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The Water Area of Sawa Lake as Derived from Land Surface Temperature and Remote Sensing Data

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Abstract

Sawa Lake is one of the unique lakes in Iraq. It is located in the southwestern part of Iraq. It is one of the closed lakes, as no surface water source works to feed the lake. The lake feeds on groundwater. The source of this groundwater is the Dammam Basin. During the past ten years, The lake has had many changes, which led to a decrease in water levels. This also led attention to study of the causes of these changes. Many types of research were presented in the study of the state of the lake. This research used remote sensing images from Landsat 8 OLI to monitor the changes during 2020-2021 by applying the NDWI equation to extract water area from image data. The results of the areas were obtained from a special report by Normalized Difference Water Index (NDWI). Then, the lake surface water temperature was derived from Landsat 8 thermal bands (TIRS). The lake water area and temperatures increased in summer and decreased in winter and autumn. Then, it is not the main reason for the change in the lake water area. The levels of the lake water rise during the dry period and decrease during the rainy period. The natural factors have little influence in reducing the lake water. It is attributed to human factors, groundwater depletion, and a reduction in water supply from the Dammam Basin, which feeds the lake.

Keywords: Sawa Lake, Normalized difference water index(NDWI), water extraction, water temperature.

1.Introduction

Sawa Lake is one of the inner basins [1]. It is located in the western desert of southern Iraq, 23 km away from Al-Muthanna Governorate [2]. It is considered one of the closed basins, as no surface tributaries pour into it [3]. The lake is one of the water sources on which the region depends [4]. What distinguishes the lake is the presence of underground sources that work to nourish it and are not fed by surface sources except for rainfall of a few millimeters in the winter season [5].

Tectonic activity in the region played an essential role in forming the lake depression [2]. The region's climate is characterized by dryness and high temperature in summer [6].and little rainfall in winter [7]. The continuing rise in temperatures and decrease in precipitation due to climate change is a significant challenge for the region [8]. The temperature difference is vital in the mechanical weathering process, as it changes the features of the earth's surface in the study area and the lack of rainfall, wind movement, and vegetation cover [9]. Because of the intense evaporation, the lake was exposed to many current studies investigated its impact on the lake and showed that the depth of the lake water decreases over time. The lake water depth was about 4 to 5 m 35 years ago, and the water depth has become between 1-2 m in recent years with the continuation of the decrease in the vicinity of the lake along with the reduction of its surroundings [10]. As a result of the lake being located in a desert area characterized by drought and high temperatures in the summer and the increased demand for water resources to meet agricultural land needs, all of this affected a decrease in groundwater levels [11]. Detecting temporal changes in the area is essential in determining changes in the area of water bodies for long periods. This is done by continuous monitoring of multi-time remote sensing data [12]. The temperature of the earth's surface is an essential source that provides us with a lot of data about the earth's surface, such as the amount of actual or potential evaporation and net radiation [13]. Remote sensing is one of the effective ways to restore regional and global land surface temperature [14]. Satellites are used to obtain images of the earth's surface, which carry devices with high spatial accuracy [15]. Many studies have used remote sensing to study wetlands areas [16]. Few researchers have conducted scientific and theoretical studies to analyze lake changes [17]. Multispectral remote sensing is used to monitor water bodies, and maps can be drawn in many ways, and this depends on the response of water bodies to those different spectral ranges. The natural difference water index (NDWI) is used to measure the area of water bodies through short-wave infrared and visible green light [18].

There are many ways to determine the water surface, depending on the water surface (specular or diffuse), the type of suspended substance in the water, the depth of the water and the visible spectra, and that the reflectivity of pure water is less than that of turbid water [19]. In recent years, algorithms have been made to show the water body, which depends on the study area's spectral characteristics. These algorithms can identify the pixels of the main water [20]. What distinguishes water bodies is that they are dynamic, as they can expand, contract, or change their appearance over time, and this is due to human or natural factors [21]. Many studies have studied the interaction between water dynamics with global climate change. Climate change has an impact on internal water bodies, and one of those influencing factors is temperature change [22]. The rays coming from the sun into the earth's atmosphere are considered the main engine of atmospheric processes, and their impact is direct and indirect on the climate elements [23].

