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The Impact of Seasonal Changes on the Land Cover of Lake Hamrin: A Comparative Study of Dry and Wet Seasons

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Abstract

This study conducted a thorough analysis of changes in land cover components of the Lake Hamrin area, located within Diyala Governorate, Iraq, focusing on the influence of human and climatic factors. Human variables included the rate of water release from the Darbandikhan Dam, while climatic factors encompassed fluctuations in temperature and annual rainfall. These factors significantly impact the lake, the largest body of water in the region, and other land cover components, leading to disruptions in the overall ecological balance.

Two satellite images from 2024 were analyzed for this research, representing two distinct seasonal periods: the first image was captured in April, following the conclusion of the rainy season, while the second was taken in October, after the summer months. Data obtained from the Landsat 9 OLI satellite, provided by the United States Geological Survey (USGS), were employed, targeting the specific area within track number 168-36. The dataset was processed using ENVI version 5.3, an advanced tool dedicated to spatial data analysis. The analysis of land cover changes in the Hamrin Lake area was conducted using the Maximum Likelihood Algorithm (MLA), focusing specifically on the interactions between climatic and human factors affecting water mass. This method allowed for a comprehensive evaluation of changes in water mass area and their subsequent impact on other land cover components, with the overall classification accuracy serving as a key performance metric. The findings revealed a significant correlation between the lake's water mass area and adjacent land classes, which revealed notable variations in the area of water bodies between the spring and autumn seasons, which affected various land cover categories and, consequently, the regional ecosystem.

Keywords: Spring, Autumn, Human, Remote Sensing.

1. Introduction

Lake Hamrin is a significant artificial water body in Iraq, crucial to the region's ecology and economy. It relies on various water sources, including the Diyala River, seasonal rainfall, groundwater, natural springs, and human-made contributions such as artesian wells and irrigation projects. These elements are essential for sustaining the lake's water levels and supporting agricultural and economic activities in the surrounding areas[1].

The lake is located in the country's northeastern region, specifically within Diyala Governorate. It was established in the 1980s as part of the Hamrin Dam Project, which was designed to regulate the flow of the Diyala River and provide essential water resources for irrigation and hydroelectric power generation. This lake serves as a unique ecosystem that supports a diverse range of organisms, including various fish species, waterfowl, and aquatic plants, highlighting its significant environmental importance[2].

Lake Hamrin is essential for upholding the ecological balance within the region. It serves as a habitat for diverse aquatic and terrestrial species, enhancing local biodiversity. The lake supports over 50 fish species and is a critical stopover for various migratory birds during their annual migrations. Furthermore, the aquatic vegetation within the lake plays a vital role in water purification and significantly contributes to the oxygen supply necessary for sustaining the ecosystem[3,4].

Lake Hamrin is a crucial water resource in the region, providing essential support for irrigation and drinking purposes, as highlighted in a Food and Agriculture Organization report[5], The lake serves as a critical water resource for the irrigation of more than 100,000 hectares of farmland, significantly enhancing agricultural productivity and ensuring food security for local communities. Moreover, the lake's water is utilized for hydroelectric power generation, contributing to the electricity supply for the surrounding regions[6].

Climate change causes significant variations in rainfall patterns, which have a direct impact on lake water levels. In recent years, a noticeable decrease in rainfall has contributed to a decline in these water levels, highlighting the urgent need for adaptive management strategies[7].

The lake is currently confronting significant environmental and developmental challenges due to the substantial depletion of its water supply. This situation arises from two primary factors: first, the demand for water for irrigation is contributing to a worrying decline in the lake's water levels; second, there is an increasing need for water for drinking and domestic purposes among the local population. These combined human activities result in the unsustainable depletion of the lake's resources, posing a threat to the integrity of this vital ecosystem and the well-being of the communities that depend on it. Therefore, it is essential to reevaluate this natural resource's management and pursue a balanced approach that ensures its sustainability while addressing its fundamental needs and respecting its capacity limits[8–10].

Erosion contributes to the accumulation of substantial sediment in the lake, adversely affecting water quality and diminishing its storage capacity. This issue poses a significant and enduring environmental and economic challenge[2,4].

Lake Hamrin, created by the dam, represents a crucial ecosystem that supports the region’s biodiversity. It is a habitat for various plant and animal species, contributing to ecological balance. Furthermore, the lake positively impacts the local climate and provides valuable ecotourism opportunities, enhancing the local economy and generating employment for residents.

Lake Hamrin exemplifies the successful integration of human engineering and natural resources. Effectively managing water and energy resources plays a significant role in sustainable development. In this way, Lake Hamrin stands as a powerful example of the collaboration between nature and human innovation, serving as a model for sustainable development practices[11,12].

