The effects of climate change on normalized difference vegetation index (NDVI) in the Al-Huwaizh marsh

Abstract

This study aims to classify Landsat 7,8 satellite data using NDVI thresholds. Initially, visible and near infrared bands of Landsat 8 satellite were used to derive Normalized Different Vegetation Index (NDVI) image. Vegetation, non-vegetation and water areas were then analyzed where thresholds for separating them are carefully determined with the aid of ground truth information of the study areaAlso, the Mann-Kendall test was conducted to analyze the trend of temperature and rainfall in the study area, as the results of the analysis showed the significant trend of temperature, on the contrary, the stability of the rainfall trend, as it was not statistically significant.The study correlated the historical trends of climatic elements as a central factor in the degradation of swamps (vegetation cover) from 2000 to 2010 and (2015-2023).The results showed that the year 2015 witnessed an increase in the area of NDVI compared to the years studied, as the total area of vegetation cover during this year amounted to about 537.47 km 2, by 79.4%.While the year 2023 was one of the worst years of the study, as the marshes witnessed an increase in the area of dry lands at the expense of the marsh waters, as the area of these lands reached about 354.69 km^{2}by 52.40%.The findings of this study are that the application of the three indices is useful for evaluating land, especially NDVI in wetlands. So it is necessary to develop and integrate with other remote sensing indices.

Keyword: NDVI, M-K nonparametric method, Climate change,Al-Hawizeh Marsh

Introduction

Marshlands are important ecosystem for living organisms. The Southern IraqiMarshlandis the central habitat for freshwater fish, provides habitat forimportant populations of wildlife and serves as a source of income for nativeeconomies through reed harvesting**(Ike & Ottah, 2019).**

The marshes were subjected topolitically-driven drying operations in the late 1980s and early 1990s as the flow of the Tigris and Euphrates rivers was altered by the construction of dams and canals upstream, and this caused an ecological disaster**(Albarakat et al., 2018)**.

The Mesopotamia wetlands which is used to be connected to each other via Tigris, Euphrates and Karkheh rivers undergo a slight degradation since 1970 as a result of dam construction on these rivers in Iraq, Syria, Turkey, and Iran. Both Iran-Iraq War in 1980-1988 and Gulf War in 1991 inflicted a significant negative impact on Al-Azim/Al-Hawizeh wetland. Till 2000, among the Hur-Al-Hammar, Central Wetland, and Al-Azim/Al-Hawizeh wetland, just a small portion of Hur-Al-Azim remained and the others have desiccated.**(Salmabadi & Saeedi, 2018)**.

Degradation is a decline in the area of vegetation that turns into barren land. This degradation led to the transformation of the marshes to barren lands. fortunately, about 30% of the Al-Huwaizh marsh remained intact because the Karkha River from Iran continued to feed the northeastern part of this marsh.(**Nations & Programme, 2001)**.After the fall of the regime responsible for these drainage alterations in late 2003, the marsh dwellers uprooted most of the earthen dams, as well as dikes on the Tigris and Euphrates rivers, and water started flowing back towards the marshlands. Within three years of normal flows, the Mesopotamian marshes began to be re-established. Native species of flora and fauna returned, and the percentage of recovery was between 50% and 60% as compared to the wetlands before alteration, showing the resilience of the marshes**(Albarakat et al., 2018).**These marshes were once the largest wetlands in southwest Asia and covered more than 15,000 square kilometers (km)**(Al-HamedSaleh & Nasser, 2015).**

The Iraqi marshlands **—**originally twice the size of the Everglades in Florida**—**has been the major wetland area in the Middle East, as of 1990, very little had changed in the region. However, within a decade, 90 percent of the ecosystem area was turned into barren dry lands by a large drainage scheme. Additional important roles provided by marshes include detention of floodwaters, protection of shorelines from erosion, aesthetics, and improvement of water quality by trapping sediments and assimilating nutrients**(Ike & Ottah, 2019)**.in addition tochange detection is a process of identifying differences in the state of objects or phenomena by observing them at different time (multi temporal analysis), therefore change detection became useful tool for detecting land cover changes. In recent times, remotely sensed imageries have been used to monitor and map wetlands changes on a global scale; especially in areas with inadequate ground-based observations**(Ozesmi & Bauer, 2002)**.

