Drought Severity Assessment using Land Surface Temperature LST and NDVI in Al Za'atari basin, Northeast of Jordan From 2010 to 2017

Awni Kasawneh[1], Sattam Al Shogoor [2,] *, Samih Rawshdeh[3], Nawras Shatnawi[4], Ali Alqudah[5], Jamal Wishah[6], and Naser Albadawi[7]

* Correspondence: Department of Geography, Faculty of Social Sciences, Mutah University, Karak, Jordan; sattam_1975@mutah.edu.jo

Abstract

The aim of the present study is to monitor and assess the Drought Condition in the Al Za'atari basin (Northeast of Jordan) due to the presence of Al Za'atari Camp for Syrian Refugees. The study utilized the advances that took place in the Remote Sensing and GIS technologies by Drought Indicators using Normalized Difference Vegetation Index (NDVI) and Land-Surface Temperature (LST). The data were obtained from Landsat-7 (ETM) and Landsat-8 (OLI). The result of the study revealed that Space Technology is one of the most important methods to continuous monitoring and Assessment Drought Condition in Al Za'atari basin and the analysis showed a negative change in most of the study areas decrease in vegetation cover, increase in Land-Surface Temperature and Decrease in Water Supply Vegetation Index.

Keywords: Drought, NDVI, LST, Al Za'atari basin.

Introduction

Drought is one of the major natural hazards affecting the environment and economy and worldwide sustainable development, Albert et al, (2002). Drought is a recurrent natural phenomenon in many arid and semi-arid regions of the world, Heim et al, (2002). Drought monitoring events in many cases impose negative impacts on the environment and cause widespread structural damages, Akhtari et al, (2008). The stress following a drought depends primarily on the strength, duration, timing, and spatial extent of the dry spell, Anja Klisch et al, (2016). The effects of drought are clearly manifested by reduced crop production, loss of agriculture; land degradation, livestock population deaths unemployment, and health problems, Murad et al, (2011). More than 50% of all deaths associated with natural hazards are drought-related, and only floods rank higher in terms of the number of people affected, Anja Klisch et al, (2016).

The development of advanced processing and analysis techniques and improved computing capabilities have resulted in new approaches that could be used for drought monitoring, Brian, (2009). Remote sensing, or attaining information about an object or area without making direct contact, often utilizes ground-based sensors, satellites, or aerial imagery, Printer et al., (2003). Many advanced remote sensing instruments have been launched that collect information that can be used to monitor different aspects of drought, Brian, (2009). Remote sensing techniques provide a platform for which plant stress and growth response can be evaluated. Sensors have been developed to measure the reflectance of incident light at various wavelengths and have been related to plant growth and vegetative cover, Joshua, (2012). Remote sensing is a technique to observe the earth's surface or the atmosphere with cameras or sensors installed in satellites. Its advantages include, its advantages include, Asian Development Bank, (2014).

(i) The ability to record data for inaccessible or dangerous areas.

(ii) A comparatively low cost per unit of area.

(iii) Wide, objective, frequent, and periodic data collection.

(iv) The availability of historical data.

There are several types of space technology applications, in this research, the main emphasis of remote sensing applications by analysis of satellite data from Landsat-7 ETM and Landsat-8 OLI. And we highlight major challenges facing the Ecosystems in the Study Area by Analysis of drought indices. Normalized Difference Vegetation Index NDVI, Land Surface Temperature LST. The use of vegetative indices has allowed users to relate differences in reflectance to changes in canopy characteristics (Hatfield et al., 2008). The Normalized Difference Vegetation Index NDVI, was initially proposed by Rouse et al, (1973). is closely correlated with green biomass and leaf area, and thus is one of the most widely used indices for agriculture monitoring, Xijie LV. (2013). The NDVI, in the range of -1 to 1, is derived from red and near-infrared channels from a remotely-sensed image — $(NIR - RED)/(NIR + RED)$. The notion behind NDVI is that plants' chlorophyll absorbs sunlight, which is captured by the red-light region of the electromagnetic spectrum, whereas a plant's spongy mesophyll leaf structure creates considerable reflectance in the near-infrared region of the spectrum, Tucker, (1979). The land surface temperature (LST) is the temperature of the skin surface of land which can be derived from the satellite information or direct measurements in the remote-sensing terminology. LST is the surface radiometric temperature emitted by the land surfaces and observed by a sensor at instant viewing angles, Prata et al, (1995). Land surface emissivity (LSE). The average emissivity of an element of the surface of the Earth is calculated from the measured radiance and land surface temperature (LST), Becker, (1995). Land surface temperature (LST) is a key parameter for the Earth's surface energy balance and is required for many applications, including agrometeorology, hydrology, climatology, ecology, and environmental studies, Sobrino et al, (2011).