The following is a review of significant prior studies conducted in this field:

-A comprehensive study was conducted on Lake Hamrin in Iraq, utilizing advanced remote sensing techniques to assess the surface area and water temperature from October 2019 to September 2020. The analysis revealed that the maximum surface area was recorded in October, measuring 264,617 km², whereas the minimum was observed in September at 140,202 km². The highest water temperature was documented in June at 45.49°C, while the lowest occurred in February at 3.09°C. These findings offer critical insights that can assist decision-makers in the sustainable management of water resources[13].

-The study underscores the critical significance of advanced remote sensing and image processing technologies in effectively managing large datasets across various levels. These technologies are integral to developing automated programs that assess and monitor operational water resources. Their applications encompass improving freshwater quality, evaluating water quantities, ensuring sustainable availability, and supporting comprehensive water resource management processes to achieve water security.

Furthermore, the research confirms that recent advancements in data processing and enhanced computing capabilities have facilitated monitoring water resources and environmental conditions with high spatial resolution. This monitoring can be conducted daily, monthly, seasonally, or long-term. Such a remarkable capacity to cover expansive areas significantly bolsters efforts to ensure the sustainability of water resources and contribute to global water security[14].

-They used remote sensing data to assess water bodies and reservoirs, which represents a sophisticated and efficient approach, enabling the analysis of extensive areas within a relatively short timeframe and at a cost-effective rate compared to conventional methods. Many studies have effectively integrated remote sensing techniques with geographic information systems (GIS) to monitor alterations in water surface areas on both local and regional scales. This study reviews research conducted in Iraq that employs these methodologies to examine changes in water surface areas by analyzing satellite imagery over various periods. The results indicate that the dimensions of natural and artificial lakes in Iraq are significantly influenced by political, economic, and climatic conditions, contributing to considerable size fluctuations over time[15].

-This study presents evidence indicating a significant reduction in the area of Lake Hamrin over the past two decades, with a particularly notable decline of 84 per cent reported in 2009. Conversely, the findings also highlight a substantial increase in the lake's surface area in 2019, which has surpassed the baseline level established in 2004. These changes in the lake's surface area and shoreline length are attributed to environmental factors and human influence[16].

This study aims to analyses the seasonal changes in Lake Hamrin and their effects on the land cover components of the surrounding area from April to October 2024. It will specifically focus on critical climatic factors, such as rainfall and temperature, and their influence on the lake's water levels. Additionally, the research will assess changes in the lake's area and the coastal strip during this timeframe and the implications of water releases on the lake's ecosystem and the subsequent changes in the environmental and geographical characteristics of the region.

2. Materials and Methods

1.2.Study Area

Lake Hamrin is an exemplary engineering accomplishment that reflects the synergy between human innovation and the natural environment. Recognized as one of Iraq's most significant artificial water features, it was created by constructing the Hamrin Dam, which is situated in Diyala Governorate, approximately 50 kilometers northeast of Baqubah.

Geographic maps delineate the lake's location, positioned between latitudes 44° 53′ 26.16" and 45° 07′ 28.03" east and longitudes 34° 04′ 24.75" and 34° 19′ 12.74" north. This strategic geographic positioning establishes Lake Hamrin as a remarkable intersection of natural beauty and human engineering, seamlessly integrating breathtaking landscapes with the ingenuity of developing substantial water projects[17].

The Hamrin Dam, located at the intersection of the Hamrin Hills and the Diyala River, is a significant engineering achievement in Iraq's history. It is notable for being the first earth-fill dam designed with a solid clay core, presenting a unique dam engineering model. Spanning 3,336 meters in length and rising to 40 meters, the dam features a 70-meter-wide spillway equipped with five gates that facilitate water discharge of up to 4,000 cubic meters per second. This meticulous design enables the dam to manage substantial water flows efficiently, mitigating the risk of flooding and promoting effective water resource management[18,19].

The Hamrin Dam was constructed between 1976 and 1981 and officially commenced operations in 1981. This significant infrastructure project spans the Diyala River, a crucial tributary of the Tigris River. The dam plays a vital role in regulating water flow, mitigating flood risks, providing irrigation water, and generating electricity. This integrated approach to water management and energy production underscores the Hamrin Dam's multifaceted contributions to society and the environment, thereby enhancing the quality of life for residents. Furthermore, agricultural initiatives that utilize water from the dam contribute to food security and foster economic opportunities for rural communities[20,21].

The Lake Hamrin area is distinguished by its remarkable plant diversity, which results from favorable climatic conditions and fertile soil that supports a wide array of plant species. This region includes aquatic, wild, and agricultural plants, each playing a vital role in the ecosystem.

Aquatic plants thrive along the lake's periphery and are essential for the ecosystem's overall health. They contribute to soil stabilization and water purification and serve as natural habitats for various aquatic organisms.

