there are challenges and limitations associated with the use of these technologies, their numerous advantages make them an essential component of modern water bodies mapping and monitoring efforts.
Different methodologies are available to extract surface areas of water bodies via remote sensing and geographic information systems. Each method chosen for extracting maps had its own distinct benefits and drawbacks, which ultimately determined its level of accuracy and the extent of its reliability as accurate data that helped determine the exact surface area.

1. The reservoir area in the Darbandikhan Dam Lake is not very stable, with large differences between the years 2017 and 2023, as it is affected by climatic factors such as lack of rain and human factors represented by the cutting off of the Sirwan River, the main feeder for this lake.
2. Both NDWI and MNDWI are efficient in extracting water-related information quickly and achieving accurate mapping results of water bodies through the use of appropriate thresholds. The MNDWI model is suitable for identifying water bodies.
3. Unsupervised classification can also be used for water mapping but with lower accuracy than NDWI and MNDWI.

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6. Recommendations

Because the process of integration between remote sensing applications and geographic information systems allows for accurately extracting maps of water bodies, it helps to define these bodies and calculate their surface area and storage volume. The following points are recommended:

1 - Intensifying scientific research in this field, as science is constantly developing and requires keeping up to obtain the desired results.

2 - Adopting this method in producing maps because they are highly accurate and complete at a lower time and cost compared to traditional methods.

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