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Waterbody change detection using Sentinel-3 thermal imagery: A case study of Mighan Wetland, Iran

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Abstract

The wetland ecosystem is an important indicator of climate change and valuable ecosystems for environment and human being that offer substantial services. This study detects the changes land surface temperature in Mighan wetland in 2018 and 2023 by using Sentinel-3 SLSTR data. Two essential factors were used for detection. LST and DTR factors detect changes in water bodies accurately and correctly. The study finds that in the eastern and southern regions of the wetland, there is a decrease in daily LST, indicating a decrease in water temperature. In the central and western regions, there is a decrease in land temperature. The nightly LST trend shows variations between different regions of the wetland, with the eastern region experiencing lesser changes compared to the central and western regions. Additionally, the article analyzes DTR trends and finds that differences between day and night temperatures decreased over time in the eastern and southern parts of the wetland. These findings contribute to understanding temperature dynamics in wetland ecosystems and their potential implications for climate change impacts.

1. Introduction

Wetlands are valuable ecosystems for both the environment and human beings, offering substantial services (Aghamiri et al., 2022; Alibakhshi et al., 2020). These ecosystems play a significant role in the hydrological cycle, carbon sequestration, ecosystem balance, microclimate stabilization, and the prevention of climate extremes such as droughts, floods, and nutrient imbalances (Mafi et al., 2021; Kattel, 2022; Zhou et al., 2022). Additionally, wetland ecosystems serve as important indicators of climate change and are influenced by climatic factors. They effectively contribute to climate change mitigation at both regional and global scales (Kang et al., 2015).

One of the main factors influencing wetland ecosystems is Land Surface Temperature (LST), which exhibits an inverse relationship with wetland presence (Wang et al., 2022; Pei et al., 2023). LST can be obtained through ground observations, land surface modeling, and satellite remote sensing techniques (Sheffield et al., 2018). In the study of land-atmosphere interactions, relying solely on in situ measurements to meet utility requirements is challenging. Satellite remote sensing technology based on satellite imagery provides a powerful tool for monitoring LST due to its ability to repeatedly observe the same area over time (Hashemi et al., 2022; Qi et al., 2022). The diurnal temperature range (DTR), which represents the difference between daytime and nighttime temperatures in a particular location, is widely used as an important meteorological indicator related to global climate change. DTR trends and variations vary depending on the time scale considered (Bonacci and Đurin, 2023).

It is crucial to assess the impact of climate change on Land Surface Temperature (LST) at both daily and annual time scales. In a study conducted by Musyimi et al (2023), short-term drought in Kenya's lower eastern counties between 2019 and 2021 was analyzed using Sentinel-3 SLSTR data. The researchers derived three essential climate variables: LST, Fractional Vegetation Cover (FVC), and Total Column Water Vapor (TCWV). Their findings revealed that variations in LST were inversely related to vegetation density and soil moisture content. Non-vegetated areas were found to have lower moisture content. Overall, the use of Sentinel-3 SLSTR products proved to be an effective data source for monitoring short-term drought, particularly in situations where in situ measurement data are limited.

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In another study by Moisa et al (2023), the contribution of forests and wetlands to LST in Yayo district was examined using multi-spectral and multi-temporal satellite Landsat images from 1986, 2003, and 2021. The results indicated that the mean LST increased from 1986 to 2003 but declined over the past two decades due to the protection of forest and wetland ecosystems.

2. Method

2.1. Study area

Meighan wetland is located in of′49°21′ to50°25′ east longitude and33°47′ to 34°44′ north latitude. Meighan wetland is located in 5.8 kilometers northeast of the Arak city in the Farahan Plain and its area is about 100 up to 110 square kilometers and its height is 1660 meter from mean sea level. This wetland is a seasonal saltwater lake and a lowland desert area, and its marginal lands has covered by halophyte bush and shrub plants, sand dunes, alluvial fans and smooth plains.