In this research, the impact of changing the study area's temperature on Sawa Lake water dynamic is studied through remote sensing and analysis of Landsat satellite images during the period 2020 and 2021.

2.Study Area

Sawa Lake is one of Iraq's unique lakes. It is one of the permanently closed lakes, located in the Sabkha area in the southwestern part of Iraq, (23(km southwest of Al-Muthanna Governorate

[9], as shown in **Figure(1)**. It is scientifically and ecologically essential and is characterized by biological diversity [24].

It is bordered on the east and northeast by the Atshan River, a Euphrates River branch, and is (3.3) km away from the west and southwest. It is bordered by the flood plain, from the south by factory salt Samawah, and from the east and west by dunes [25]. Sawa Lake is located between longitudes (44°59'35.64" and 45°0'44.73") and Latitudes (31°18'36.91" and 31°18'53.95") [26]. The topography of the study area increases at a rate of 2.7 m per km as we move from the northeast to the southwest [2]. Sawa Lake has an area of 4.7 km2, a maximum length of (13.5 km), a maximum width of 1.936 km, and a minimum width of (0.5 km) [10]. A gypsum barrier surrounds it, its height ranges between (2-5)m, and its length is (12.5 km), which makes it isolated and closed to the surrounding area [4]. It rises above sea level (18-16) m and from the Euphrates River (11) m [6]. The average temperature of the study area ranges between the minimum and the highest (27.4-49.5), and the rainfall is 110 mm per day [27]. The wind direction is northwesterly at a (4.1)m/sec [4]. West, the study area, is surrounded by desert lands and is divided into three types, a gypsum desert, dunes, a stone desert, and the region containing groundwater, as well as a little rain. In the area, there are very few houses that back to farmers working during the growing season, and the rise in temperature leads to an increase in the water needs of crops cultivated in this area during this season [28].

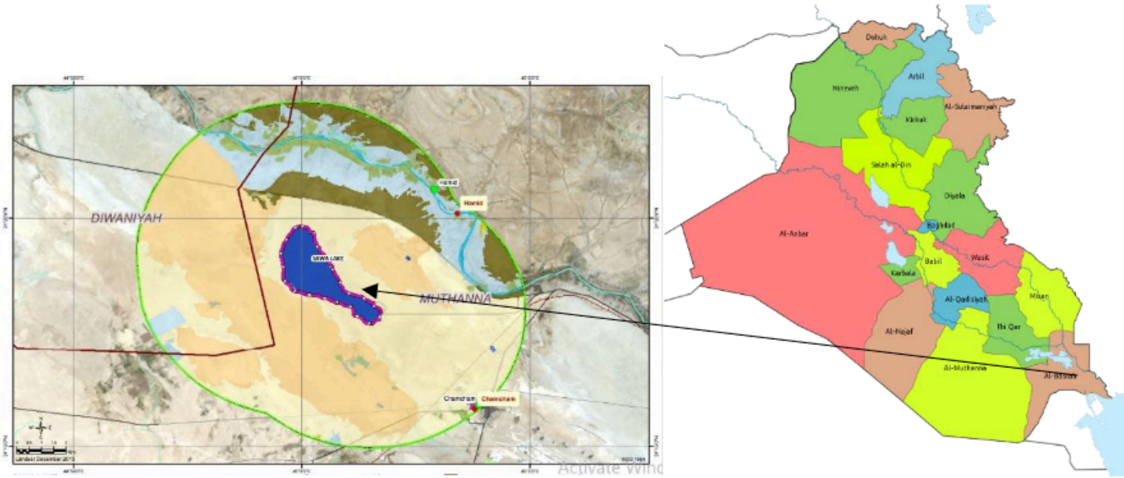

Figure 1. Study area of the Sawa lake, Iraq

3.Methodology

This research uses the available data from Landsat 8 sensor (OLI) satellite. ENVI 5.3 program was used to clip the study area and convert the clipped images data from digital pixels to wave values through the following reflectivity equalizer [29]:

$$\rho\lambda = (Mp * Qcal + Ap)/\sin\theta \quad (1)$$

Where $\rho\lambda$, = TOA planetary reflectance. Mp= = reflectance was multiplicative of each band. Qcal= represents pixel value in DN.Ap = reflectance additive scaling for the bands and (θ) = solar elevation angle

