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Environmental Study about Sirte Sabkhas Impact on The Surface Salinity at Western Coastal of Libya Using MODIS Satellite Techniques

Dawi Muftah Ageel

Department of Environmental Sciences, Faculty of Science, Elmergib University, Khoms, Libya.

E-mail: dmageel@elmergib.edu.ly

دراسة بيئية حول تأثير سبخات سرت على الملوحة السطحية في الساحل الغربي لليبيا باستخدام تقنيات MODIS الفضائية

الضاوي مفتاح عقيل

قسم علوم البيئة، كلية العلوم، جامعة المرقب، الخمس، ليبيا.

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Abstract

In this study, MODIS sensor techniques were used because of their quality images, and their data is available for seven years (2015-2021) to surface salinity in the study area. It was discovered that Sirte Sabkhas contributed to the surface salinity of the Libyan western coast. Surface salinity degrees were more intense in the summer and spring seasons and less in the winter and autumn seasons due to the feeding of Sirte Sabkhas. The south, southeast, and southwest winds had an important role in Sirte Sabkhas's effect on surface salinity on the western coast. The differences between salinity values during study seasons are considered evidence of the Sabkhas' impact.

***Keywords**: Environmental study, Modis, Surface Salinity, Sabkhas, Sirte.*

الملخص

تم في هذه الدراسة استخدام تقنيات استشعار MODIS لجودة صورها، وتوافر بياناتها لمدة سبع سنوات (2015–2021) للملوحة السطحية في مياه منطقة الدراسة. وقد اكتشف أن سبخات سرت تساهم في الملوحة السطحية للساحل الغربي الليبي. وكانت درجات الملوحة السطحية أكثر شدة في فصلي الصيف والربيع وأقل في فصلي الشتاء والخريف بسبب تغذية سبخات سرت. وكان للرياح الجنوبية والجنوبية الشرقية والجنوبية الغربية دور مهم في تأثير سبخات سرت على الملوحة السطحية في الساحل الغربي. تعتبر الفروق بين قيم الملوحة خلال مواسم الدراسة دليلا على تأثير السبخات.

الكلمات الدالة: دراسة بيئية، موديس، الملوحة السطحية، سبخات، سرت.

1. Introduction

The Salinity is an important indicator of climate change due to higher global temperatures than normal. Also, the high salinity of salt water increases its density, and its freezing point decreases, this explains the warm waters of the Mediterranean at winter in the surface layers (Cael & Ferrari, 2017).This phenomenon contributes in algae growth significantly, which impede photosynthesis process of small marine organisms (Foudriest , 2022). Global warming has led to changes in precipitation patterns, as studies indicate that temperature rise increases

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evaporation, which leads to an increase in ocean salt concentrations (Union of Concerned Scientists, 2019).

Salinity is a measure of salts that dissolved in water. Salts in seawater not include sodium chloride only, but other elements such as calcium, magnesium, and potassium. These materials enter the ocean through complex processes including volcanic eruptions and hydro thermal vents on the ocean floor, as well as less complex routes such as wind and rocks on earth, which dissolve into sand and then salt. Seawater contains an average of 35 parts dissolved salt per thousand parts water (Britannica, 2020)

As a result of climate change and increase in the surface temperature of earth, resulted a lot of ice melting, and thus salinity in ocean water decreased over the past fifty years, as monitoring satellites of ocean salinity recorded an unprecedented decrease in salinity of North Atlantic waters, so salinity degree became a reliable indicator of global warming (Cullum, 2016).

Also, there is another polluting phenomenon to increase the salinity in the sea and ocean waters, it is increase in water susceptibility of electrical conductivity. This conductivity prevents the energy emitted from the ocean surface. In effect, what happens is that the energy bounces off the surface and returns to the ocean floor (it is absorbed by the ocean water); Therefore, higher salinity lead to greater electrical conductivity, and thus to greater energy retention, and this is opposite of fresh water (Assiry, 2006).

Mediterranean Sea is a part of Atlantic Ocean across Gibraltar strait and it is surrounded completely by land on the north by Europe, on the south by Africa and on the east by Asia. Mediterranean Sea has tides, but it is very limited due to its narrow exit and entrance with Atlantic Ocean via Gibraltar. Mediterranean Sea has a high level of salinity because it is considered semi-closed. Also, it is experiences high temperature increase of humidity degree and evaporation. Salinity level is uniformly high throughout the Mediterranean basin, with average surface water around 38 C^o, with exception of western part from basin. In eastern part salinity approach 40 C^o during summer season. Salinity level in most areas of Mediterranean Sea is high, and decreases towards the Strait of Gibraltar in west and increases in east and north (Encyclopedia, 2015).

Salinity variations depend on balance between evaporation and precipitation, the extent of surface and deep water mixing, human intervention, estuaries, and local climatic changes. Hydrochemical properties of Mediterranean Sea are affected by oceanic biomass cycle (Encyclopedia, 2015). Mediterranean Sea is saltiest sea after Dead sea in the world. Gibraltar strait considered an outlet for changing Mediterranean Sea waters from Atlantic Ocean, it is 14 kilometers wide. In addition to the Suez Canal, which is only 200 meters wide. Evaporation and salinity rates decrease significantly (Smith *et al.*, 2013).