SLSTR, referring to the Sea and Land Surface Temperature Radiometer, is a dual scan temperature radiometer operating for the ESA Sentinel-3 mission in low Earth orbit as a part of the Copernicus Program. SLSTR products offer highly accurate global and regional Sea and Land Surface Temperatures (SST and LST) for climatological and meteorological applications. In this study, four Sentinel-3 SLSTR Level-2 LST products were downloaded from the Copernicus Open Access Hub. Sentinel-3 SLSTR product generates land surface parameters with a one km spatial resolution.

2.2. Land Surface Temperature (LST)

Land Surface Temperature The radiative temperature of the land in bare soil conditions and the effective emitting temperature of vegetation as determined from a top-view of a canopy determined by infrared radiation are referred to as Land Surface Temperature (LST) (Li et al .,2013) While local modeling relies significantly on field data, remote sensing has become the primary source for LST estimation at different scales (Dar et al .,2019;Meng et al.,2017). The Radiative Transfer Equation (RTE) can be applied to a given thermal IR band to convert radiance observed at a sensor into Land Surface Temperature using Equation (Vlassova et al.,2014)

$$Lsensor = \tau * \varepsilon * LTs + Lu + \tau * (1 - \varepsilon) * Ld \qquad (1)$$

where Lsensor is the top-of-atmosphere radiance; LTs is the radiance related to the surface temperature of a black object as per Planck's law; Ts is the LST; and Lu and Ld are the upwelling and downwelling atmospheric radiances, respectively. τ is the atmospheric transmissivity, while ε is the land surface emissivity. Radiance is expressed in $W \cdot sr^{-1} \cdot m^{-2} \cdot \mu m^{-1}$ (Musyimi et al., 2023).

2.3. Diurnal Temperature Range (DTR)

The daily range of the surface air temperature in a day, i, given as DTRi, represents the difference between the maximum, Tmax ,i, and the minimum, Tmin,i, daily temperature of each day, i, within the analyzed period: (Bonacci and Đurin, 2023).

$$DTRi = Tmax,i - Tmin,i$$

3. Results

3.1. Land Surface Temperature (LST)

LST distribution in Meighan wetland depicted varying spatiotemporal patterns. Figure 1 shows that daily LST estimates ranging between 18 ◦ C and 30 ◦ C in May 2018 and in night LST vary between 18 ◦ C to 26 ◦ C.

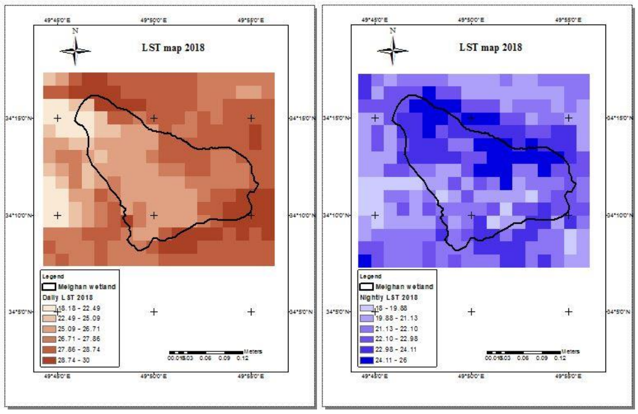


Figure 1. Daily and Nightly LST in 2018

In the same time in May 2023,the daily LST estimates between 19◦ C to 26◦ C and nightly LST estimated ranging between 15 ◦ C and 24 ◦ C (Figure 2).

