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Research Article

Surface Water Changes and Water Depletion of Lake Hamrin, Eastern Iraq, Using Sentinel-2 Images and Geographic Information Systems

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Abstract

Iraq's lakes and rivers are currently exposed to drought because of climatic and political conditions. This study uses satellite images and geographic information systems to display the water depletion and the change in the surface water area of Hamrin Lake. Sentinel-2 imagery of 2018 and 2022 was used to analyze the surface water area changes and water depletion. A comparison was made by studying the changes that happened between 2018 and 2022 respectively. Moreover, a supervised classification technique was implemented using the Support Vector Machine algorithm (SVM). Besides the shrinkage of Hamrin Lake was determined based on 2017 to 2022 Sentinel-2 images and the Normal Difference Water Index (NDWI). Findings showed an extreme change occurred in the surface water area of the lake, which had decreased by 73% in study years and changed to land in 2022. Based on the

resultant maps clear alteration is notable in the shape of the lake from north to southeast where the maximum retraction occurred. The surface water area was 144 km^2 in 2018 which decreased to 39 km^2 in 2022 and was concentrated in the western part of the lake. Besides, the lake's capacity has become 234 million cubic meters, and the amount of water in it is very little while its capacity is more than two billion cubic meters. This sharp drop in the water level in the lake indicates that what is flowing to the lake is less than what is released from it, especially due to the lack of rain. In addition to the drought, the neighboring countries have taken measures to change courses, cut off some rivers, and build dams, all of which are additional influential factors that impose quick intervention and action to prevent the lake from drying out completely.

Keywords
Hamrin Lake; support vector machine; sentinel-2 images; water depletion; remote sensing

1. Introduction

The water issue is one of the necessary components for keeping the environmental structure balanced to provide all the human needs, particularly in countries characterized by dry and semi-dry weather such as Iraq, as water is a consequential resource in controlling the population distribution and economic activity, mainly in agriculture, thus it has an essential role in providing people with a needed food supply [1]. Satellite remote sensing images can greatly help monitor water surface dynamics of lakes and water bodies worldwide [2, 3]. Iraq experienced severe drought in the past years and lost a large water capacity, as rainfall rates decreased by 40% from the normal level. In the same period, the water flow from the rivers decreased significantly due to Turkey's project to build dams in the catchment of the Tigris River and irrigation projects and dams that are under construction in the sources of the Iranian Tigris River, which reduced the flow of rivers to Iraq in the future [4]. Using remote sensing data, studies were conducted on Iraq lakes, and the result was human and natural activities that made drastic alterations to the lakes' surface areas over the past years. These sudden changes recorded mainly were associated with policies of water management related to political events; on the other hand, the water level is low due to the lack of rain [5, 6]. For example, based on six satellite images, the surface water area changes of Al-Razzazah lake were evaluated and mapped from 1989 until 2020, where the total surface area has turned out to be one-sixth of the previous area of 1989 [7]. While a study found a correlation between the rainfall rates and their effect on the water surface area of Hamrin Lake from 1990 to 2019, which showed the scarcity of rainfall is the most important factor affecting the water capacity [8]. Based on Hussein [1], used satellite images and area calculations and concluded that there is a discrepancy in the entire Hamrin lake area from year to year, with a clear increase in the water level being recorded in some years while a significant decrease was recorded in other years. Furthermore, Titolo [5], used the Normal Difference Water Index (NDWI) besides Sentinel-2 data for distinguishing the surface area to investigate the receding of lake Hamrin and deduced dramatic changes in the lake's shape. Updated data and accurate information are necessary to

evaluate the results of changes [9]. For land cover detections, pixel-based classification algorithms have been developed [10]. The distinguished one involves Maximum Likelihood Classification, Support Vector Machine (SVM), and Decision Tree [11]. The classification type and training data attributes influence classification performance; these conditions must be carefully considered [12]. SVM classification reliability of hyper-spectral images has been approved in many papers [11, 13].