Found that, deep of salinity layer in the western part of Mediterranean Sea increases every year by 0.001 (psu). Scientists say the change is consistent with the expected effects of global warming, these changes may seem small, but they have been accumulating at a faster rate since the 1990s. According to detailed study in 2010, from Geophysical Research Journal (GRJ), indicate to high levels from salinity in marine waters, lead to increased corrosion of ships, iron bridges for power or transportation plants, offshore drilling platforms, and diminishing coral

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reefs as they reduce their uptake of nitrogen, in addition to chloride poisoning. It also slows the photosynthesis process in marine plants. Also, the pH decreases when salinity degree increases, this meaning that water becomes more acidic, which effects on marine life and its biodiversity, thus changing seawater ecosystems (Borghini *et al*., 2014).

Noted that, marine plants and coral reefs adapt to salinity by breaking down salt into chlorine and sodium ions, where they store the salt and then get rid of it later through the respiration process. But when salinity levels exceed the normal rate, they become poisoned and die. In general, excessive salinity from the normal rate, it prevents some species of fish from reproducing, or prevent plants from growing, or change their behavior, which reduces their chances of survival in that environment. Since the Mediterranean Sea is a closed sea, some land use issues such as building dams on rivers will change fresh water amount that flows into this sea and thus will inevitably increase salt water density (Borghini *et al.*, 2014).

An optical sensor has been developed for surface salinity measure to the water mass of earth. It is based on a fluorescent probe saturated with chloride and fixed into insulated film from the air, there is two methods were presented for measuring salinity by chloride concentration. First, change the salinity corresponds to a change in the ionization intensity of chloride. Second, fluorescence intensity information is converted to phase angle information by adding luminophores (luminophore is a phosphorous chemical compound responsible for the luminescent element properties is ruthenium trapped in polyacrylonitrile beads. Use it to determine salinity in ocean water). MODIS satellite data used for surface water salinity observations. It has been added to the series of satellites used in various fields of science to provide scientists with long-term surface salinity data for ocean water with global coverage to understand climate change and its relationship to the water cycle (NASA, 2002).

Data used to create sea surface salinity maps weekly and monthly, with a single track spatial coverage of up to 150 km. Also MODIS data using to know how salt water moves between ocean water and atmosphere as a result of precipitation, evaporation, and the relationship of ice melt and river runoff to salinity concentrations and densities. These data will further clarify the global water cycle by estimating the global precipitation and evaporation amounts (NASA, 2002).

MODIS satellite allowed a better understanding of salinity levels and their relationship to the prevailing climate and its time scales. Taking seasonal satellite images of surface salinity and linking them to time series revealed a strong relationship between the fluctuation of direct salinity rates with the surface temperatures of the Indian Ocean waters (Hamuna *et al*., 2015). Other study on surface salinity using MODIS satellite revealed the relationship between fluctuations in salinity levels in tropical bays in the tropical Pacific Ocean and rainfall rate fluctuations (Fu & Liu, 2003).

In other study, monitoring and modeling evidence from MODIS satellite indicated that there is a relationship between rising levels of evaporation in the Mediterranean Sea and the Greek Aegean Sea and freshwater flows in the waters of those seas, where the hottest areas become the most evaporative and therefore saltier, and the areas with the least evaporation become least salty as a result of that flows of fresh water. There is a consensus among the research community that using the MODIS satellite to surface salinity measure of oceans is considered to have effective and important results (Moore *et al*., 2018).

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There are many important studies of the surface salinity water using MODIS satellite, which revealed the relationship between terrestrial water reservoirs and their salinity due to sea salinity. Surface salinity observations of the seas via MODIS satellite allow tracking groundwater reserve near shores and changes in marine salinity rates on that reserve (Palacios, *et al*., 2019).

These studies have improved our understanding of the interactions between water mass and their extreme currents and water levels in stocks, and clarify effect of increased marine salinity on the contributions of increased stocks. Where there was a study by Funda (2012) check out from the relationship between increase of salinity and decrease of underground water quality into Indian ocean shores, which Contributed to crop failure, salt agricultural soil, and leaded to population migration from those regions.

Also MODIS data to sea Surface salinity have been exploited in biochemistry field through several studies, for example, Bellerby *et al*. (2007) studied ocean acidity, carbon cycle and their relationship by salinity.

Salinity is sensitive to freshwater inflow because it contributes to its alkalinity. Therefore, the alkalinity properties of fresh water are affected by the distributions and density of sea surface salinity, and this makes salinity a good indicator of sea surface alkalinity. And by benefiting from high-resolution global of MODIS measurements, it has become easy to assess acidity and alkalinity of oceans by monitoring their salinity through accurate and reliable annual time series. Also, surface sea salinity data provide extensive knowledge about relationship of inter-water exchanges between the atmosphere and oceans, which helps estimate quantities of global fresh water flowing into seas and oceans, and predict future climate (Stammer *et al.*, 2014).