Remote Sensing is the science and art of acquiring information(spectral, spatial, and temporal) about material objects, area, orphenomenon, without coming into physical contact with theobjects, or area, or phenomenon under investigation**(Hassan & Al-Asadi, 2023; Mokarram et al., 2015; Rajlaxmi Chouhan, 2004).**

Digital image processing of satellite data provides tools foranalysing the image through different algorithms andmathematical indices. Based on reflectance characteristics,indices have been devised to highlight features of interest on theimage. There are several indices for highlighting vegetation-bearingareas on a remote sensing scene(**Bhandari et al., 2012**)**.**

There are several studies that have reported the use NDVI to monitor changes in vegetation cover at the national and global level**(Al-obaidy & Al-baldawi, 2019; Gaznayee et al., 2022; Husna, Vina Nurul, 2022; Makrouni et al., 2016; Milad et al., 2015)**.However, vegetation could be a criterion for global climate changes**(Bagherzadeh et al., 2020),**Hence, the investigation of the vegetation cover index provides results that can be used for crisis management and appropriate planning in dealing with environmental problems.this study aims to monitor the changes that occurred on the land covers (Hur Al-Hawizeh), by comparing multiple satellite images for the years (2000,2005,2010, 2015, 2020,2023), which is called multiple temporal analysis, calculating the Vegetation Index (NDVI) to separate the vegetation cover through The effect of some climatic factors on the vegetation cover in the study area.

Data and Methodology

Study Area:

The current study was conducted in myassan province with surface area of about 676.92km^2 in southeastern Iraq, The study area is located between latitude 31° 22'N - 31° 47'N and Mushrah and Al-Kahla was relied upon, because the main source of the Al-Hawizeh Marsh in Maysan Province is fed by the Al-Mashrah and Al-Kahla rivers, and directly affects plant growth in this part of the wetlands.In addition, dependence was made on meteorological data issued by the Iraqi General Organization for Meteorology, and the use of rain and temperature data most closely related to the change of vegetation cover, moreover, the aim of the climatic data was to analyze trends of their change during the study period. fig1.

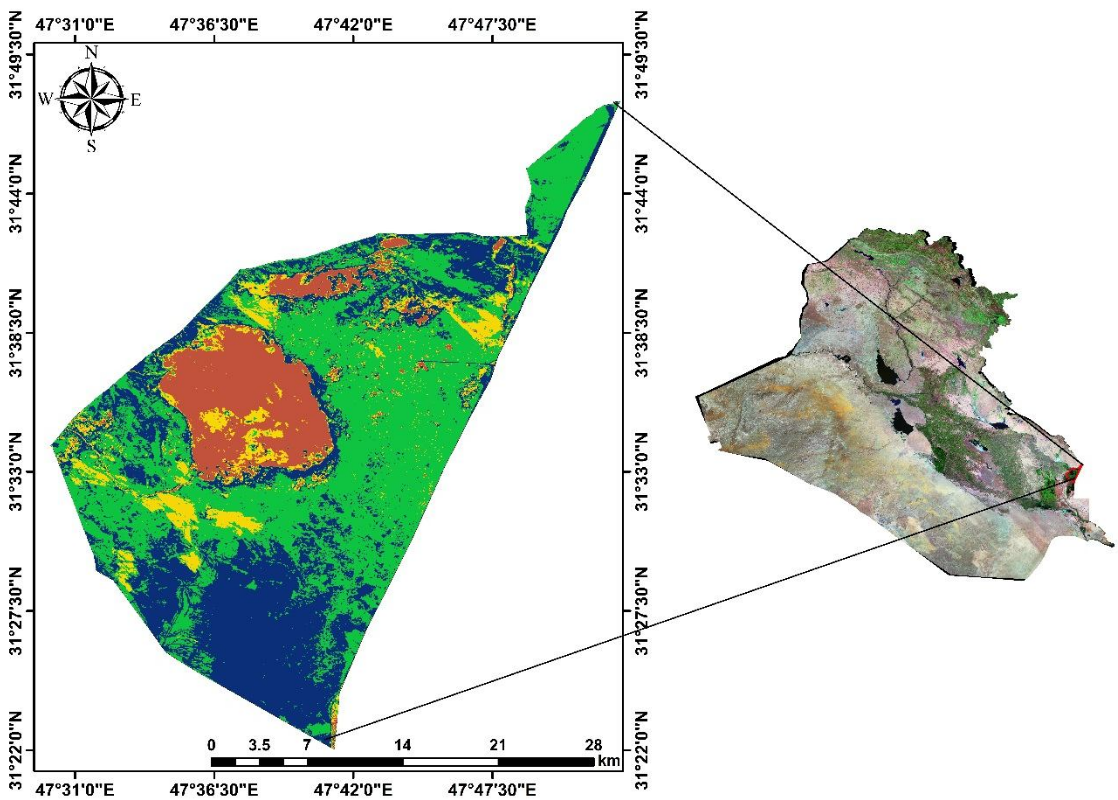

Figure 1. The study area.