Nowadays, Iraq suffers from a hot climate and scarcity of r; besides, the policy of neighboring to build dams and cut water sources from Iraq, all these negatively affect the water capacity of the lakes. In this study, we used remote sensing and GIS applications. We employed the SVM classifier to extract and calculate the surface water area and determine water levels in Hamrin Lake. It is important to conduct detailed research on the capacities of lakes over different years using modern systems that reveal the extent of change in surface area and volume of residual water to put control policies and avoid lake drying out.

2. Materials and Methods

2.1 Study Area

The study area is Hamrin Lake, a man-made lake known as Diyala dam, which lies in Diyala province, about 50 km northeast of Baquba [1]. Figure 1 represents the study area of the Hamrin Lake location. The capacity of Hamrin Lake is almost 3.95 billion m^3, with a 445 km^2 area [14]. It was constructed in 1981 and extends along the Diyala river, one of the Tigris tributaries which bonded between (34°22′ N, 44°49′ E) to (34°2′ N, 45°12′ E). Hamrin is subject to various changes in the surface area, occasionally affecting its actual shape. The most consecutive retraction of surface water area was recorded in 2008, when it decreased by 80%, because of damming of the Lund River by the neighboring country [5], and it reached 21.23 km^2 as a surface area. In contrast, the maximum rate recorded in 1988 and the surface water area was 358.38 km^2 [1].

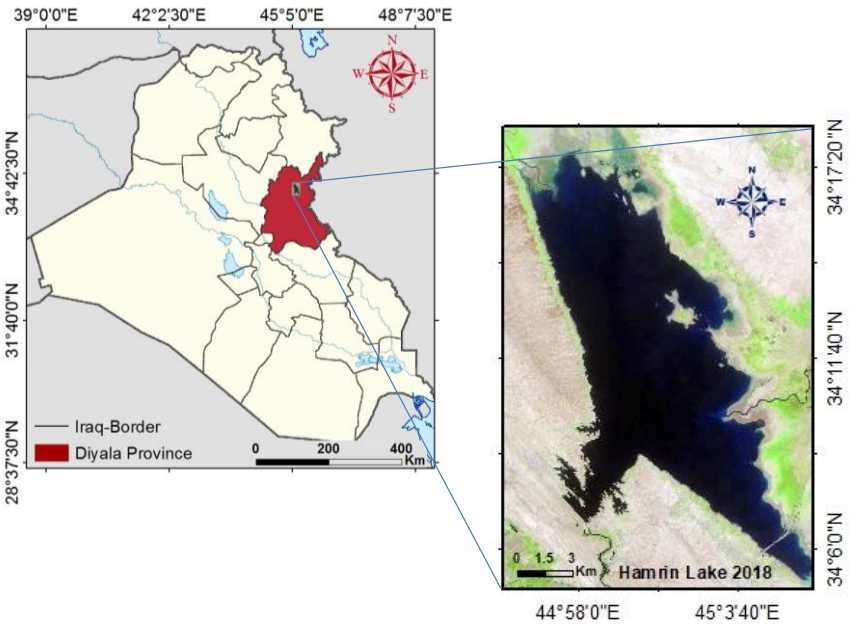

Figure 1 The study area Hamrin Lake location.

The lake is the source of irrigation for the city and agricultural lands, as eighty percent of the population depends on agriculture. The water scarcity crisis has caused the cancellation of agricultural plans and the collapse of the agricultural sector throughout the province, in addition to severe damage to livestock. The lake is considered the primary and main water source in Diyala Governorate, so it was important to conduct research and investigate the state of the lake with the advancing years to display the current status of the lake, which suffers from drought.

2.2 Methodology

The methods applied in the research are shown in Figure 2. Moreover, the dataset attributes of the used images are reported in Table 1.