The images were extracted with a smaller area by selecting the coordinates [496335 E, 3469215 N (Upper)], [505305 E, 4360635N (Down)]. A stacking process was performed in seven bands, including [aerosol, blue, green, red, infrared near-infrared (NIR), short wave infrared (SWIR 1), and short wave infrared (SWIR 2)]. Some adjustments were made to seven bands, including (band name, wavelength, image capture time, pixel size, and sensor type).

To monitor the changes in the lake's water area, it is necessary to measure the water area during a specific period to study these changes and know the reasons for that. Therefore, the period was chosen in the years (2020-2021), when the lake's water level decreased and the lake's size decreased. The geographical Information Systems (QGIS) program was used. This program is considered one of the best and most accurate programs in analyzing the image elements that were pulled from the satellite and one of the best programs used in engineering and geographic mapping. It was used by applying the (NDWI) method as in the following equation (2) [30].

NDWI= (Rgreen – RNIR) / (Rgreen + RNIR) (2)

where R green reflectance of the green band.RNIR reflectance of the near-infrared band.

The NDWI value ranges from -1 to 1. The sample type is water if NDWI >0 and non-water if NDWI ≤0[5].

The reclassification table window was applied to measure the area of the four classes. Through it, the reflectivity values were arranged from the minimum value to the maximum value, and the difference between these values represents the areas of the four classes. The reflectivity value for water was positive, and for plants and soil, it was negative [5]. A reference to the satellite image data was determined by downloading the ground control points (GCP is a point on the earth's surface of a known location) on the image modified by the (QGIS) program. The area limits of the lake water were fixed by downloading the GCP, which was considered a reference for monitoring changes in the lake water area in recent years. To study the impact of the temperature of the study area on the fluctuation of the lake water levels, the reading data of the temperature during the year's seasons were followed up in the period specified for the study. This was obtained during (2020-2021) from the meteorological data of the study site for NASA. The surface temperature of the study area was measured from the band (10) by converting the reflected spectral radiation from the region to the brightness temperature, which was done using the data from the heat band file (10). The following brightness temperature equation was applied [31]:

$$T = \frac{K^2}{log(\frac{k^1}{s^1}+1)} - 273 \qquad (3)$$

T: Temperature (C°),1 and K_2: Heat Transfer ConstantsS_1: spectral radiance (w/(m2*sr*m2)).

4.Results and Discussion

The results reached in our research represented the readings of the lake area. They were obtained from the QGIS program from the report (NDWI) and the temperature readings obtained from the application of the brightness temperature equation, which was conducted during the period (2020-2021) and these results can be It is described as follows:

1. The results of the readings taken from (NDWI) showed fluctuation and instability in the lake water levels during the specified period. All indicators and readings indicate a varying decrease in the lake area during the year's months, as the lake's lowest area reached (3.1032)km^2 in January 2020, after which the area stabilized until the end. After that, the area expanded until it reached its

most enormous amount in mid-July, which was (3.726) km^2, and then began to decline until it went an area of (3.2545) km^2 in December. This was close to the area in January of the same year. In 2021, the water level fluctuation was more significant than in 2020. The decline continued significantly, as its area reached at the end of March(1.0751) km^2 and then began to rise drastically to reach July 24,624 square kilometers to stabilize its area. With a slight increase until the beginning of September, its area suddenly decreased to get the lowest area during December by (0.774) km^2, the lake's lowest area reached during the period specified for the study. The results obtained from the NDWI readings can be observed in the following **Table (1).**

Table 1. The Sawa Lake area in years (2020-2021)