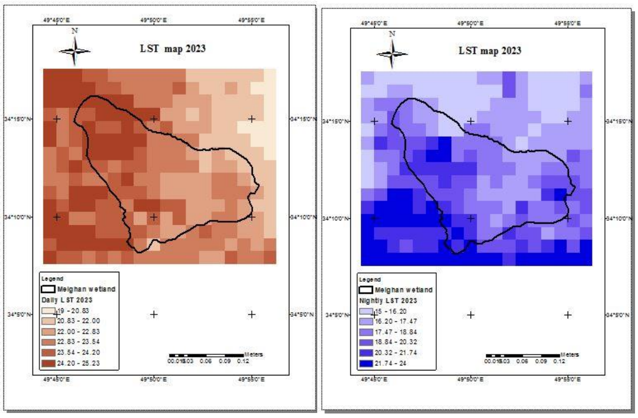
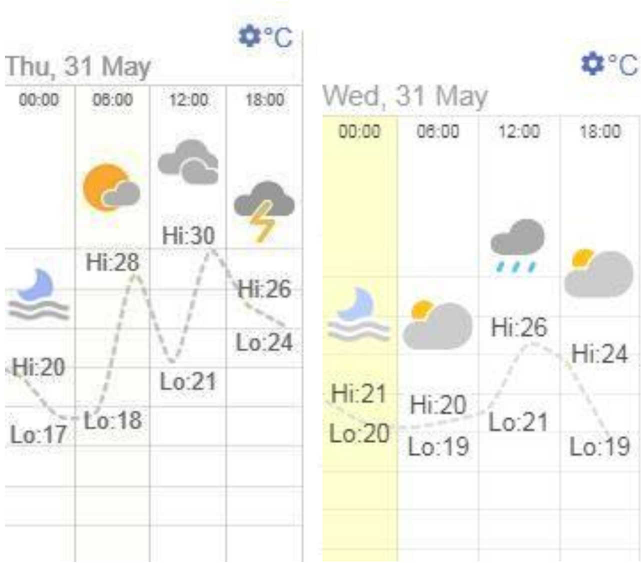


Figure 2. Daily and Nightly LST in 2023

It should be noted that in this study, we aim to monitoring the changes of LST so the LST images were calibrated with true tempreture (Figure 3).

As shows Figure 4 the daily LST and nightly LST trend between 2018 to 2023 is decreasing .



A B

Figure 3. A-real temperature in 31-05-2018
B- real temperature in 31-05-2023

In the East and South of wetland daily LST trend is between -6 ◦ C to -4 ◦ C that shows the water tempreture is decreased.In Central and West of wetland LST trend is between -4 ◦ C to -2 ◦ C in these regions , land tempreture decreased. The nightly LST trend between 2018 to 2023 estimated between -2.96 ◦ C to 0.96 ◦ C in the eastern and between -0.96◦ C to 1.01 ◦ C in western and southern in the Central of wetland it changes between -4 ◦ C to -2.9◦ C.The LST trend is between -9.7◦ C to -6.5 ◦ C in the north of wetland.

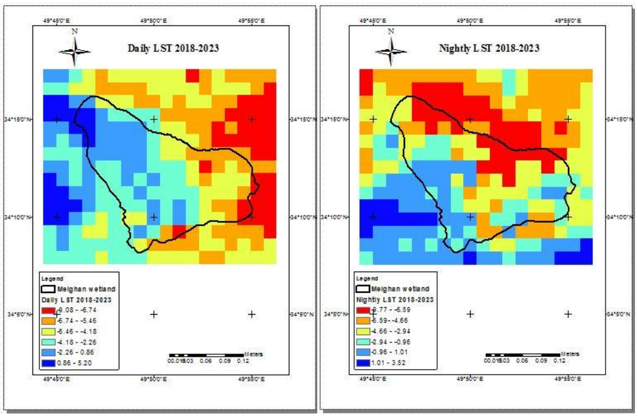


Figure 4. Daily and Nightly LST Map 2018-2023

3.2. Diurnal Temperature Range (DTR)

Figure 5,6 shows a series of DTRs observed at the Meighan Observatory in2018 and 2023. A statistically insignificant downward trend is observed.DTR in 2018 showes a difference between 4◦ C to 8◦ C in the East and South of wetland and in the Central and West ,tempreture is varied between -2 ◦ C to 4.8◦ C. In 2023, DTR changes between -0.3◦ C to 2.88◦ C In the East and South,DTR varies between 2.88◦ C to 7◦ C in the Central and West and in the North is more than 4◦ C .

4. Discussion

Higher daily LST differences in East and South of wetland shows that the water body tempreture deacresed and gets cooler.Although the Center and West of wetland that are covererd by vegetation and land observed few changes in LST.In the East and South nightly LST trend is lesser than the Center and West of wetland.