Study Objectives

The purpose of this study is to employ Space Technology Applications to conduct drought monitoring for the period between June 2010 and June 2017 in Al Za'atari basin using Drought Indicators, NDVI Normalized Difference Vegetation Index, WSVI Water Supply Vegetation Index, and LST Land-Surface Temperature, extraction from Landsat-7 (ETM) and Landsat-8 (OLI) data analysis. The study also aims at finding the relationship between LST and NDVI, and the relationship between LST and WSVI using satellite image data.

Study Area

Al Za'atari basin is located in Northeast of Jordan near the Syrian border, as shown in Figure (1), between 32° 7' - 32° 24' N and 36° 9' - 36° 36' E. The basin area is (500) km2. The elevation above sea level range from (568 - 944 m) as shown in Figure (2).

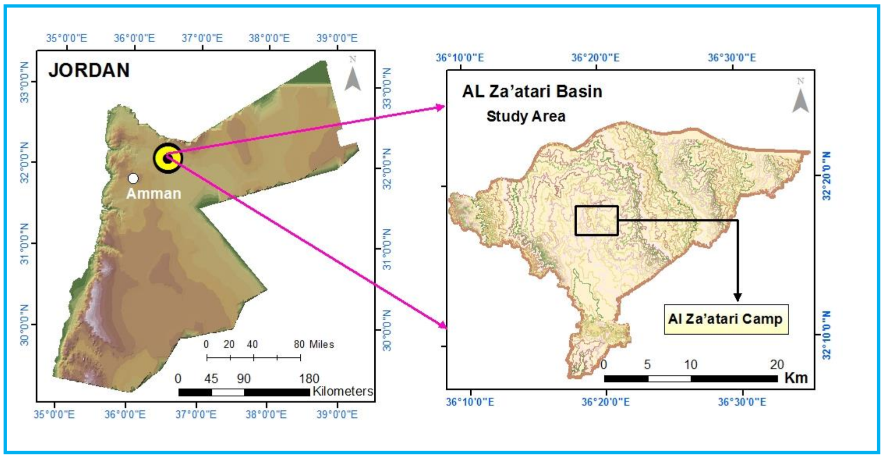

Figure (1). Location of the study area

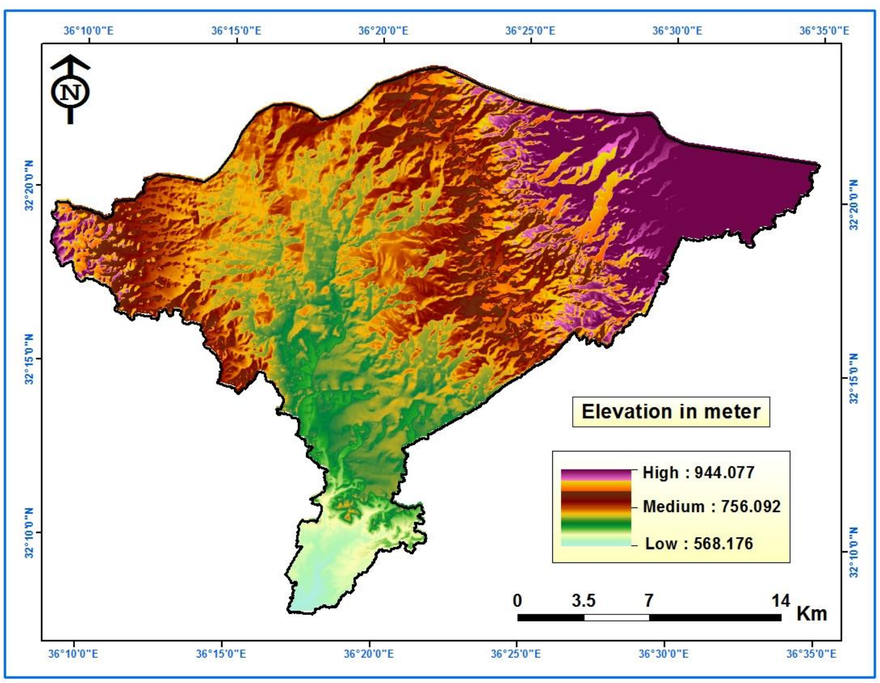

Figure (2). The elevation above sea level for the study area

Data Used

The study was based on satellite images data from Landsat-7 Enhanced Thematic Mapper (ETM) and Landsat-8 Operational Land Imager (OLI) (OLI) data analysis. The metadata for the satellite is shown in Table (1).