Date	Area(m^2)	Date	Area(m^2)
19/1/2020	3.1032	21/1/2021	2.5362
23/3/2020	3.321	26/3/2021	1.0751
26/5/2020	3.1311	13/5/2021	1.2195
13/7/2020	3.726	16/7/2021	2.4624
15/9/2020	3.5353	2/9/2021	2.5182
20/12/2020	3.2545	5/11/2021	1.8576
		23/12/2021	0.774

Figure (2) shows the change in the area of Sawa Lake through the zigzag curve in the period (2020-2021), and the recorded readings show a decrease in the area of lake water in the autumn and winter seasons to mid-spring, starting from the end of the tenth month to the end of the fourth. The increase in the water area is limited in summer and begins from the middle of the fifth month to the end of the tenth month. It declines with the fluctuation of its proportions, representing a dashed straight line. This situation is repeated within two years in addition to the continuation of the lake water.

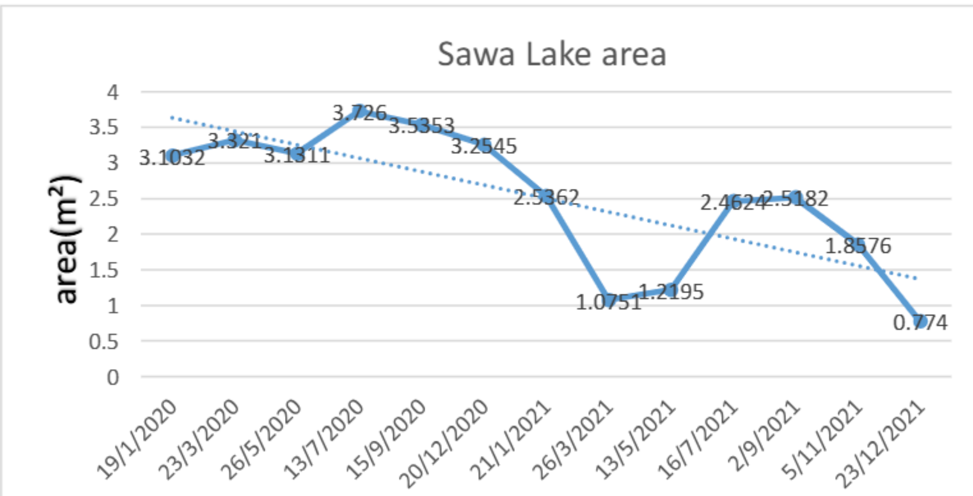

Figure 2. Sawa lake area in proud (2021-2021)