In areas where salinity is a driver of vertical layers in particular in the seas. Surface salinity effects on air and sea interactions. For example, a decrease in sea level helps create and maintain a thin, mixed layer of salt. This layer, called the barrier or absorbing layer, helps absorb and retain solar radiation falling on the surface layer, which leads to an increase in sea surface temperatures. On the other hand, a barrier layer can prevent vertical mixing and trapping of cold water in the mixed layer and thus the emergence of small sea cyclones in previously unknown places (Reverdin *et al*., 2007).

Michela *et al.* (2021) calculated a surface salinity of trend map to Levant Sea water by seasonally adjusted time series. This analysis showed a clear salinization of Levant Sea in decade from 2010 to 2020, which is associated with influx of Atlantic Ocean water, and thus shows a clear increase in salinity values.

2. Methodology

2.1. Study Site

This site includes the western part to Gulf of Sirte coast from the eastern location side and entire western Libyan coast from the western location side (Figure 1). Within coordinates; 31.13102,11.54883SW & 35.22618,16.34766 NE; and it covers an area of 238,272 km^2. Study area located within the North Africa coast, it is characterized by a Mediterranean climate. It is not a snowy climate or a dry desert climate, and temperatures range from 10 degrees a minimum

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in winter season or 40 C° a maximum into summer season. This climate plays a role in salinity concentrations during study area.

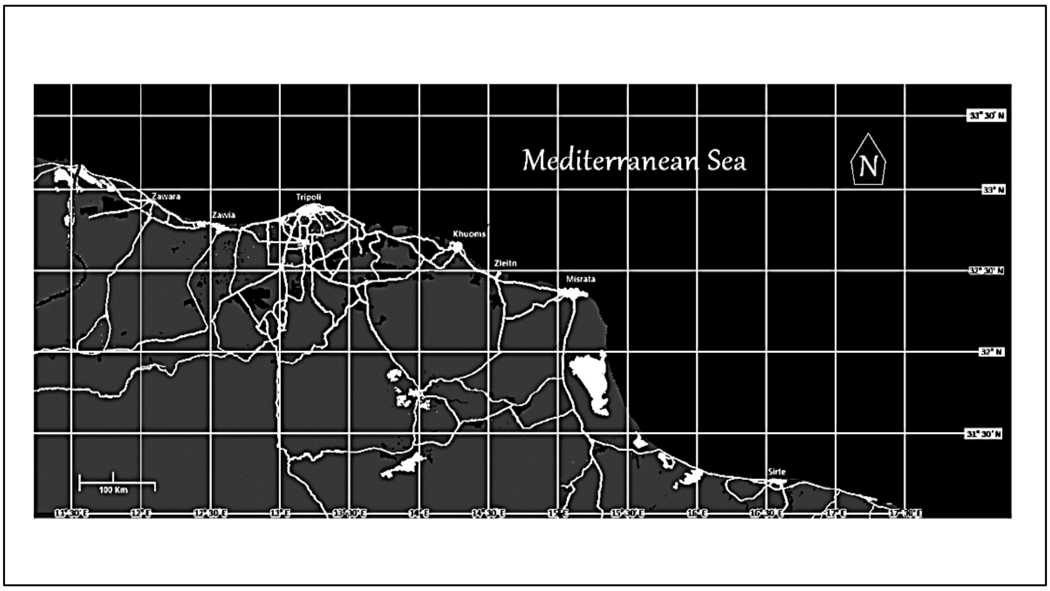

Figure 1. Study location map

While at spring, weather is moderate normally, from 10 to 21 C°. In April, it is turbulent between cold and heat, with ranging from 12 to 24 C°. May temperatures begin to rise, as shown as green line in Figure (2), from 15 to 27. Thus, temperatures rise to their peak in August, where they begin to gradually decline until mid-November, when the cold season start, as shown in cyan color.

Rainfall throughout the year has a major role to reducing the intensity of surface salinity water, because it reduces evaporation levels and feeds the water mass with fresh water. Generally, weather is moderate to weak into the year, it is ranging from 10 to 70, as appear in Figure (3).