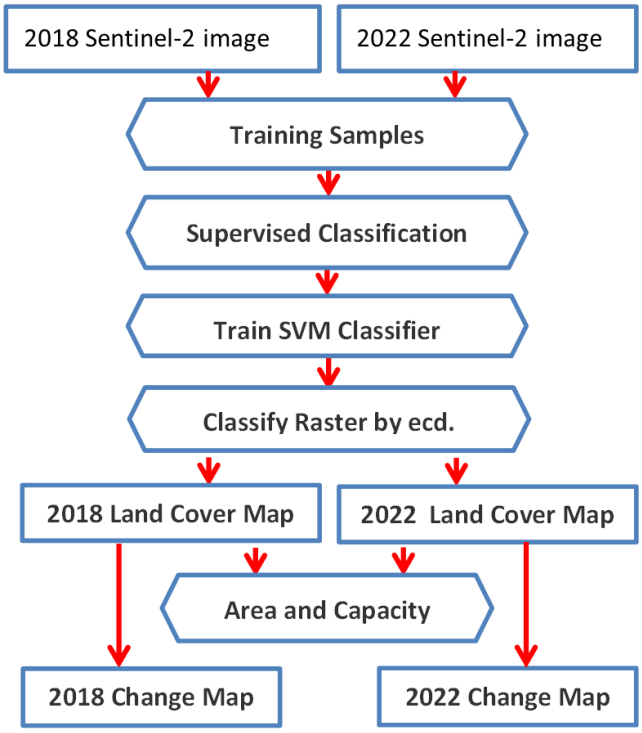

Figure 2 The methods applied in the research.

Table 1 The dataset attributes of the used images.

Attribute	2018 Sentinel-2 image	2022 Sentinel-2 image
Acquisition Date	06-10-2018	06-08-2022
Resolution	10 m	10 m
Cloud Cover	0.08830	0
Product Type	S2MSI1C	S2MSI1C
Datum	WGS84	WGS84
Map Projection	UTM	UTM
UTM Zone	38N	38N

In this study, two Sentinel-2 images; of the years 2018, and the year 2022 were used, with (10 m) resolution and low cloud cover.

The spatial reference of the images was WGS_1984_UTM_zone_38N. The used Sentinel-2 Images in the study are shown in Figure 3.

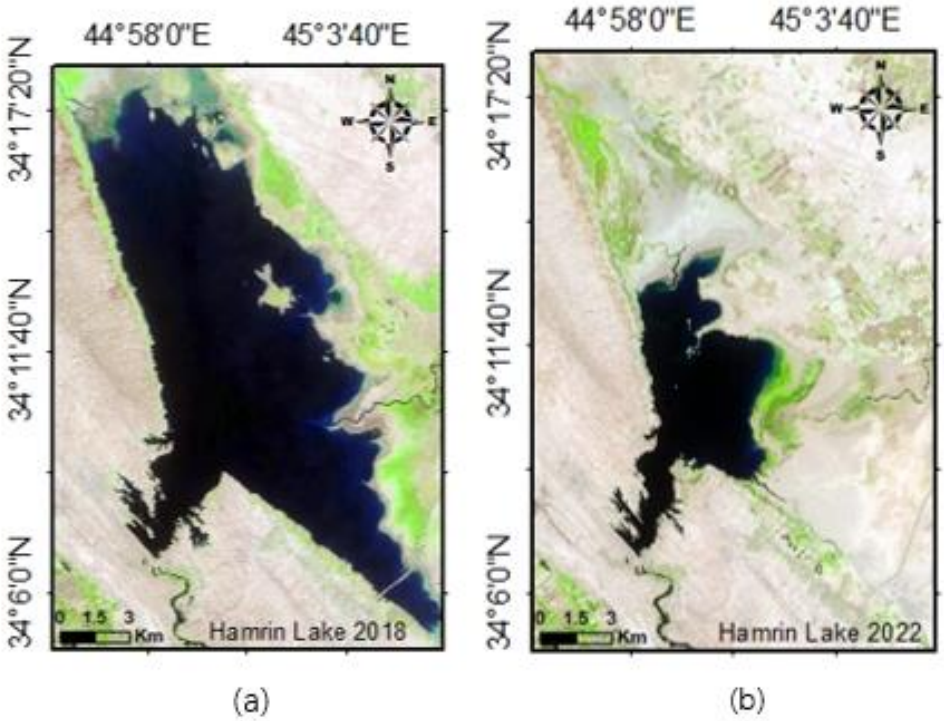

Figure 3 Sentinel-2 Images of Hamrin Lake of; (a) the year 2018, and (b) the year 2022.