Wild plants, including grasses and shrubs adapted to the semi-arid climate—such as wormwood and sage—are integral to maintaining ecological balance within the area.

Furthermore, agricultural plants, such as wheat, barley, vegetables, and fruits, are crucial for the local economy and provide significant nutritional support to the community. Additionally, pastoral plants are essential in supporting livestock farming, enhancing the livelihoods of those in the region[22].

The Hamrin Lake area is experiencing substantial development, reflecting the region's economic and social advancement. This growth encompasses establishing residential neighborhoods, enhancing modern infrastructure, and developing industrial facilities, including gravel quarries and brick factories, which significantly contribute to economic activity. It is essential to approach this development with careful management to maintain a balance between progress and environmental sustainability[26,27].

The region is defined by a series of hills encircling a lake in northeastern Iraq, with elevations ranging from 200 to 500 meters above sea level. Composed of sedimentary and limestone rocks, these hills influence the local climate. The area is a natural barrier against moisture-laden winds, increasing precipitation on the windward slopes. Additionally, mountains contribute to temperature regulation by mitigating the effects of hot winds. Furthermore, they support the lake's water supply through small streams originating from their slopes, particularly during the rainy season, thus enhancing the sustainability of water resources in the area[12,24].

The hills surrounding Lake Hamrin function as natural barriers that safeguard the lake from pollution and minimize the risk of desiccation. These geographical features also play a crucial role in mitigating the impact of winds that carry dust and other pollutants. Furthermore, the hills significantly influence human activities, including agriculture, livestock grazing, and tourism, thereby vital to the region's ecological and economic landscape[25].

Lake Hamrin is a complex ecosystem characterized by hills that provide natural barriers, and the Diyala River is a vital water source for the region. However, the area faces significant challenges in balancing urban development and sustainability. Effective management of Lake Hamrin necessitates comprehensive collaboration at both local and regional levels to ensure the conservation of its natural resources and to enhance overall sustainability[1].

The following procedures were followed in this study, as explained below:

Selection of Spatial Data: This study used Landsat-9 satellite imagery from April and October 2024 (Level 2) to conduct a comparative analysis of the impacts of climatic and anthropogenic changes on the land cover surrounding Lake Hamrin.

Spectral Data Conversion and Reflectivity Correction: The visual data have been converted into reflectivity values, taking into account prior spectral correction procedures that eliminated atmospheric distortions. This process ensures the accuracy of the reflectivity values utilized in the subsequent analysis, as represented by the following **Equation (1)**[26]:

$$\rho_\lambda = 0.0000275 \times Q_{cal} - 0.2 \quad (1)$$

Where ρ_λ TOA planetary reflectance and Q_{cal} is the pixel value of the band.

- The spectral layers were systematically stacked and then cropped to align with the defined boundaries of the study area.
- A collection of training samples has been conducted to represent the primary land cover classes, including soil, water, urban areas, and vegetation.
- The Jeffries-Matus Ita measure was used to assess separability between subclass pairs. This approach ensured that the training samples remained spectrally distinct and did not exhibit any overlap.
- A supervised maximum likelihood classifier was employed to categories satellite scenes into delineated classes systematically. This approach ensures a robust data analysis, enhancing the classification process's accuracy.
- The classification accuracy was evaluated by calculating the Kappa coefficient and overall accuracy. Additionally, we performed a separability evaluation and identified unclassified regions within each spatial scene.
- An analysis of land cover changes resulting from fluctuations in the area and volume of Lake Hamrin over the designated study period.
- Data regarding rainfall, temperature, water releases, lake area, and coastline will be meticulously collected from reputable sources, including the Iraqi Ministry of Water Resources and esteemed international organizations such as the Food and Agriculture Organization (FAO). The results will be presented through thorough statistical analysis and graphical representations, allowing for a comprehensive comparison of the two months.
- Calculating the lake area and coastline using statistical analysis and graphs to display the results and compare the two months.