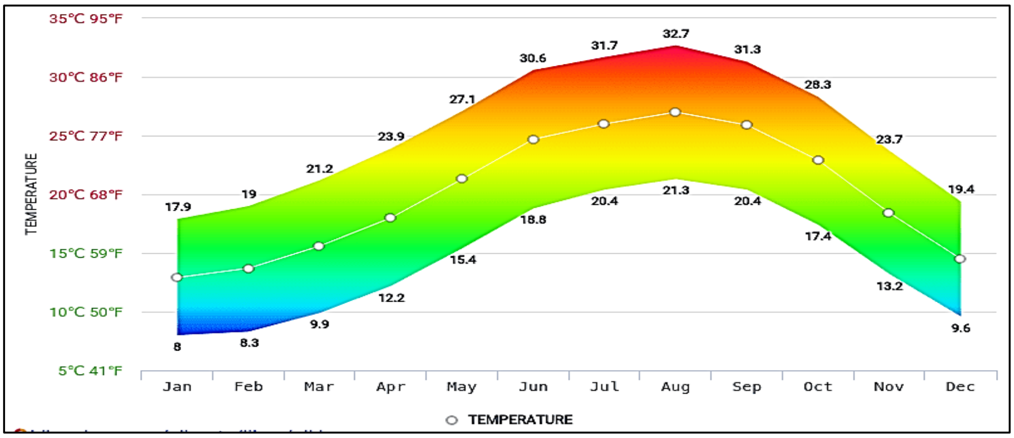

Figure 2. Heatdistribution over study location
(**Source:** Hikersbay website, State Department Climate Response)

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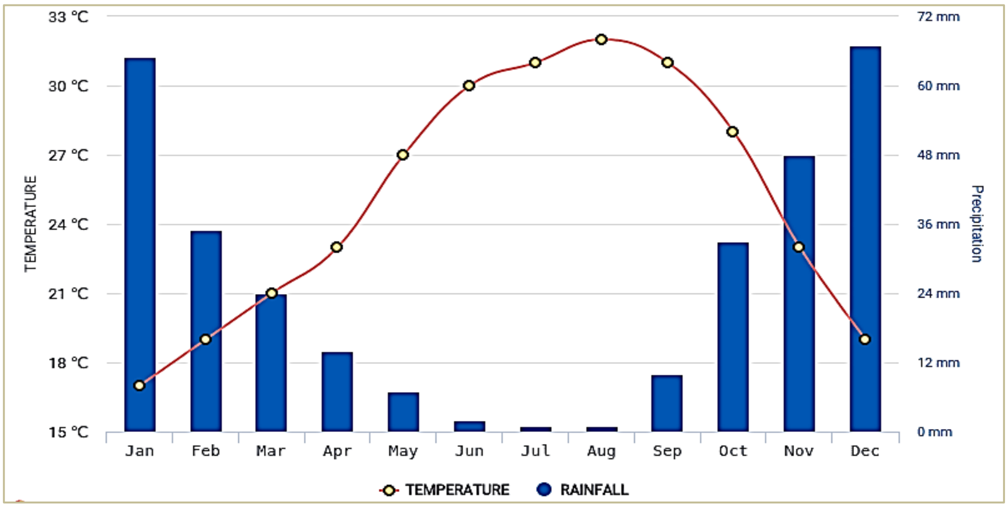

Figure 3. Monthly rainfall rate of study area (**Source:** Hikersbay climate data website)

Sirte Gulf is an open bay in south of Mediterranean Sea (Figure 4). It is part of southern shores of Mediterranean Sea and extends 800 km from Benghazi city in the east to and Misrata city in the west. Marshes in the western part of Sirt Gulf (which was targeted in the study), the largest of these marches include; Wadi Tamt, Bei Al-Kabir, Buirat Al-Hassoun, and Al-Washka.

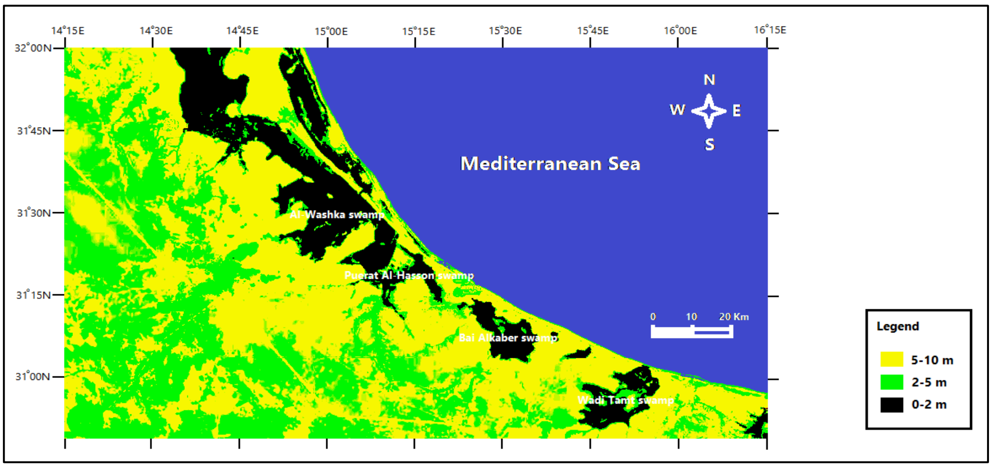

Figure 4. Sabkhas of Sirte gulf

2.2. Materials

It's hard to verify from variations of natural phenomena such as salinity for one year only. Therefore, this study was chosen for seven years (from 2015 to 2021), it was considered sufficient to clarify the salinity degree changes at study site. Time series are used to be more concise and clear than spatial data, which are often repetitive and similar despite their clarity. Study area waters were monitored by MODIS satellite, where data were obtained from version, 5.0 by the Aquarius data processing system and are available from NASA's Active Archive Center for Physical Oceanography, affiliated with the Jet Propulsion Laboratory (JPL), and can

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be downloaded from website; (NASA, 2002). It produces Level 2 data with a chart of one degree per month for satellite image data of surface salinity degrees.