Based on ARC-GIS version 10.3, a supervised SVM classification was applied. The principle of this method is to separate hyperplane creation from the trained data.

GIS includes useful tools and applications that facilitate the process of analysis and evaluation in addition to creating models [15-20] and detecting changes [7, 11]. The classification process by SVM included creating training samples and then classifying the raster using the Esri classifier definition file (ecd.). This file involves the information necessary to establish a certain type of Esri-supported classification. To perform the classification, the input raster must match the same input raster used to create this ecd. file. The resulting land cover maps are then used for extracting areas for each year separately so the comparison can be applied usefully. The final step involved calculating water levels based on lake depth and extracted areas. The equation of SVM can be written as [11]:

$$f(x) = sign\left(\sum_{i}^{r} \propto_i y_i x_i + b\right) \quad (1)$$

$$f(x) = sign\left(\sum_{i}^{r} \propto_i y_i k(x, x_i) + b\right) \quad (2)$$

where a vector (xi) is of each r training case, it represents a spectral response composed of a description of the class item (y_i). $\propto_i$ (i = 1, ..., r) are multipliers of Lagrange, $k(x, x_i)$ is the task of the kernel while b refers to hyperplane space from starting point [11].

Moreover, NDWI was used to compare changes based on Sentinel-2 Images from 2017 to 2022. This Index is used to monitor changes in water content for water bodies. Because bodies of water strongly absorb light in the visible to the infrared electromagnetic spectrum, NDWI adopts green and NIR near-infrared bands to shade water bodies. NDWI is sensitive to buildings and can result in the overestimation of water bodies. The NDWI function of Sentinel-2 can be written as follows:

$$Sentinel - 2_{NDWI} = (B03 - B08)/(B03 + B08) \quad (3)$$

For Sentinel-2 $(B03)$ Band 3 represents green, and $(B08)$ Band 8 represents NIR [21].

3. Results and Discussion

Based on NDWI, Figure 4 represents Hamrin Lake shrinkage from 2017 to 2022. Hamrin Lake's land cover map and differences between the two years 2018 and 2022 are shown in Figure 5. The surface area in 2018 was equal to 144 km^2. It will became 39 km^2 in 2022. The decrease can be seen on the maps.