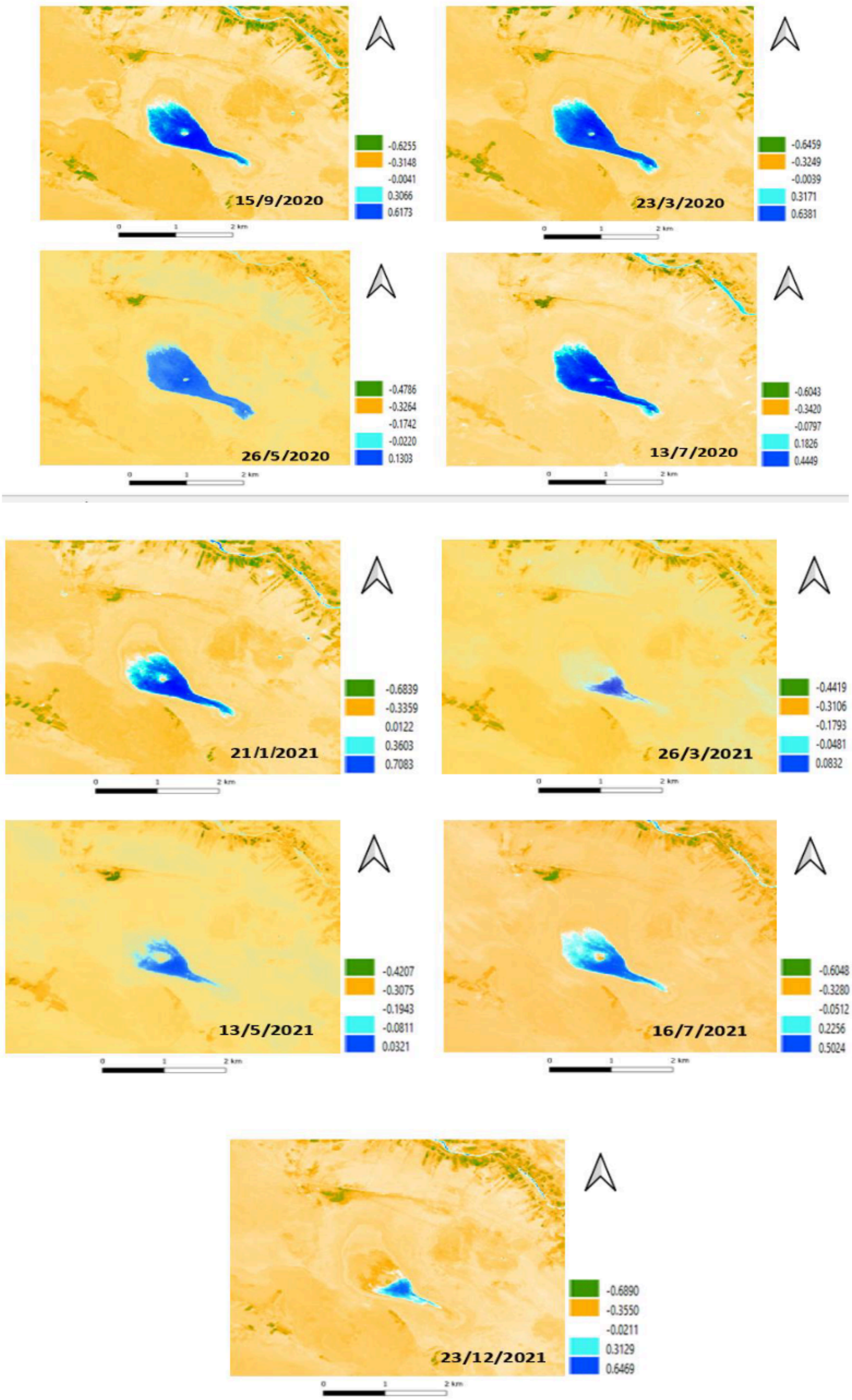

Figure 3. Water cover changes (2020-2021) Positive values range between 0.312-0.646 represent water, while negative values represent plants and soil.

2- The GCP was used as a constant reference to compare the lake area. The results showed that the amount of the area fluctuated relative to the GCP during the seasons, showing low in the first and last months of the year. It also showed an increase in the soil area instead of a decreasing water area. As for the months that fall in the middle of the year, specifically from the month The fifth to the end of the tenth month, an increase in the lake area appeared. This situation was repeated during the two years specified in the research.