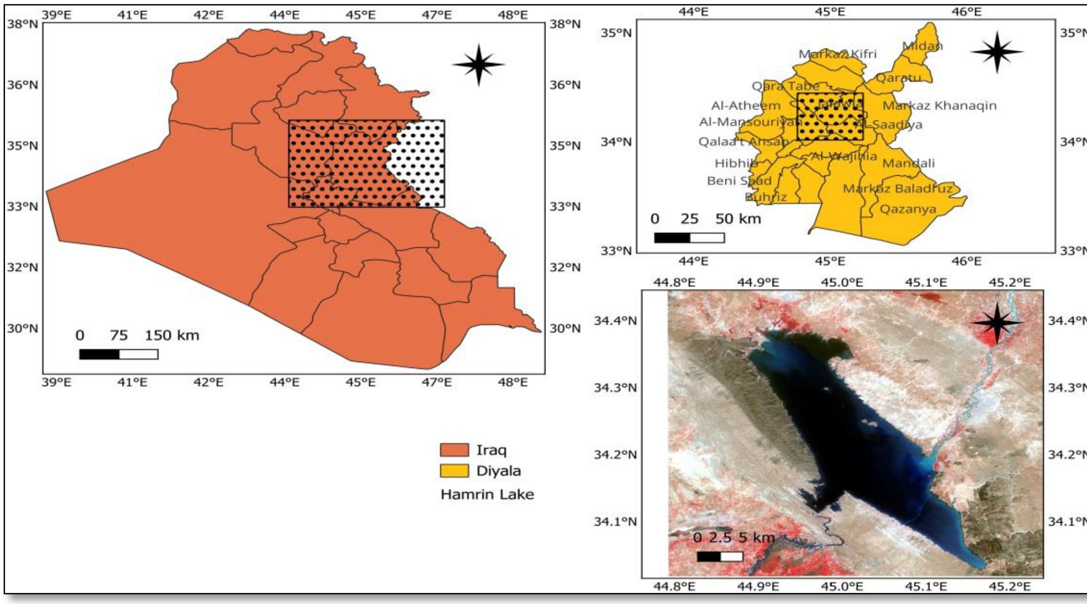
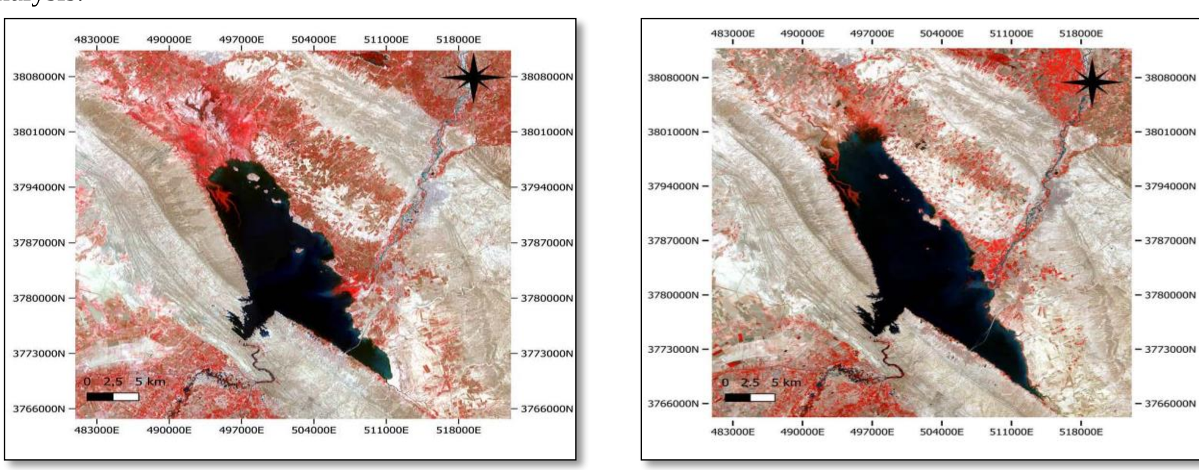


Figure 1. The Geographic Location of Hamrin Lake within the Diyala Governorate, Iraq" .EPSG:4326-WGS84"

3. Results

This study analyses Landsat 9 satellite scenes acquired during two distinct seasons in 2024, as depicted in **Figure 2**. The first focus is on the spring season, which marks the peak of the rainy season in Iraq, when Lake Hamrin typically reaches its highest water levels. The second scene focuses on the autumn season, which marks the end of summer, characterized by limited rainfall and rising temperatures[13]. **Table 1** provides detailed data on these observations, offering valuable insights into the lake's state during these periods and reflecting the hydrological and environmental changes experienced in the region**.** In light of the significant climatic and environmental changes observed in the Lake Hamrin area over recent years, a land cover classification methodology has been implemented to accurately identify the water mass and distinguish it from other components in the region, as illustrated in **Figure 3**. The results of this classification were analyzed to provide a comprehensive understanding of the lake's current status and the environmental changes occurring within the area. This analysis is essential for informing and guiding sustainable actions.

Careful selection of training samples was undertaken for each land cover category, and the separation factor was calculated using the Jeffries-Matusita scale to assess the differentiation between sub-pairs. Notably, the lowest separation factor value recorded over three years of satellite imagery was 1.91, indicating that there was no spectral overlap between the training samples that represented different land cover classes. This ensures the accuracy and distinctiveness of the training samples utilized in the analysis.