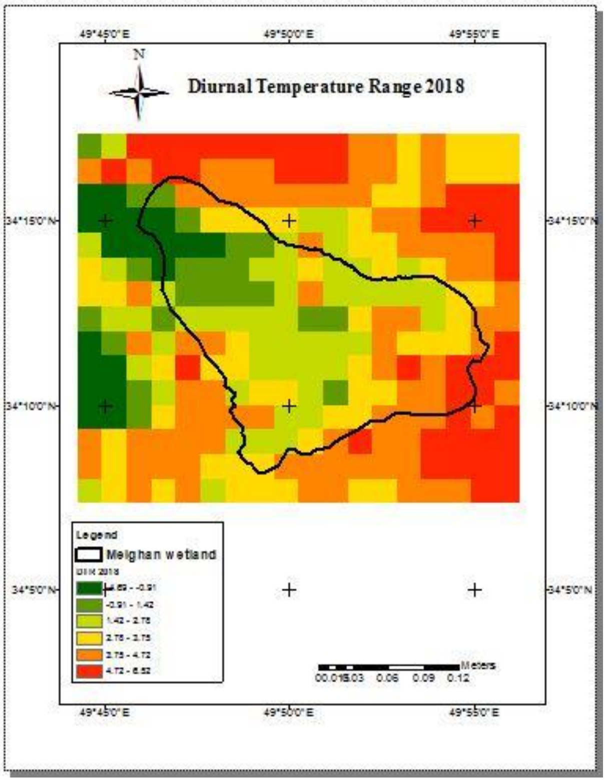


Figure 5. DTR Map 2018

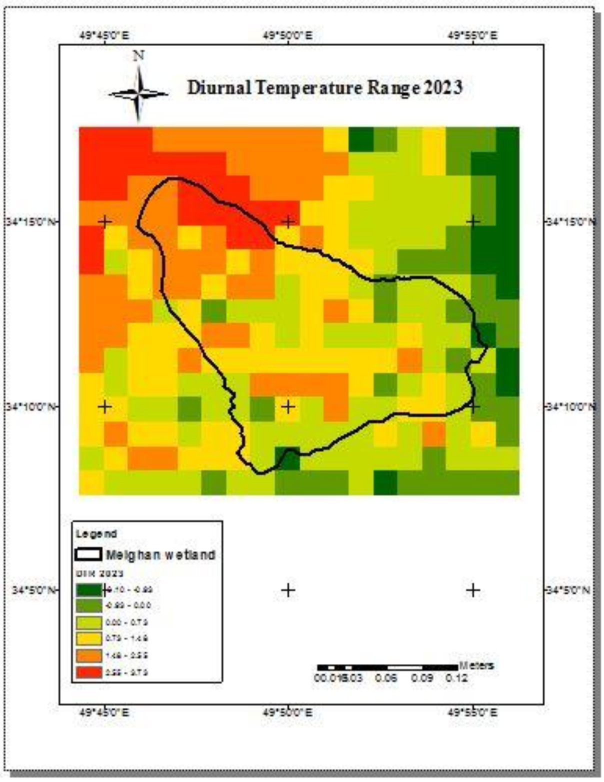


Figure 6. DTR Map 2023

Mustafa et al (2023) showed that LST values over West Africa varied between 20.6 ◦ C and 34.6 ◦ C in

2010, 20.6 ◦ C to 37.6 ◦ C in 2018, and 21.2 ◦ C to 38.7 ◦ C in 2020, which is relatively consistent with the current study. Furthermore, LST increases are associated with changes in land cover from vegetated to non-vegetated surfaces which can be used as an indirect drought indicator.

DTR trend in 2018 and 2023 shows that in the eastern and southern parts the differences between day and night decreased toward to 2023.

An increasing temperature is observed in the western and central parts of the wetland while results show rising temperature in 2023.

5. Conclusion

The results of LST and DTR trend show that the stability of the weather has increased in 2023 and the air temperature has become more moderate.

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