Table (1). Metadata of Landsat-7 ETM and Landsat-8 OLI

SENSOR	LMIN	LMAX	DATUM	ELLIPSOID	UTM_ZONE
Landsat-7 ETM P/R-173/38 (June 2010)	3.200	12.65	WGS84	WGS84	37
Landsat-8 OLI P/R-173/38 (June 2017)	1.238	22.001	WGS84	WGS84	37

Methodology

To achieve the objectives of this study, the following methodology was used for data processing and analysis as out listed in the flow chart given below. Image processing was necessary to calculate the Normalized Difference Vegetation Index (NDVI), Water Supply Vegetation Index WSVI, and Extraction the values of (LST) during the years of study. And to get the required objectives the methodology was divided into four major stages. Figure (3).

Stage (1). Calculate the values of (NDVI) from satellite images.

Stage (2). Extraction the values of (LST) from satellite images.

Stage (3). Calculate the values of Water Supply Vegetation Index (WSVI) using the values of (NDVI and LST).

Stage (4). Spatial analysis.

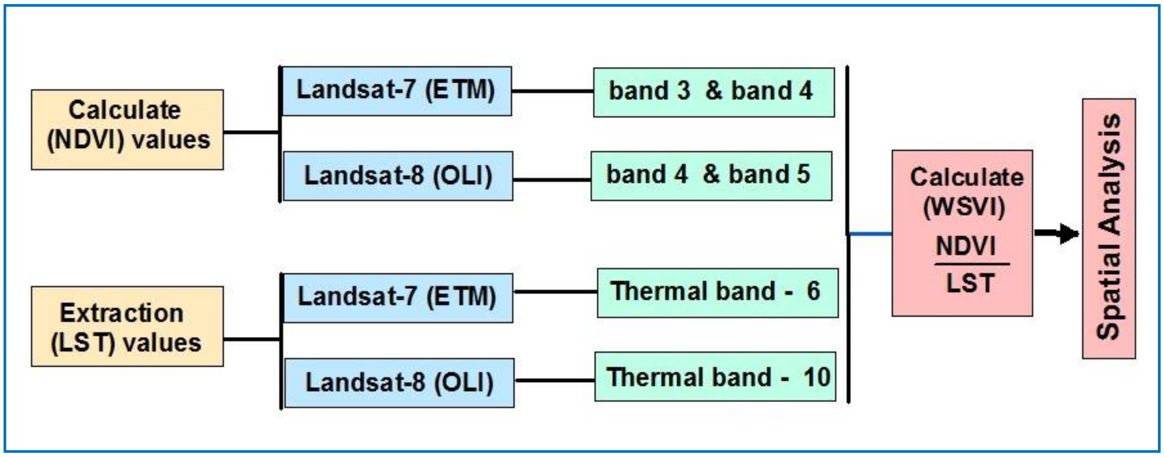

Figure (3). Flow diagram of research methodology

Stage (1). Calculate the values of (NDVI) by the equation:

$$\text{NDVI} = \frac{(\text{NIR - Red})}{(\text{NIR + Red})}$$

Where: RED is the red band reflectance from a sensor. NIR is the near-infrared band reflectance

Stage (2). Extraction the values of (LST) by the equation:

$$L_\lambda = L_{\min} + (L_{\max} - L_{\min}) * \frac{DN}{255},$$

Where: The LMIN and LMAX are the spectral radiances for each band at digital numbers. DN is the pixel DN value

The next step is used to make the satellite data comparable with the in situ (LST) measurements. Using the following equation for conversion from radiance to LST value

$$T_b = \frac{K_2}{\ln(K_1/L_\lambda)+1},$$

Where: K 1 = Calibration constant shown in table (2). K 2 = Calibration constant show in table (2). T b = Surface Temperature. T b = T b–273 (Conversion of Kelvin to Celsius).