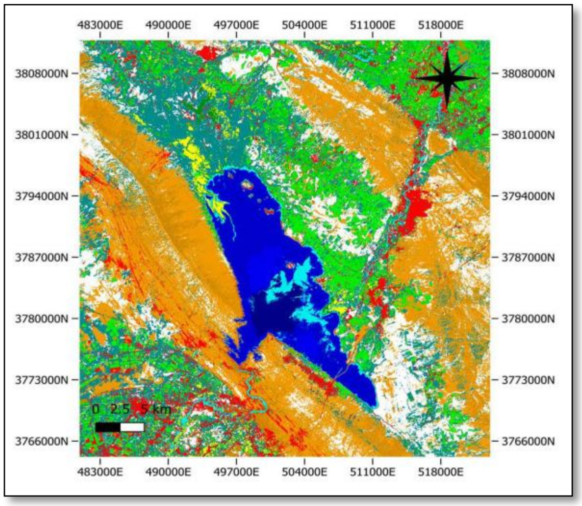


October 2024 April 2024

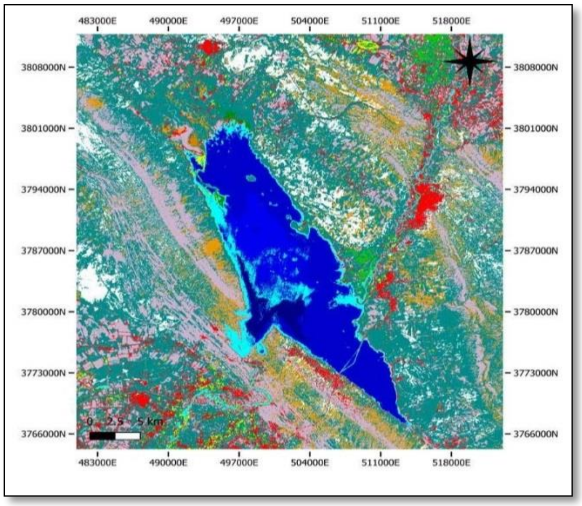
Figure 2. Satellite images of the lake Hamrin for two seasons"EPSG:32638-WGS84/UTM Zone 38"

Table 1. presents the scenes information that utilized in the study.

No.	Data	Time	Landsat	Path, Row	Cloud Cover	Resolution Of Band (m)
1	April 27th 2024	7:32:51	OLI-9	168,36	0.5	30
2	October 4th 2024	7:33:09	OLI-9	168,36	0.01	30



April 2024



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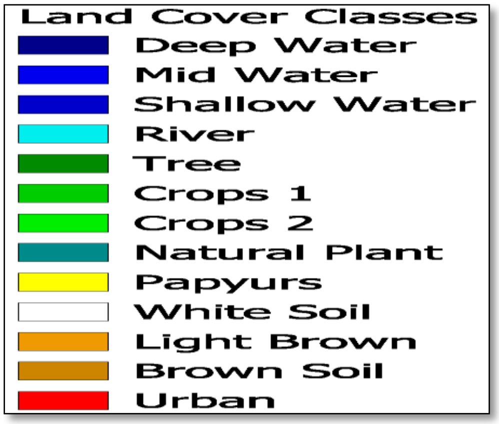

Figure 3. Land cover after classification based on training samples "EPSG:32638-WGS84/UTM Zone 38"

The overall classification accuracy percentage and the kappa coefficient were calculated to ensure the accuracy of the classification process regarding the approved training samples. The overall classification accuracy achieved was 99.56%, accompanied by a kappa coefficient of 0.99, indicating the reliability and effectiveness of the classification process. Furthermore, the analysis reveals a significant variation in the surface area of Lake Hamrin, with calculations performed for both the total surface area and the coastal strip, as presented in **Figures 5** and **4**.

This analysis focuses on the fluctuations in monthly and annual rainfall levels during the rainy seasons for the study period. **Figure 6** presents the annual rainfall data for winter 2024. The research utilized the Khanaqin Climate Station as its data source. Established in 2013, this Sopel-type station is situated at a longitude of 45.35° and a latitude of 34.39°, ensuring its reliability for accurate climate data. As indicated in **Figure 6**, the period from May to October 2024 had the lowest rainfall levels, while the rainy season experienced the highest rainfall totals.

In addition to the rainwater that contributes to Lake Hamrin, the lake is also significantly sustained by water releases from the Darbandikhan Reservoir, which serves as its primary source of water. **Figure 7** illustrates a frequency chart summarizing the quantities of water released into Lake Hamrin over the past six years. This data highlights the crucial role of these releases in maintaining the lake's water levels and ensuring its ecological balance.