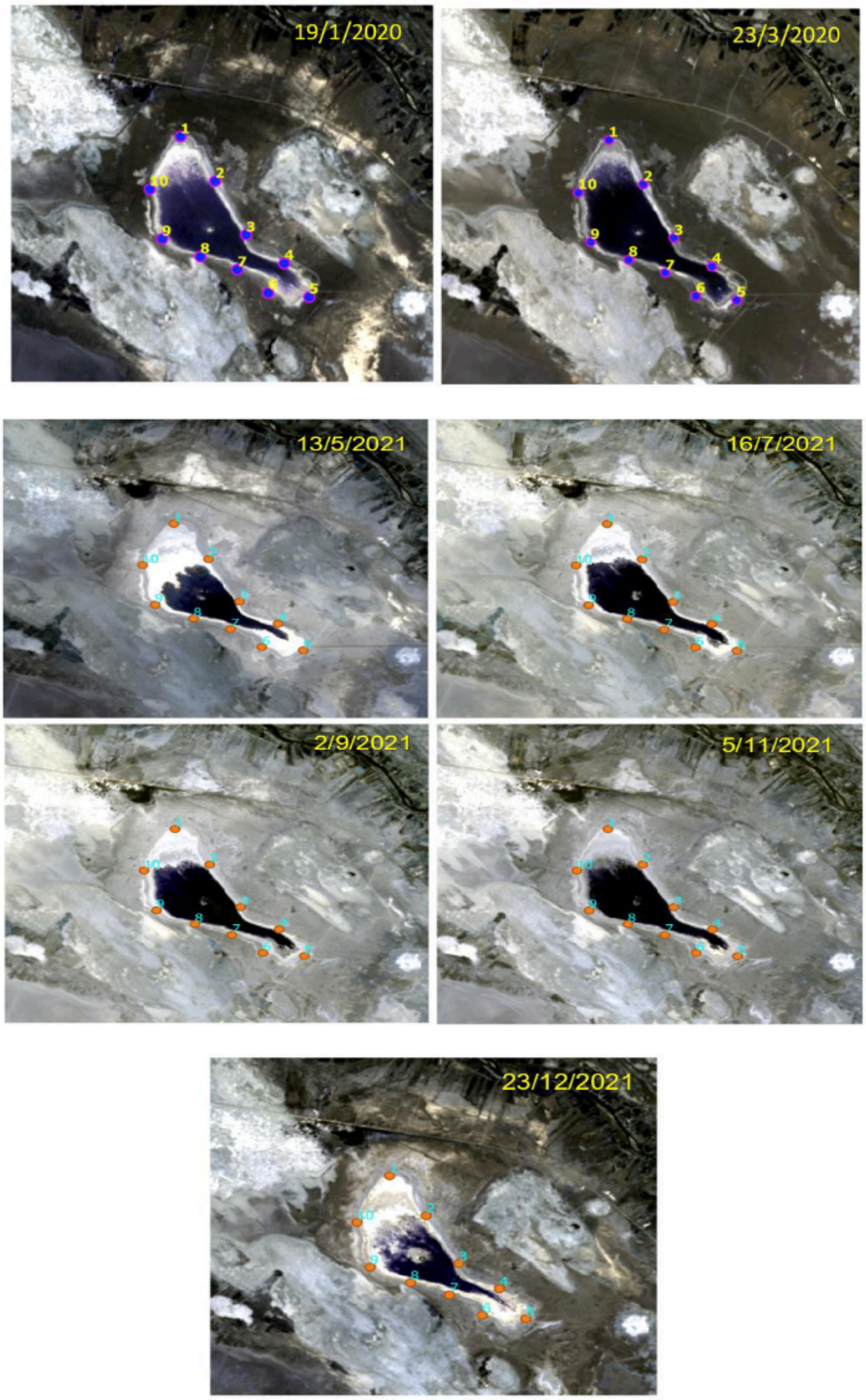

Figure 4. Sawa lake with (GCP)locations, Landsat-8 OLI from 2020-2021.

3- We applied the equation of brightness temperature to the intensity of the spectrum emitted from the surface of the lake water and based on the band 10 data (from the Landsat 8 satellite of the OLI sensor. The results representing the average surface temperature of the lake water during the specified period (2020-2021) were obtained. The readings appeared low in autumn and winter, medium in spring, and high seasonality in summer. In 2020, its lowest amount was in January, which was 13 C°. It has 9 C°, the highest amount was 30 C°, and **Table (2)** shows the amount of these readings. The highest amount was in July, 30.5 C° in 2020. And it was the lowest amount.

Table 2. shows the surface temperatures of Lake Sawa water from the brightness temperature equation during the years (2020-2021)

Data	T(C°)
19/1/2020	13
23/3/2020	17
26/5/2020	23.5
13/7/2020	30.5
15/9/2020	28.5
23/12/2020	12.5
21/1/2021	9
26/3/2021	20
13/5/2021	30
16/7/2021	33
2/9/2021	32
5/11/2021	20.5
23/12/2021	12.5

The graph shows the fluctuation of the surface temperatures of the lake water obtained from the brightness temperature equation in the application of remote sensing. This fluctuation in temperature represents a normal condition because the weather in the study area is cold in winter. hot, so the curve shape has bottoms that appear in the cold winter season. It has peaks that appear in the hot summer season, as shown in **Figure (5).**

4- The temperature readings obtained from the image in 2020 showed the lowest degree was 8.33 C° in January and the highest temperature was 37.96 C° in July. Still, in 2021 the lowest temperature was in January 4.91 C°, and the highest temperature was 36.48 C° in July, as shown in the following table, as shown in **Figure (6).**

Table 3. shows temperatures (during the years (2020-2021).