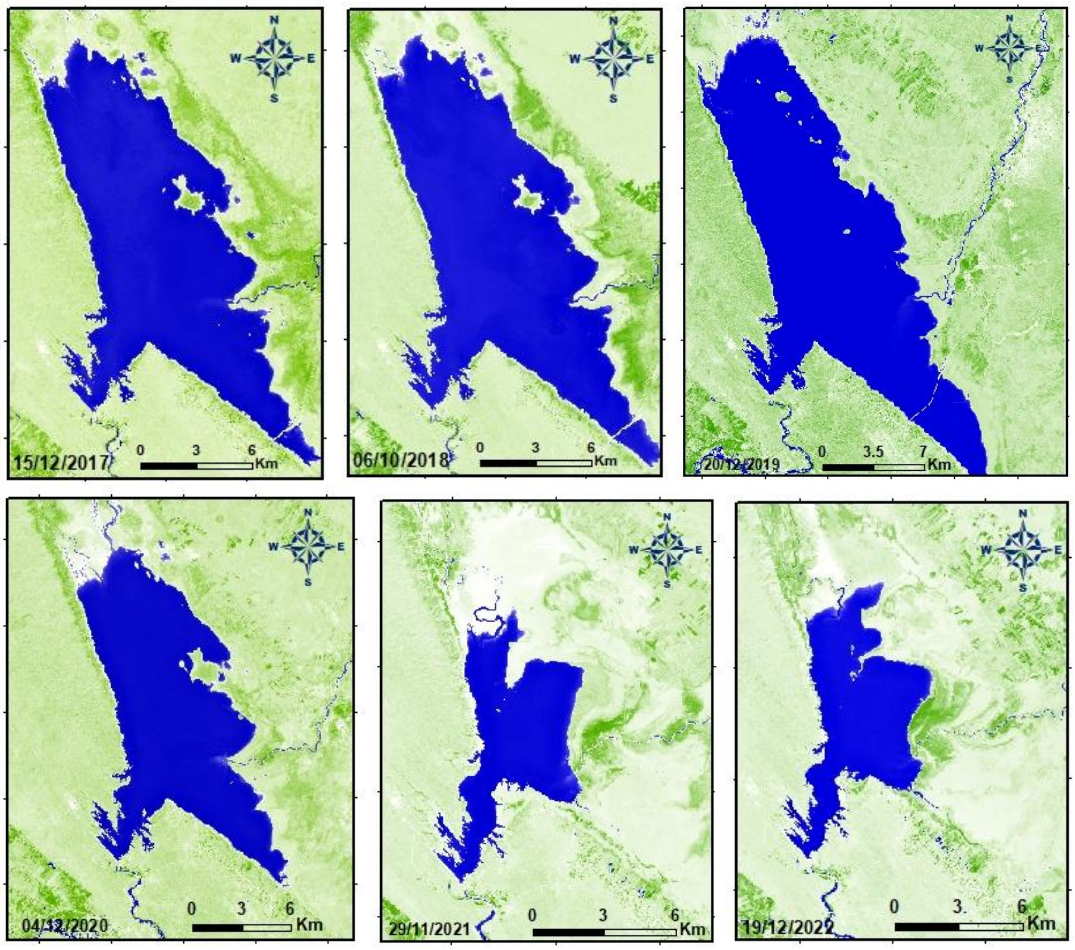

Figure 4 Hamrin Lake shrinkage from 2017 to 2022.