Mann–Kendall (M–K) nonparametric method:

The Mann-Kendall test is one of the most important non-parametric tests used by researchers, especially in the study of trends in climatic elements ,one of the advantages of this test is that it is non-barometric and does not require a normal distribution of data.Moreover, In case of inhomogeneous time series data analysis, having low sensitivity to sudden breaks is the second most important advantage of the test. According to the null hypothesis (Ho) of the test, there is notrend and the data are randomly and independently ordered. The judgement of null hypothesis is tested by alternative hypothesis (H1), which assumes the existence of trend**(Basariret al., 2018**) .

According to the above introduction, the M- Ktest can be calculated by the following equation.

$$E[S] = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n-1} sgn(xi - xj) , \dots \dots \dots \dots \dots \dots \dots (1)$$

Where Xi and Xi are the annual values in years j and i,j> respectively, and N is the number of data points. The value of sgn (Xj-Xi) is computed as follows:

$$sgn(xi - xj) = \begin{cases} 1, & xi - xj > 0 \\ 0, & xi - xj = 0 \\ -1, & xi - xj < 0 \end{cases} ,\dots\dots\dots\dots\dots\dots\dots\dots....(2)$$

These statistics represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N>10), the test is conducted using a normal approximation (Z statistics) with the mean and the variance as follows:

$$VAR(S) = \frac{1}{18}\left(n(n-1)(2n+5) - \sum_{k=1}^{p} qk(qk-1)(2qk+5)\right)\dots\dots\dots\dots\dots\dots..(3)$$

Here p is the number of tied (zero difference between compared values) groups, and qk is the number of data values in the pth group. The xlstat program was used to extract the results of the Mann-Kendall time series test.

Normalized Difference Vegetation Index (NDVI):

It is worth mentioning, the NDVI equation has been used which is calculated by the following formula, Table1:

$NDVI_{L8} = \frac{B5 - B4}{B5 + B4}$			$NDVI_{L7} = \frac{B4 - B3}{B4 + B3}$		
Sensor	Path/Row	Acquisition Date	Sensor	Path/Row	Acquisition Date
OLI/TIRS	166/038	2015	ETM	166/038	2000
OLI/TIRS	166/038	2020	ETM	166/038	2005
OLI/TIRS	166/038	2023	ETM	166/038	2010

Table 1. Satellite platform and sensor type and date of remotely sensed data used in this study.

NDVI values have a range (-1 _ + 1). In general, the result is positive, indicating that the cell contains a cover, the higher the positive value resulting, the more plants and density(**Al-obaidy & Al-baldawi, 2019)**.

Result and Discussions:

temperature trend analysis:

The temperature time series data obtained from Iraqi General Organization for Meteorology are shown in Table 2. The Maximum temperature ranged between 14.4 and 40.5°C, and the minimum temperature recorded at Al-Amarah station ranged between 8.5 and 38.1°C.In Al-Amarah station, in terms of the monthly mean temperature, the highest mean was recorded during July, August, and June around (39, 38, and 37°C), respectively.On the other hand, the lowest mean temperature recorded for December, January and February was (13.4, 11.7, 14.5°C) respectively.The analysis revealed that in terms of the mean monthly temperature, July has the highest mean, while January has the lowest mean among the months of the time series.Likewise, in the context of the standard deviation, the month of December and March, April, recorded the highest standard deviation towards (1.513,1.594,1.918)respectively, while June, July and August were the least months recording the standard deviation by (0.841,0.650,0.972)respectively, and the rest of the months have almost the same standard deviation.The MKTM was applied on time series temperature data for all the discern met stations. The Mann–Kendall model states that if p value is ≤ to the significance level (α = 0.05), Ho will be rejected. Rejecting Ho means that there is a significant trend in the time series data. On the other hand, if p value is greater than the significance level (0.05), Ho will be accepted. Accepting Ho indicates that no significant trend has been detected. By rejecting the null hypothesis, the result will be statistically significant**(Atta-ur-Rahman & Dawood, 2017).**Mann–Kendall Trend Model was also applied on mean monthly temperature for all monthly. It was found from the analysis that there is no significant trend change) in mean monthly temperature, the probability (p) value was found greater than the confidence level of alpha value, so H_o has been accepted, which clearly specifies that there is no trend (change),with the exception of January, February and September, in which the test results clearly showed a trend, amounting to about (0.018,0.041,0.02)respectively.In addition, For the months of March, April, May, July, August, October, November and December, the value of the tau coefficient was about (0.165, -0.127,0.022,0.167,0.091,0.277,0.251,0.165) respectively. Table3, and these values are not statistically significant at the level of significance (0.05), which means accepting the null hypothesis and rejecting the alternative hypothesis and which are less significant compared to the months (January, February, June, September)whose values were about (0.394, 0.339, 0.362, 0.504) respectively, indicating a significant trend., indicating significant trend.