Data	Ts (C°)
19/12020	8.33
23/3/2020	15.74
26/5/2020	28.8
13/7/2020	37.96
15/9/2020	36.02
23/12/2020	8.93
21/1/2021	4.91
26/3/2021	18.19
13/5/2021	29.21
16/7/2021	36.48
2/9/2021	35.58
5/11/2021	18.24
23/12/2021	10.82

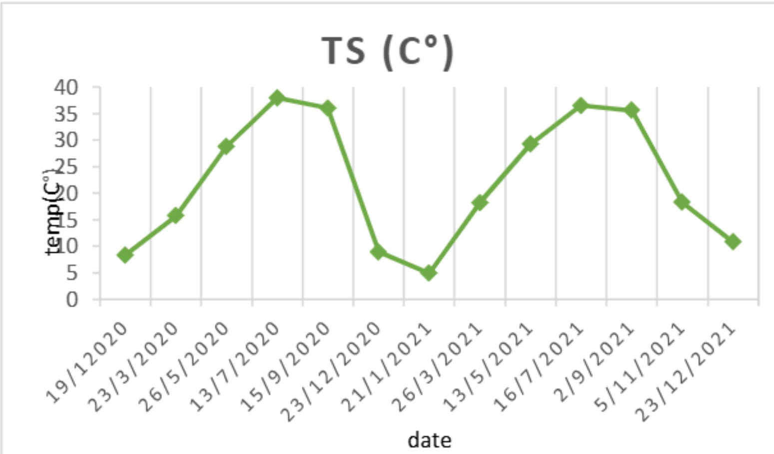

Figure 6. Temp. changes during (2020-2021)

5- The curves in **Figure (7)** showed a phase convergence of the two curves with a slight difference in amplitude, as there is a small difference in temperature in both tables, and the two curves were combined (2,3).

6- The results of the readings of the surface water temperature of Sawa Lake and the readings of the lake water area showed similarity in some periods of increase and decrease. This can be seen in the fluctuation of the lake water area curve with the curve phase of the lake surface temperature fluctuation. There is an increase in each of them in summer and a decrease in autumn and winter. The highest point of each was reached in July 2020.

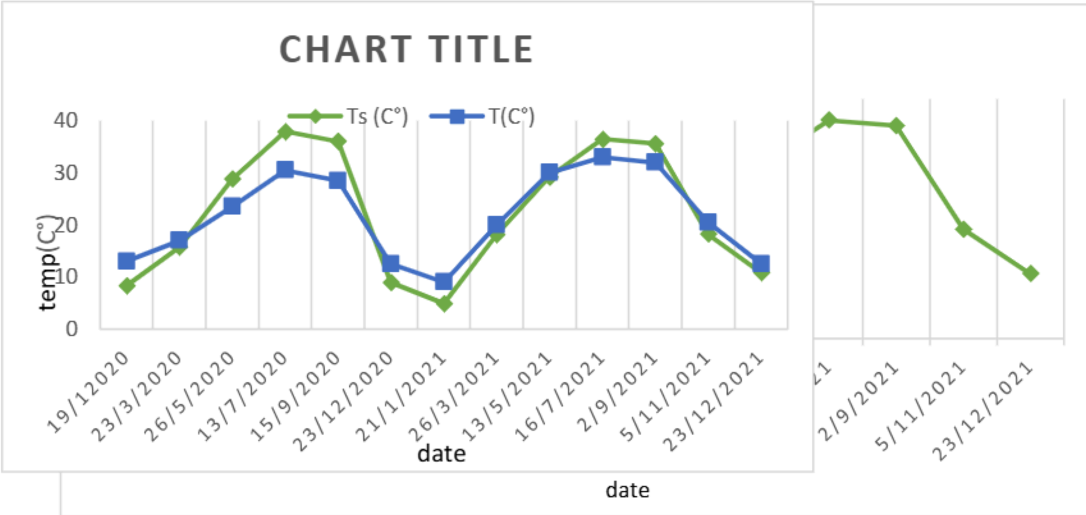

Figure 7. Temp. and water Temp. changes during (2020-2021)