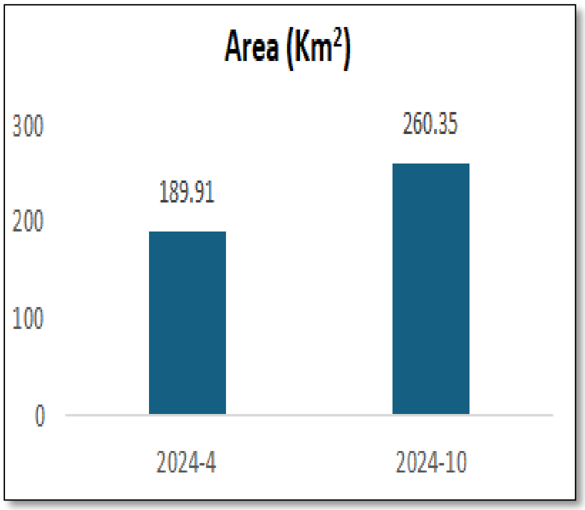

Figure 4. Change in Lake Area for two seasons for 2024

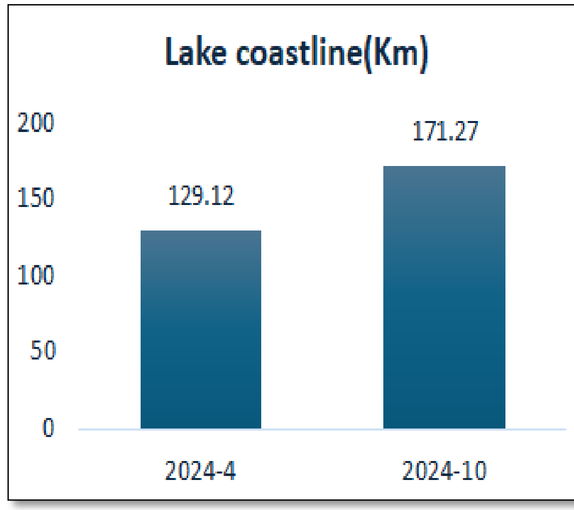

Figure 5. Change in coastline for two seasons for 2024

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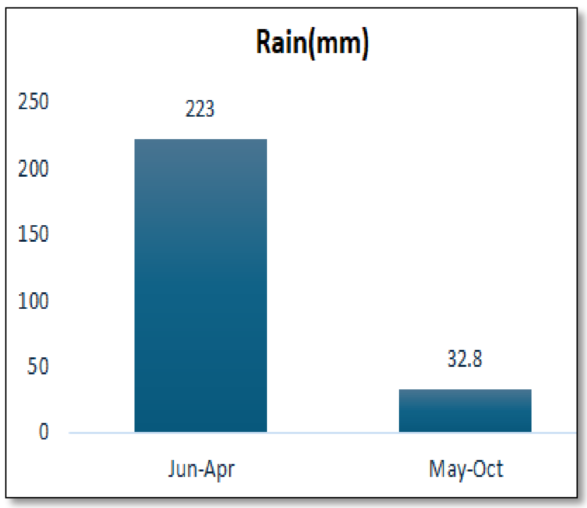

Figure 6. The amount of rainfall recorded at the end of the rainy season in April and the rainfall recorded for the end of the year 2024

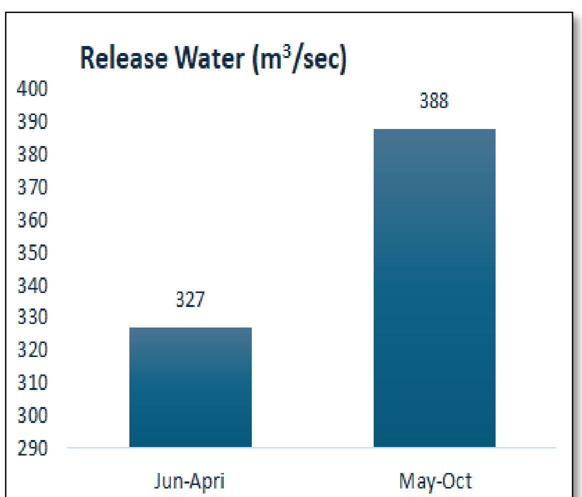

Figure 7. Rate of water release from Lake Darbandikhan to Lake Hamrin during the year 2024

Figure 7 clearly depicts the lake's primary reliance on water discharges, which are correlated with the acquired scenes. Notably, the lake experienced its highest recorded water levels and coastal strip during autumn for the first time in several years of drought and elevated temperatures. This improvement can be attributed to the effective management of water resources, which has mitigated excess flows from Darbandikhan Lake, as well as consistent irrigation practices on agricultural lands. These measures have significantly improved the lake's condition. Furthermore, A quick review of temperatures throughout the year shows that they are at their highest level in the summer, as shown in **Figure 8.**
Figure 9 represents a quantitative analysis of area changes in the subclasses of the scene in the study area during the two periods of April and October for the year 2024. This temporal comparison is an essential analytical tool for understanding the environmental and human factors that influence the dynamics of ecosystems, revealing complex interactions between Climate variables and human pressure. This analysis provides a reference framework to support natural resource management decisions, while highlighting the need for subsequent studies that measure the cumulative effects on ecosystem services.