Variable	Minimum	Maximum	Mean	Std. deviation
JAN.	8.5	14.4	11.774	1.325
FEB.	12.6	17.1	14.506	1.224
MAR	17.0	23.5	19.564	1.594
APR	20.0	28.0	25.500	1.918
MAY	31.1	38.1	32.890	1.413
JUN	35.7	38.6	37.020	0.841
JUL	38.1	40.5	39.090	0.650
AUG	36.1	39.9	38.340	0.972
SEP	32.8	37.6	34.350	1.431
OCT	25.0	30.1	27.655	1.408
NOV	16.4	20.7	18.755	1.195
DEC	10.0	15.7	13.435	1.513

Table 2. Summary of monthly maximum, minimum, mean and standard deviation temperature for the Al-Amarah station.

Variable	Mann–Kendall statistics(S)	Kendall's Tau	Variance (S)	p value	Model interpretation
JAN.	74.00	0.394	946.00	**0.018**	Reject H_o
FEB.	64.00	0.339	948.00	**0.041**	Reject H_o
MAR	31.00	0.165	944.33	0.329	Accept H_o
APR	-24.00	-0.127	948.00	0.455	Accept H_o
MAY	4.00	0.022	939.33	0.922	Accept H_o
JUN	68.00	0.362	946.00	**0.029**	Reject H_o
JUL	31.00	0.167	939.67	0.328	Accept H_o
AUG	17.00	0.091	944.33	0.603	Accept H_o
SEP	95.00	0.504	947.00	**0.002**	Reject H_o
OCT	52.00	0.277	946.00	0.097	Accept H_o
NOV	47.00	0.251	944.33	0.134	Accept H_o
DEC	31.00	0.165	944.33	0.329	Accept H_o

Table 3. Mann–Kendall model results of mean monthly temperaturefor the Al-Amarah station.

Rainfall trend analysis:

The results of statistical analysis of the rainfall data for the study area for the period 2000 – 2023 are discussed in this section, as shown in Table 4.In the analysis of the rainfall trend, the months of autumn, winter and spring were analyzed because they are the months in which the pressure systems arrive, especially (the Mediterranean depression, the Sudanese depression) affecting the amounts of rainfall. overall, these seasons are characterized by atmospheric instability throughout the year.Usually, rainfall begins during the autumn season, from the beginning of October to the end of May, as it represents rainfall during the autumn and spring seasons intermittently and far apart, as well as heavy rainfall due to thunderstorms.Table 4 shows a comparison of basic monthly rainfall statistics over the study periods.

It turns out that the highest amount of rainfall recorded during the study period for the months of May, November and December was (138.4,147.0,112.2mm) respectively. Moreover, the least rainfall months were (March, April, October) with an amount of (64.2,69.9,45.8mm)respectively.As for the mean of the time series, it turns out that the months of November, December and December recorded the highest rate by (34.78, 32.98,26.27) respectively, which indicates that these months bring approximately more than 55% of the annual amount of rainfall during the study period.