In 2021 the lake recorded the highest surface area in July and the highest surface temperature in August, with the lowest point in January 2020. In 2021, the lake reached the lowest surface area in December and the lowest surface temperature in January of the same year. These results indicate that the temperature is not the reason for the decrease in the area of the lake water because the increase in temperature leads to the evaporation of water and thus leads to a decrease in the area of the water, but what happened with the lake is the increase in the area during the period of high temperatures, as shown in the **Figure (8)**:

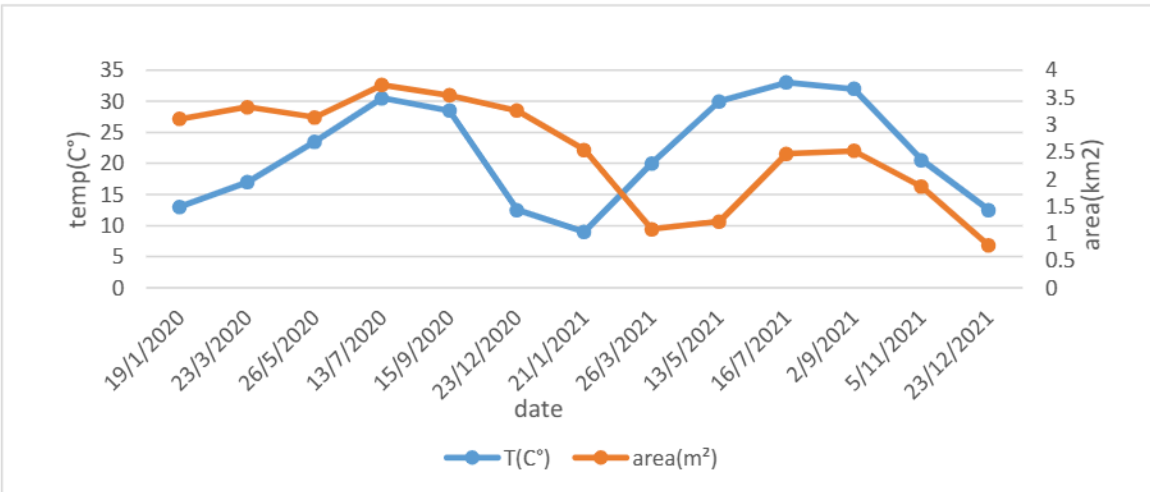

Figure 8. Temp. and the water area changes during (2020-2021)

5.Conclusions

1- The NDWI indicates a large fluctuation in the area of Sawa Lake during the years (2020-2021), it decreased, and its area reached less than (1) km^2 at the end of 2021 in January. This is a serious indicator indicating the disappearance of the lake permanently soon.

2- The lake area increases in the summer and decreases in the fall and winter until the end of the spring months.

3-The increase in the lake water temperature in the summer coincides with the rise in the lake area. The decrease in the temperature of the lake water in the winter and autumn is also in conjunction with the decrease in the lake area.

4- The temperature change in the study area is not the cause and the essential factor in the decrease is the water area of Sawa Lake.

5- The increase in the water area of Sawa Lake occurs in the dry seasons, and the decrease in its area appears in the rainy seasons. This indicates that the weather elements in the study area, represented by temperature, evaporation, and rain, are not the main reason for the change in the lake water levels.

6- The Sawa lake area decreased because the groundwater misuse in the area has lowered the underground water table that is itself drained by wells (4000 wells and more than 1500 wells illegally dug for agriculture), with low rainfall and climate change. 2022 is a drought year for the second consecutive time.

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