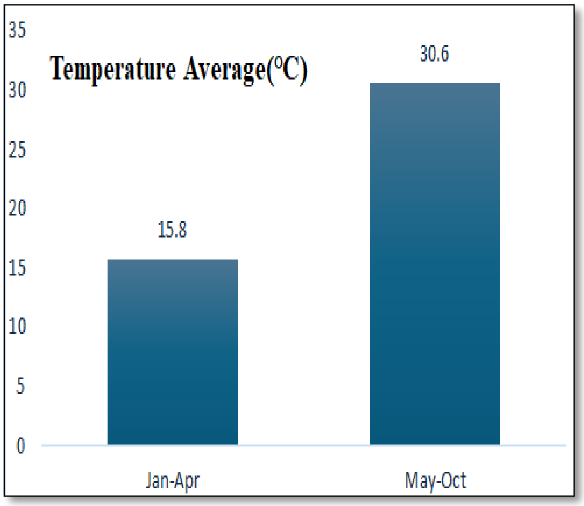

Figure 8. Average temperature change during the year 2024

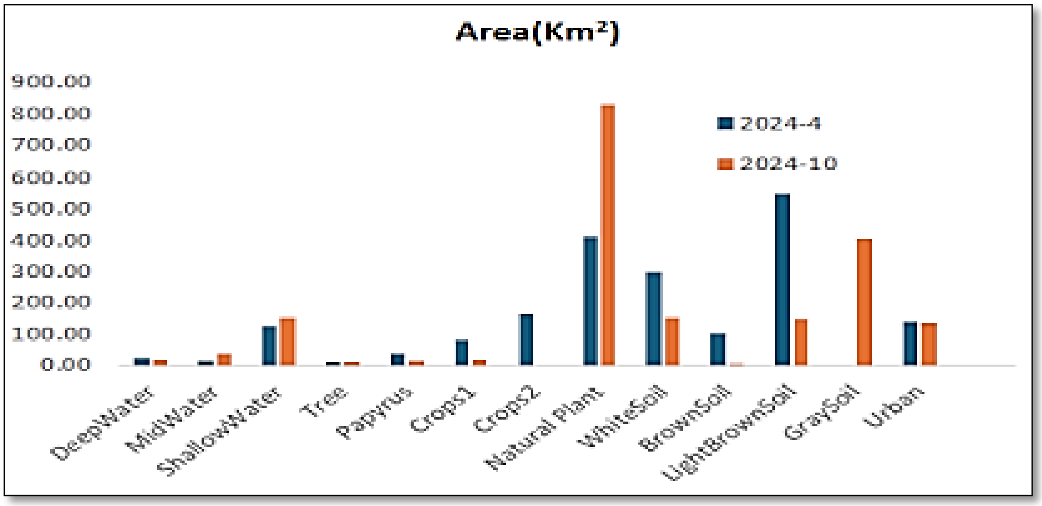

Figure 9. Area of each subcategory during the spring and autumn seasons

The subclasses of the training samples—river, deep water, and intermediate water—have maintained stability across the two seasons, showing no significant changes. This consistent behavior reflects the hydrological system's capacity to sustain balance despite seasonal variations. Effective irrigation management, which involves optimizing water use for agricultural purposes while also preventing excessive depletion of resources, has played a crucial role in alleviating pressure on deep water resources. These resources are crucial for preserving biodiversity and providing a suitable habitat for aquatic organisms, such as fish and plants. It is noteworthy that the summer season marked the resumption of fish farming in the lake after several years of suspension due to unstable security conditions.

Climatic factors also play a significant role in shaping the region's environmental dynamics. The significant rainfall during the winter had restored the water bodies and enhanced the ecosystem's ability to restore its natural equilibrium. Additionally, reduced temperatures during the fall contributed to lower evaporation rates. These climatic dynamics indicate the considerable environmental changes the region has experienced, characterized by unprecedented seasonal rainfall and heavy flooding, which have substantially impacted local ecosystems and hydrology, guiding them toward a new state of balance and sustainability.

Furthermore, the region's geological characteristics play a vital role in water retention within the river, where the clayey soil acts as an insulating layer, preventing river water from seeping into groundwater supplies. Additionally, ongoing efforts to manage encroachments have significantly contributed to preserving the lake's feeding resources.