Variable	Minimum	Maximum	Mean	Std. deviation
JAN.	0.00	79.3	26.278	24.215
FEB.	0.60	71.9	11.961	16.800
MAR.	0.10	64.2	16.983	20.917
APR.	0.00	69.9	17.139	21.316
MAY.	0.00	138.4	10.742	32.453
OCT.	0.00	45.8	8.434	14.143
NOV.	0.00	147.0	34.783	46.975
DEC.	0.00	112.2	32.989	32.940

Table 4.Summary of monthly maximum, minimum, mean and standard deviation rainfall for the Al-Amarah station.

As mentioned earlier, Trend statistical measures imply testing the null hypothesis Ho (that there is no trend) against the alternative hypothesis Ha (thatthere is a trend). The Mann - Kendall test was carried out on rainfall, and the results were presented in Table 5. The level of significance was taken at 0.05, and clearly, that the p. value for all months is greater than the critical value, except for the month of May. The p.value was about (0.010), which indicates a trend of change. Null hypothesis of no trend can be easily rejected and alternative hypothesis of trend in the temperature can easily be accepted.Even though, the statistical analysis of the Mann-Kendall test showed that there is no trend of change in the amount of rainfall, but as a matter of fact, the rainfall at the study station varies greatly from year to year, because the pressure systems that cause rainfall depend on the conditions in which they are formed, whether In terms of its strength or shallowness, and based on the many factors, the amount of rainfall changes over the study area.

Variable	Mann–Kendall statistics(S)	Kendall's Tau	Variance (S)	p value	Model interpretation
JAN.	-41.00	-0.268	0.00	0.131	Accept H_o
FEB.	47.00	0.307	0.00	0.081	Accept H_o
MAR	19.00	0.124	0.00	0.501	Accept H_o
APR	-7.00	-0.046	0.00	0.823	Accept H_o
MAY	69.00	0.457	692.33	**0.010**	Reject H_o
OCT	3.00	0.021	667.67	0.938	Accept H_o
NOV	3.00	0.020	667.67	0.941	Accept H_o
DEC	-42.00	-0.275	696.00	0.120	Accept H_o

Table 5. Mann–Kendall model results of mean monthly rainfall for the Al-Amarah station.

Classifications of vegetation and land cover:

The distribution of the changes that occurred in the NDVI of the Hawizeh marsh and for the first studied period 2000-2010 is shown in a table6.

clearly by the year 2000, that the percentage of vegetation cover in the Al-Hawizeh Marsh did not exceed 38% (distributed to dense and medium vegetation), while the largest percentage, amounting to about 62%, included swamp waters (shallow and deep waters), and It is worth mentioning, that the area of dense vegetation does not exceed 56.79 km^2, while the vegetation cover area of medium density is about 201.14 km^2.When comparing the results of the NDVI analysis in 2005 with the year 2000, we find that there is a clear difference in the land cover area of the Hawizeh Marsh .on the other hand, The area of dense vegetation increased to about 131.74 km^2, by 19.46%.The medium-density vegetation covered an area of about 259.35 km^2, by 38.31%.,Hence, (Ike & Ottah, 2019)confirmed The increase in the marshland areas and that of the shallow water areas can be attributed to the ensuing anthropogenic activities at the end of the Second Gulf War and of Saddam Hussein's regime in the year 2003. The dykes and canals that once drained the marshes were destroyed, thus re-flooding several large marsh areas.

It seems that the natural conditions represented by the climatic elements and the water drainage of the Al-Kahla and Al-Musharah rivers have a crucial role in the volume and water level of the Al-Hawizeh Marshes, and it is known that the presence of water also plays an important role in the density of vegetation cover, in 2010 the percentage of dense vegetation decreased compared to 2005 by about -7.74%, with an area of 79.36 km^2.While the average density of vegetation covered an area of 214.44 km^2, by 31.68%.In fact, as shown in the fig (2), the vegetation cover during the year 2010 appears to be scattered over the marsh area.It appears during the year 2010 that the classifications represented by water are larger in area than the classification of vegetation, which gives an indication that during this year the discharges of the rivers feeding the Hawizeh marshes increased and the water levels rose at the expense of the vegetation cover.