The obtained data were analyzed to be pure and free of interference, using the Specialized Analysis Program, SeaDAS version7.5.3, for its ease of spectral analysis of the surface salinity ranges. The noise was caused by clouds, mist, dust, clouds, or rough sea in the study area. The time series method was used as an important method in understanding the time of decrease and rise in temperature of the study water. Especially in times when spatial coverage is difficult due to climatic conditions, sea roughness, or turbidity effects from pollution sources. Time series data obtained from same specialized program in spatial analysis mentioned above. A time series is a sequence captured at consecutive, equally spaced points in time. It is a series of discrete time data for the same variable.

3. Results and Discussion

The most important finding of this study is that the coastal salinity was affected by supply of Sirte Sabkhas; and it had a greater effect on the coastal surface salinity increases into study area, in response to the climatic changes of the year seasons. This effect decreased in winter and autumn seasons over the study period, despite the strong winds and fluctuating rains in these two seasons (Figure 5).

Similar interactions were observed between Sabkhas supply and surface salinity during time series of study years (Figure 6) and in their effect on surface depths (Figure 7) of the western Libyan coast. Moreover, Sabkha supplies also decreased under conditions of heavy rain and low evaporation compared to conditions of increased evaporation rates and little or no rainfall, indicating a synergistic effect of Sabkha on coastal water salinity and climate change. Figure (5) shows the spatial distributions of surface salinity direction into study waters. Sirte marshes influence was clear on the western Libyan coast during the study period from 2015 to 2021, the surface salinity was density off Sirte marshes coast, and surface salinity of Sirte marshes column was spread in the study area, during study period. Despite their gradation and different distributions. Surface salinity scores exceeded 38 (psu) and did not arrive below 36 during study period. The increases in surface salinity were clearly similar, as the salinity increase was similar in those years. The salinity mass change of the spatial distribution is inferred by two distinct peaks, 38.4 and 37.2. This peak was recorded in 2018, 2020, and 2021.

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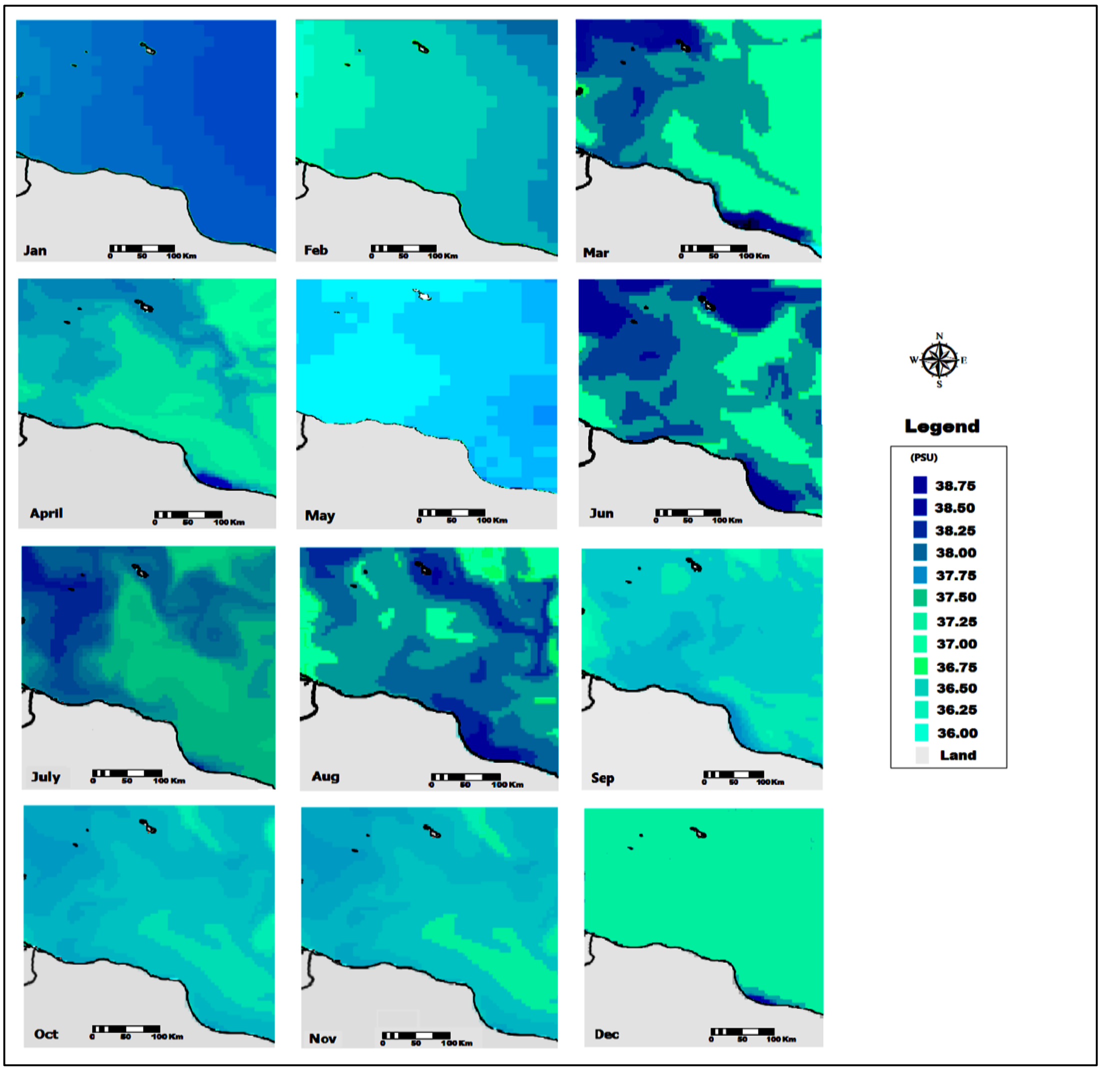