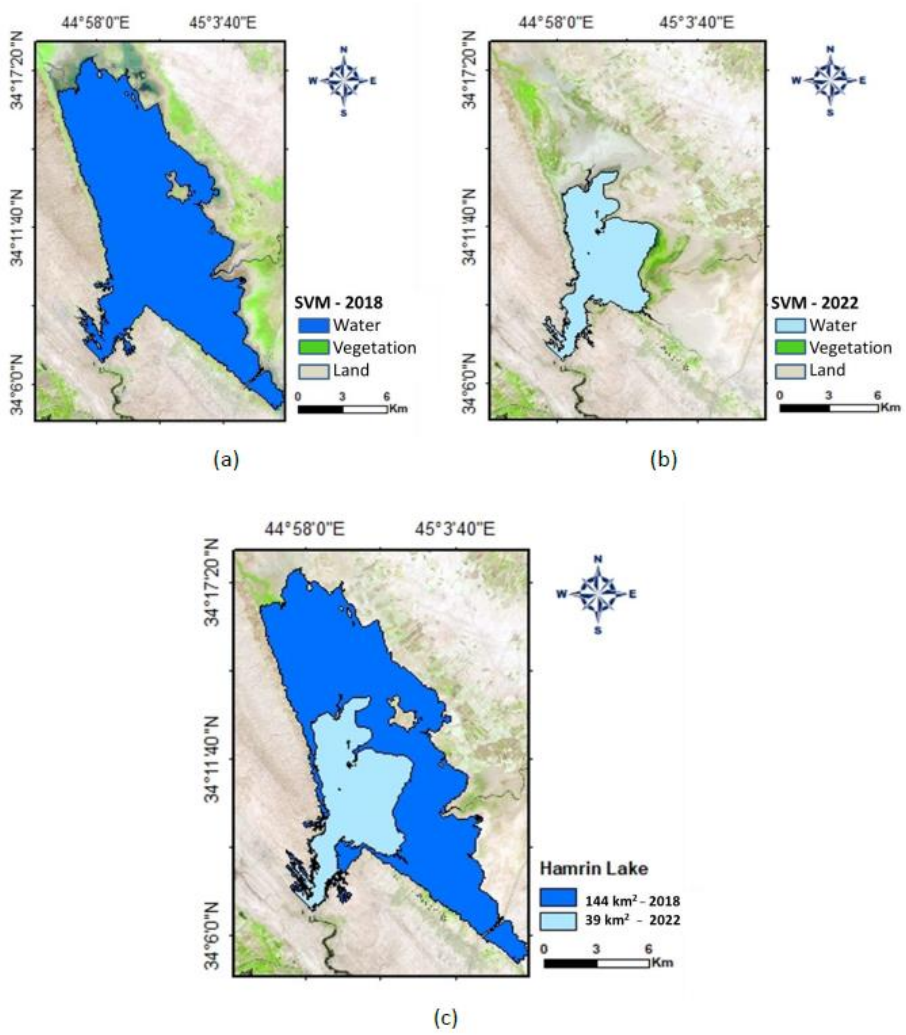

Figure 5 Hamrin change map of; (a) year 2018, (b) year 2022, (c) Retraction rate.

The surface water area change map of Hamrin Lake in the years 2018 and 2022 has been shown in Figure 5(c). The area changes can be seen visually on the map, where substantial changes in the surface area happened in the year 2022. Figure 5(c) shows the retraction of the lake area from the north to the southeast. The area was retracted by 105 km^2. Based on Khalaf [22] used NDWI and satellite images of Hamrin from 2019 to 2020 at the rate of one image per month and concluded that the highest water surface occupied 617.264 km^2 in October, and the lowest surface occupied 202,140 km^2 in September in September.

Furthermore, the water level was calculated based on obtained surface areas and lake depth. The calculated capacity in 2018 was 864 million cubic meters, while it decreased to 234 million cubic meters in 2022.

Monthly and Annual precipitation dataset from NASA/Modern-Era Retrospective Analysis of research and applications MERRA-2 of the dates 01/01/2018 to 12/31/2021 for (Hamrin Lake) was analyzed and studied in this research for location latitude 34.1943 and longitude 44.9975. MERRA-2 is the original long-term international analysis to incorporate meteorological assimilation, integrate space-based observation of aerosols, and designate their relations with other physical progress in the weather system. Figure 6 shows monthly and annual precipitation from

NASA/MERRA-2 dataset. From Figure 6**,** we can see the precipitation lack in the latest years, especially in 2021 and 2020. The low rainfall periods have negative effects on lake continuity.

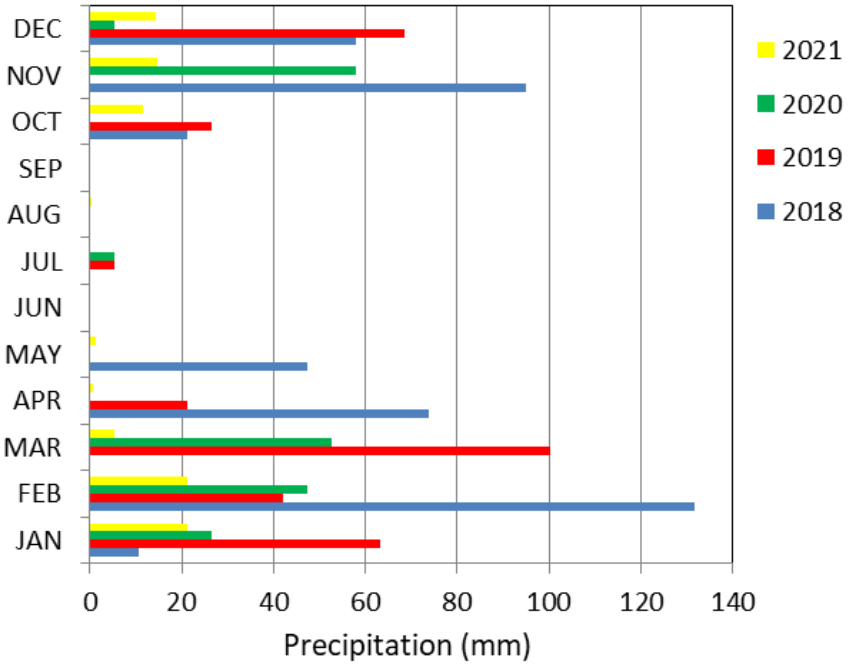

Figure 6 Monthly and annual precipitation NASA/MERRA-2 precipitation sum (mm).