	VALUE	CATEGORIES	RATIO(%)	AREA(km^2)
2000	-0.642_ -0.348	Shallow Water	26.51	179.42
	-0.347_ -0.191	Deep Water	35.39	239.57
	-190_ -0.0302	Medium Vegetation	29.71	201.14
	-0.0301_ 0.412	Dense Vegetation	8.39	56.79
2005	-0.375_ -0.201	Shallow Water	19.87	134.48
	-0.200_ -0.12	Deep Water	22.36	151.35
	-0.119_ - 0.0631	Medium Vegetation	38.31	259.35
	-0.063_ 0.21	Dense Vegetation	19.46	131.74
2010	-0.724_ -0.276	Shallow Water	11.61	78.6
	-0.275_ -0.178	Deep Water	44.99	304.52
	-0.177_ -0.0570	Medium Vegetation	31.68	214.44
	-0.0569_0.237	Dense Vegetation	11.72	79.36

Table6.Statistics of NDVI Values between 2000-2010 forAl- Hawizeh Marsh.

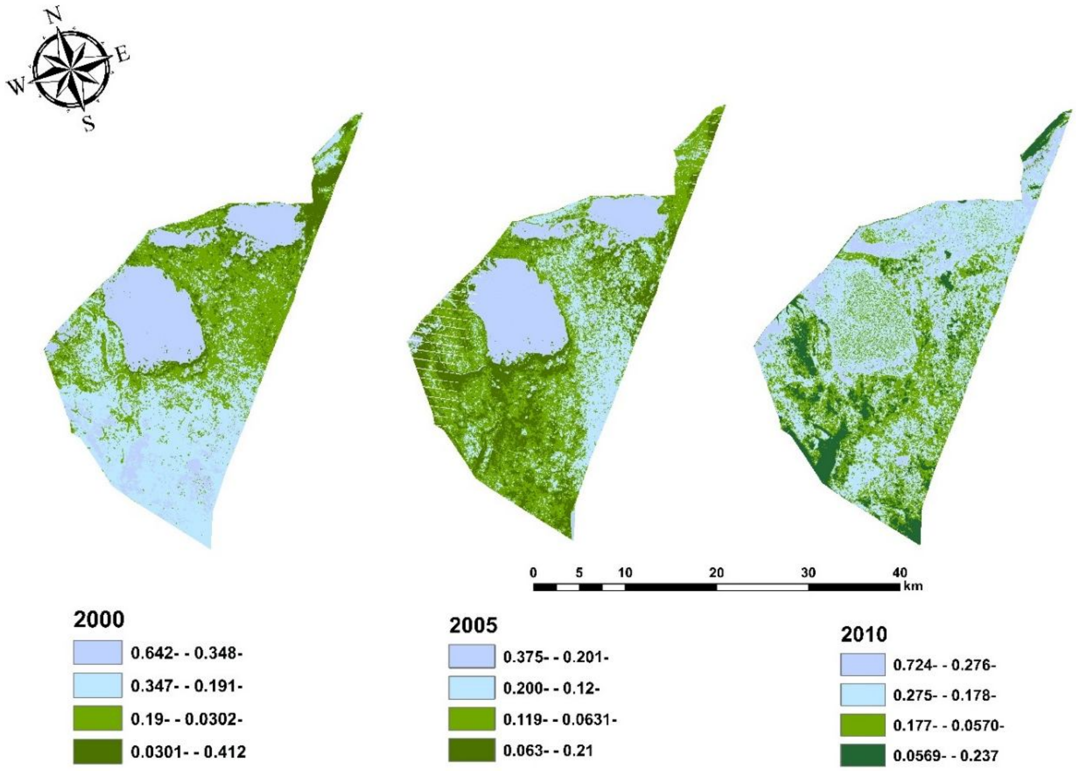

Figure 2. NDVI classification in the study area.

The year 2015 is considered the best year during the study period. It is clear that this year the percentage of vegetation cover was greater than the water area compared to all years of the study, as it appears through Figure (3) that most of the area of theAl- Hawizeh Marsh is covered with reed and papyrus plants, as the area of dense vegetation reached about 219.67 km 2 at 32.45%, followed by medium-density vegetation with an area of 317.80 km 2 and 46.95%.Furthermore, the case did not change for the year 2020, but there was a slight decrease in the vegetation area, and it amounted to about 214.00 km 2 for dense vegetation, 32%, and about 318 km 2, and 47% for medium-density vegetation.The year 2023 is considered the worst year that the marshes went through in terms of low water levels and an increase in the area of wastelands, as these lands reached about 354.69 km 2, while the area of dense vegetation reached about 75.89 km^2 at 11.21%, and the vegetation cover of medium density reached 139.38 km^2 and 20 .59% table7, fig3.