Figure 5. Barotropic flows of Sirte Sabkhas during study period

From the obtained data, found that salinity concentrations varied depending on their directions at the study area. In salinity direction was towards to the west, surface salinity rate was low, about 36 to 36.5 psu, while it ranged from 36.8 to 37.2 in the northwest direction. Also found that surface salinity concentrations increased in the eastward, and ranging from 37.5 to 38.7, where surface currents played a fundamental role in this, which occur throughout study years. Data was distorted by 30% of the total obtained data, as a result of clouds, sea roughness, turbidity degree, and satellite changes in frequency angle, which made it difficult to obtain on clear and accurate images at a third data. Monthly data was clearer than weekly data, with lower distortion rates up to 10% of the total recorded data.

At spring and winter seasons, thermal energy of sea water increased due to the aqueous mixing between surface and depth waters, and thus surface salinity was greater. During summer season, surface water was less warm and mixing of surface water was lower due to wind currents were weaker than rest year, so salinity levels were lower in this season. Spatial data indicated that the surface salinity of Sirte marshes was dominant and influenced their distribution during the study period. Figure (5) shows these spatial effects, showing variation

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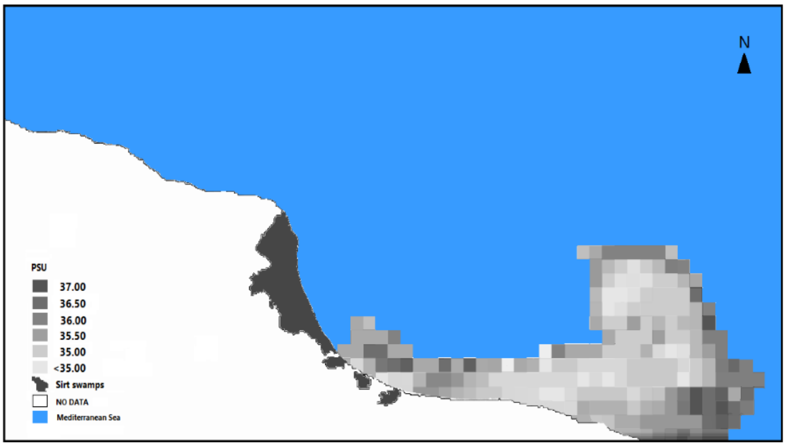
between study years. Data were similar in August 2015, with 38.0 psu, compared to a rate of 37.8 psu in October 2017. In October 2019, a significant increase was recorded 38.4psu, compared to 38.3 psu at April 2019. In September 2019, there was a gradual decrease in salinity, recorded 37.3 psu. October 2020 recorded same value with a slight increase 37.6 psu. In April 2021, surface salinity degree increased compared to previous years for the same month during the study period, as it was at a rate of 38.0, in June 2021 recorded 37.5 psu, and in August 2021 recorded at 37.7 psu.

Also, low values were found during study period, such as during February 2018, when recorded 36.2 psu, observed in March 2021 at a rate of 37.4psu, as was observed in September 2018 at a rate of 36.3 psu, and in February 2021 recorded 37.3 psu. Likewise, in June 2015 recorded 36.5psu, in November 2015 was 36.2 psu, in August 2021 recorded 36.8psu, and in February 2021, it recorded 36.3.psu.

From results, surface salinity distributions are high, it is towards to high salinity strongly and there is a little decrease in salinity rates relatively. Time series data recorded that precipitation leads to a decrease in surface salinity at winter and autumn seasons (Millot, 2017). Also, strong winds lead to an unsteady distribution of salinity on study area as a result of what is known as coastal eddies as shown in Figure (6).