Furthermore, Figure 7 represents the trends in the sum annual precipitation of Hamrin Lake for four years (2018 to 2021).

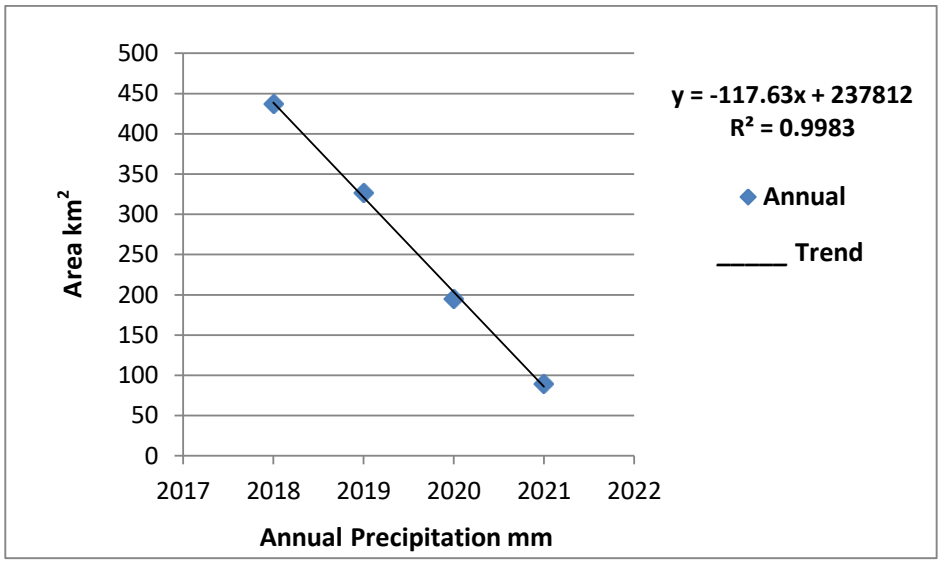

Figure 7 Trends in the sum annual precipitation of Hamrin Lake during four years.

Based on the NASA/MERRA-2 precipitation sum, the trends of surface water area were reported with a 0.99 R^2 coefficient of determination. A high correlation of decreasing area each year imposes rapid intervention to develop appropriate strategies to prevent the drying up of the

lake in the coming years. Hadi [8] showed a significant recorded correlation of 0.84 between rainfall and Hamrin lake's water value. Besides, a study was conducted by Hadi et al., [23] in which they proved precipitation deficiency in a cumulative manner thru study years, and thus its effect on the drying up of rivers and lakes [23]. Moreover, based on Khalaf [22] lake Hamrin experienced a decrease in lake's surface area, which threatens to dry up the lake, that consistent the current study results.

4. Conclusions

The study's goal was to calculate the surface water area of Hamrin Lake and its residual water level to date. The water cover was extracted using the SVM classification approach. The study concluded an extreme reduction in the lake's surface area in the year 2022 with a very high retraction in water level. The negative effects of climate and rainfall scarcity during 2021 and 2022 have led to a change in the lake's surface area with an alteration in the morphological shape of Hamrin Lake with a drop in water level. Besides these influential factors, the lack of water flowing into the lake and mismanagement also affected the lake's drought. In addition to the policies of neighboring countries in cutting the watercourse from the rivers towards Iraq. The water shortage in Hamrin Lake, the province's first water source, reached 73 percent in the summer of 2022, meaning that a large part of the lake has dried up, negatively affecting agricultural areas due to the water crisis. One of the solutions is to supply the Diyala River which supplies the lake with water from the Tigris to avoid the destruction of agricultural lands so can slightly achieve the water demand requirements.

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Author Contributions

Huda J. Jumaah and Mohammed H. Ameen acquired the data as well as conceptualized and performed the analysis; Huda J. Jumaah wrote the manuscript and discussed the analysis; Bahareh Kalantar edited, restructured, and optimized the manuscript.

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Competing Interests

The authors have declared that no competing interests exist.

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