	VALUE	CATEGORIES	RATIO(%)	AREA(km^2)
2015	0.179- 0.0424-	Shallow Water	12.60	85.27
	0.0424- 0.0329	Deep Water	8.00	54.18
	0.33- 0.085	Medium Vegetation	46.95	317.80
	0.0851- 0.313	Dense Vegetation	32.45	219.67
2020	0.0205- 0.00164-	Shallow Water	13.00	88.00
	0.00163-0.107	Deep Water	8.00	54.00
	0.108- 0.204	Medium Vegetation	47.00	318.00
	0.205- 0.372	Dense Vegetation	32.00	217.00
2023	0.264- -0.0125	Shallow Water	15.80	106.96
	0.0126- 0.142	dry land	52.40	354.69
	0.143-0.265	Medium Vegetation	20.59	139.38
	0.266- 0.558	Dense Vegetation	11.21	75.89

Table7. Statistics of NDVI Values between 2015-2023 forAl- Hawizeh Marsh.

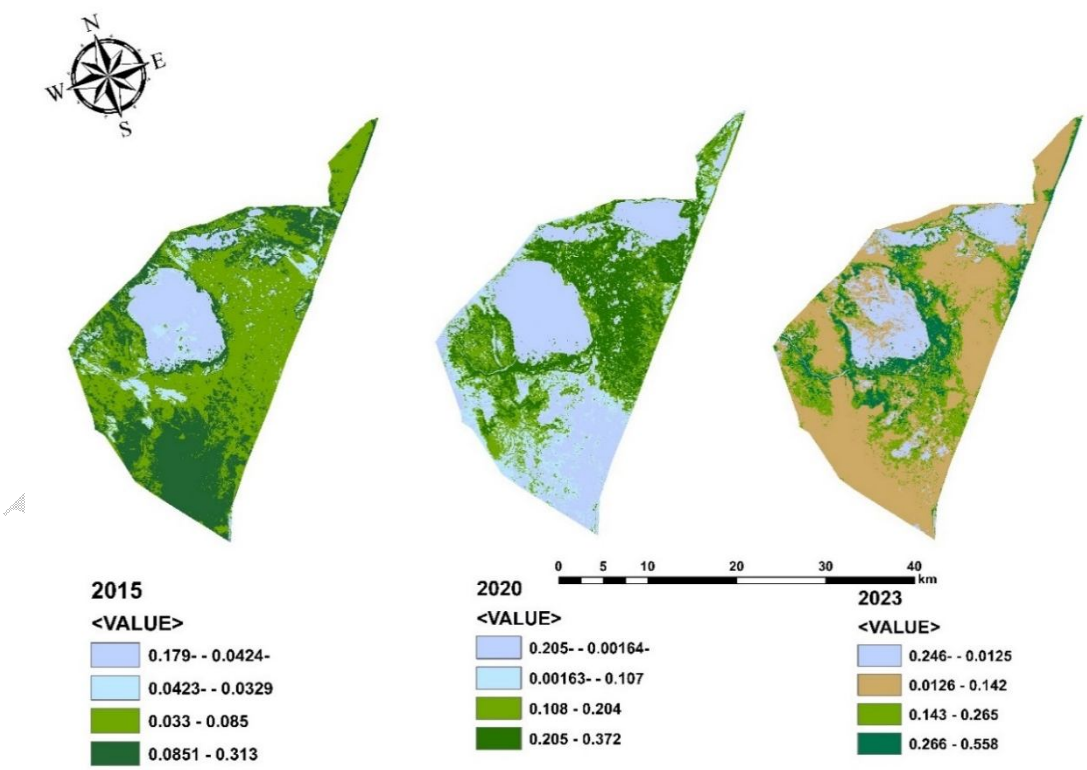

Figure3.NDVI classification in the study area.

Conclusions:

In this study, the potential effects of climate change on long-term trends of temperature and rainfall in Myssan province were examined using 20-year records. Also, the changes that occurred in NDVI due to natural conditions in the study area were indicated.In general, the results of this study reveal that the study area is witnessing a rise in temperature trends, especially during the months of January, February, June and September,Apparently, the trend of rainfall is stable and no experiencing significant trends.This study has demonstrated the applicability of remote sensing technology and GIS in monitoring Changes in the ecosystem of theAl- Hawizeh Marshes. It also highlights on the impact of climate changes on the density of vegetation cover during the different periods of the study.

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