Figure (7) represents data of time series during study period. Generally, annual distributions of surface salinity were similar, but although some months are low, into most study years found that there is noise at satellite images while taking temporal data, but for most satellite images, the salinity distribution is clear. Time series shows the variation in surface salinity rates between high during spring and summer and low during winter and autumn. Which determines impact of Sirte marshes on the coastal salty waters, as shown by the spatial tensions of those marshes at Figure (6).



a

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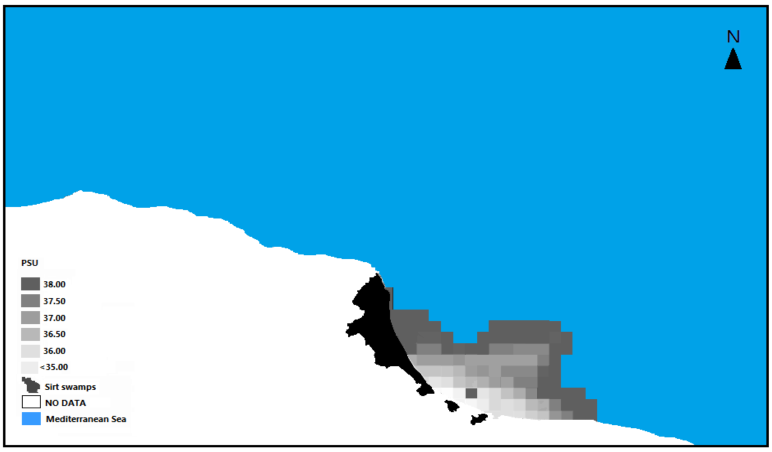
b



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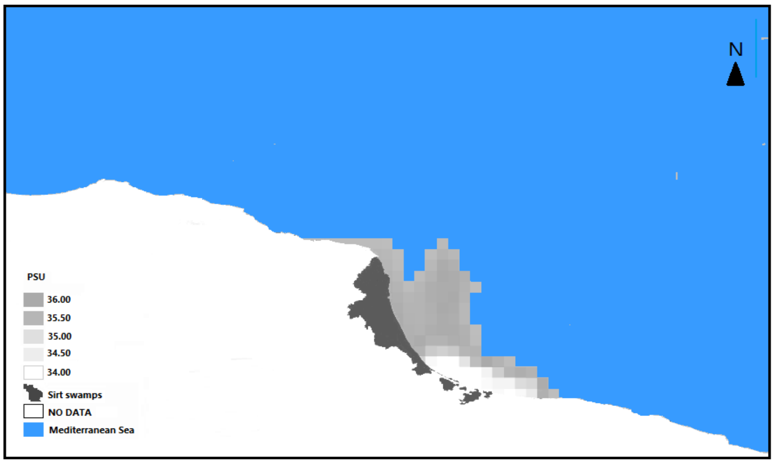

d

Figure 6. Common distribution through various months during study period; ***a)*** December; ***b)*** August; ***c)*** March; and ***d)*** October

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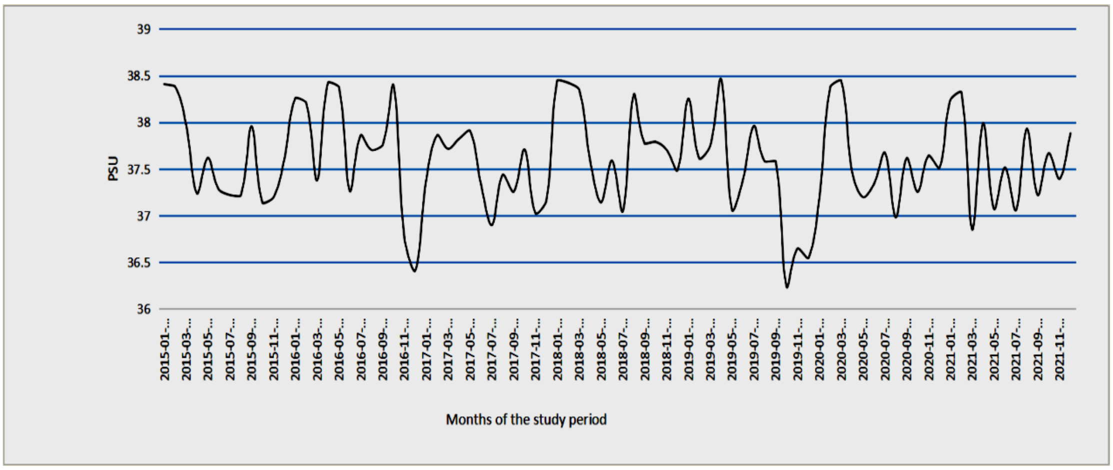

Figure 7. Maximum and minimum of surface salinity degree by time series during study period

Also time series shows that Sabkhas influence was strong by its supply into study seasons, and surface salinity rate remained constant in the rest of seasons, which indicates an increase in evaporation into summer season because of high temperature, and this effects on reproduction fish, flourishing of coral reefs, lack of oxygen, seaweed, crustaceans, and shellfish. Time series shows that surface salinity remained stable in that months have low influence, and it did not exceed a barrier of 37.5 degree on average. compared with other seas it was high. This means that water mass currents was weak in Mediterranean Sea, which contributes to salinity consolidation in water column through sea depth. Time series may show slight discrepancies into winter and autumn seasons compared to the rest of seasons, because of less rainfall in some years compared to other years during study period. which means higher salinity records to them.