4. Discussion

The data indicate that urban areas within the urban class demonstrated relative stability, with only minor variations present. This stability can be attributed to spectral overlaps, as the similarities in spectral responses between buildings and soil make it difficult to differentiate between these classes accurately. Furthermore, the Landsat 9 satellite, with its spatial resolution of 30 meters[27], faces limitations in distinguishing subtle changes in urban regions. While the region has experienced increased urban activity due to security and economic stability, it has not yet reached a stage of significant expansion.

Shallow waters have undergone a notable decline, transitioning to medium-level status due to the heavy rainfall and flooding encountered during this year's rainy season, which the region has not experienced in two consecutive years. It is essential to recognize that coastal waters are particularly susceptible to climate change, with their dynamics easily influenced by changes in water levels and sediment flow. The increased rainfall and flooding have directed higher water flow toward deeper areas, consequently reducing coastal water levels. This decline may adversely affect local ecosystems, as many species, including migratory birds, depend on these waters for sustenance and breeding.

It can be observed that there is a decline in areas with white and brown soils, attributed to human activities and climatic influences. A significant contributing factor is soil erosion, which has increased due to heavy rainfall and flooding, particularly in regions characterized by steep slopes. Urbanization has also impacted soil areas, as the expansion of construction projects often replaces natural soil with artificial materials.

A notable example of this development is the construction of a bridge over the lake, which is currently over 80% complete and is set to become the longest bridge in Iraq. Activities such as exploration, quarrying, and the establishment of brick factories have also contributed to changes in soil conditions.

It is essential to recognize the role of current security stability in the region, which has fostered increased economic and industrial activity. However, the environmental implications of soil loss must also be carefully considered, as diminished natural soil can lead to decreased fertility, which can adversely affect agriculture and food production.

The Papyrus has significantly reduced its area, primarily due to its reliance on surface water resources. Variations in surface water levels or increased evaporation rates can dramatically compromise the vitality of papyrus ecosystems. Furthermore, human activities play a critical role in this decline; the expansion of urban and industrial areas frequently destroys natural habitats vital for papyrus's sustenance. In addition, agricultural and industrial practices that necessitate substantial water consumption further aggravate this situation, adversely affecting the surrounding ecological environment[28].

For agricultural crops, there was a clear variation between the winter and summer seasons, reflecting the regional agricultural diversity. However, fluctuations in spectral values are mainly due to satellite scenes coinciding with the harvest season, as well as the period of soil preparation for the new agricultural season. The positive role of security stability in promoting agricultural activity cannot be overlooked, especially in an area that was historically a center for the influence of these terrorist groups, which allowed farmers to expand the cultivation of various crops.

Natural plants have witnessed a remarkable ecological increase, with the area of natural vegetation cover increasing significantly due to abundant rainfall during the rainy season. This contributed to improved soil conditions, such as increased moisture and fertility, which helped promote plant growth. Despite the high temperatures in the summer and high evaporation rates, coupled with increased humidity levels, this contributed to the ecological recovery. Consequently, this helped accelerate plant growth cycles by improving gas exchange within plants.

The area of light brown and grey soil has increased, due to multiple effects, including climate change. High temperatures and soil dryness after the rainy season have contributed to changing the characteristics of the spectral soil, which is related to light brown soil. As for the gray soil, human activities play an essential role in the accumulation of organic deposits resulting from agricultural and industrial activities around the edges of the lake represented by fish farms scattered along the coastal length of the lake and industrial waste produced from the nearby hydroelectric station and the heavy water treatment plant in the Saadia region, all of this led to an increase in the area of gray soil. Keeping in mind the long-term effects that affect the sustainability of soil, as it may lose its ability to support plants and agriculture.

5. Conclusion

The results of the spectral analysis conducted in the Lake Hamrin area reveal complex environmental changes resulting from the interaction of natural processes and human activities. This research was carried out during both the spring and autumn seasons. Various water types within the lake—such as rivers, deep water, and medium water—demonstrated a remarkable capacity for adaptation to seasonal changes. In contrast, the shallow waters exhibited significant fluctuations, particularly during the rainy season, highlighting their sensitivity to environmental conditions. Additionally, clay soils played a crucial role in regulating water infiltration.

During the autumn months, observable changes in vegetation cover were attributed to climatic factors, including evaporation and humidity levels. Papyrus plants, in particular, have been influenced by seasonal variations as well as human activities, such as agriculture and industrial development. Furthermore, soil properties demonstrated alterations resulting from both climate fluctuations and human intervention. Data collected from urban areas indicated relative stability, showing limited impact from climate change; however, adjacent soil and environmental structures did experience changes due to economic activities.

This research highlights the importance of adopting sustainable environmental practices to ensure the resilience and stability of local ecosystems. It is recommended that strategies be implemented to balance human development with the conservation of natural resources, thereby protecting the Lake Hamrin ecosystem for future generations.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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