Study of salinity depth for shows increase in salinity with depth, reaching 39 (psu) as shown in Figure (8), meaning that mixture water is weaker and it is clear from top to bottom. Also light absorption is weak due to salinity increasing with depth. Based on depth results and extent of the salinity surface makeup with depth due to Sirte Sabkhas, found that high in summer and spring as shown in Figure (9) during study period. In this study, the depth shows extent of salinity amount into winter that coming from marshes to study coast, where salinity depth exceeded 25 meters at spring and 20 meters at summer, while did not exceed 10 meters into autumn during whole study years.

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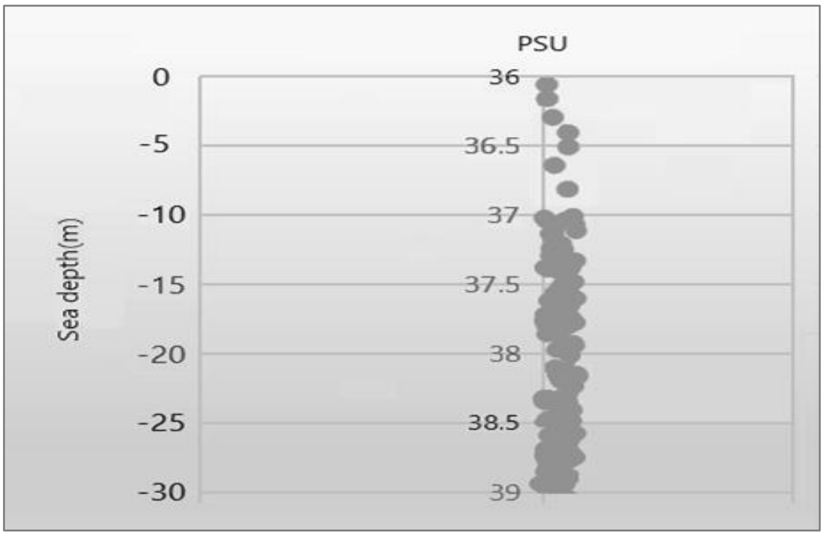

Figure 8. Water column for salinity surface levels with sea depth

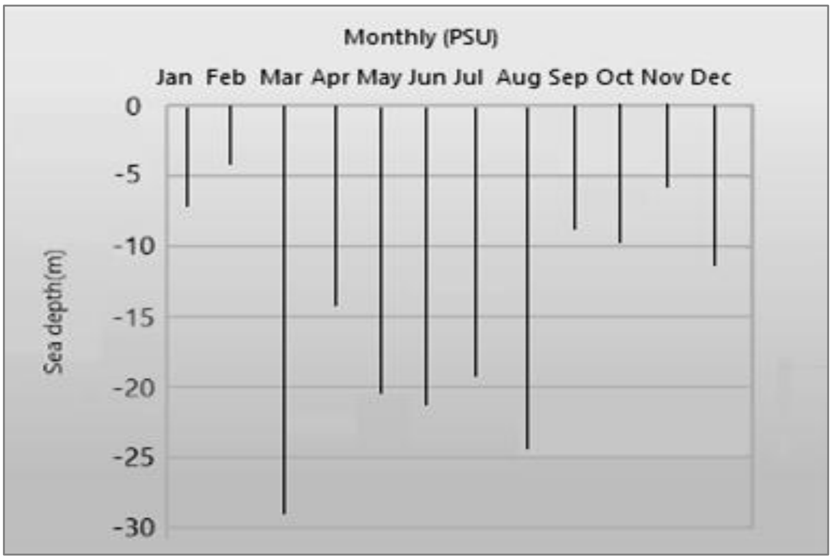

Figure 9. Water column of salinity surface levels monthly

4. Conclusion

From the results, the impact of the Sirte sabkhas was clear, as the rise in surface salinity was related to extent of the Sabkhas supply. Time series and depth analyzes revealed that this increase did not decrease to a significant degree during study period, it did not fall below36 (psu), because of marshes supply was high and distributed throughout the entire study area into study years. Decreased rainfall and high temperatures were other factors in increasing surface salinity. MODIS technology validated these influential factors through this study.

This study is considered important in monitoring and revealing the spatial and temporal distributions of salinity and its concentration. It is recommended to take this study as an important indicator of the relationship of salinity in the study area to other environmental

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problems such as the acidity of that water or extent of carbon dioxide gas into it and the biogeochemistry in the study waters.

Impact of salinity density on fisheries and marine biomass, such as coral reefs and fish reproduction, and on vacationers in the growth of dangerous jellyfish and some algae, in addition to the role of salinity in affecting port basins, corrosion, and damage to them. For all of this, it is recommended to treat the problem of high salinity by identifying and exploiting the least dense areas and staying away from the areas with the highest salinity and alerting them.

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