Table (2) Calibration constant of Landsat-7 ETM and Landsat-8 OLI

SENSOR	Constant 1-K1 (Wm-2sr -1µm)	Constant 2-K2 (Kelvin)
Landsat-7 ETM	666.09	1282.71
Landsat-8 OLI	774.89	1321.08

The next step is used to Conversion of Kelvin to Celsius, The temperatures are estimated in degrees Kelvin, and are then converted to degree Celsius by the equation:

$$TB = T\ (\text{Kelvin})\ -273$$

Stage (3). Calculate (WSVI):

Water supplying vegetation index is an indicator based on the relationship between Normalized Difference Vegetation Index and surface temperature. This method provides an effective method of estimating surface moisture condition by the equation:

$$\text{WSVI} = \text{NDVI}/\text{LST}$$

Stage (4). Spatial analysis and Find a relationship between all previous variables.

Normalized Difference Vegetation Index *(NDVI)*

Generally, the value of NDVI is divided into non-vegetated land and vegetated land. As mentioned before about the value of NDVI, the negative values and zero value represent non-vegetated land while positive values represent vegetated land.
figure (4) shows a decrease in vegetation cover in the study area from 2010 to 2017. The area of vegetation cover in 2017 was (108 km²) which represents (22%) while it was (150 km²) which represents (30%) in 2010 of the total area of the study area. That means the rate of change in vegetation was (28%) from 2010 to 2017. The figure also shows that most of the change in vegetation was concentrated in the west and east of the study area.

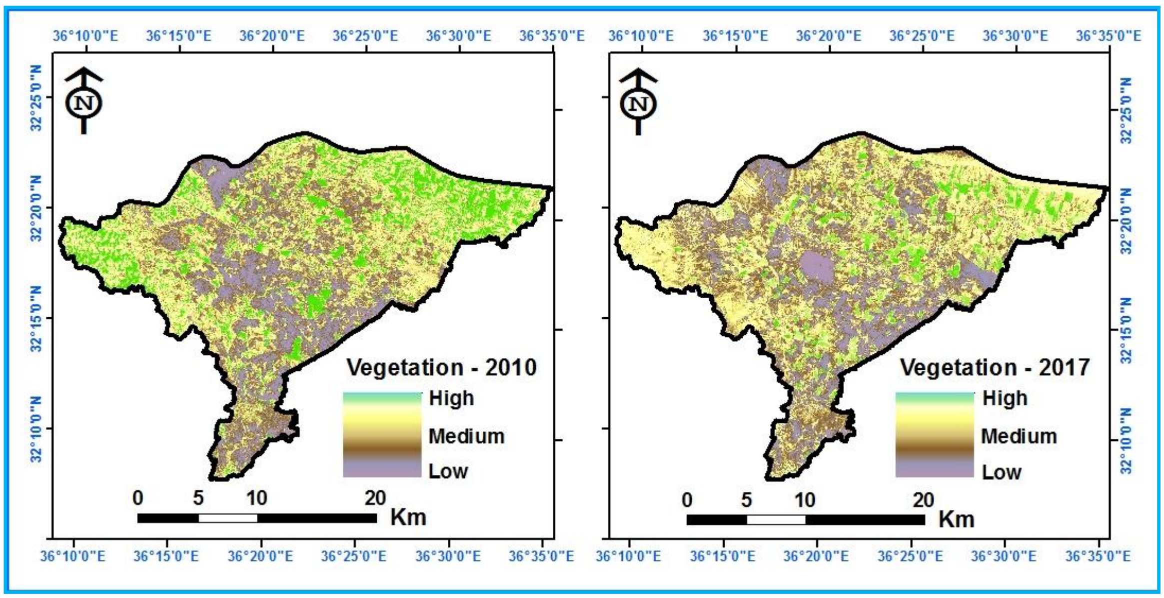

Figure (4). Vegetation in the study area from (2010 – 2017)

The most common measurement is called the Normalized Difference Vegetation Index (NDVI). Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high values indicate temperate and tropical rainforests (0.6 to 0.8), NASA, (2000). In this study, it was found that most of the NDVI values are very low values of NDVI (0.1 and below) corresponding to arid regions of rock and sand according to NASA classification.

Land Surface Temperature *(LST)*

Figure (5) shows the Land Surface Temperature LST in 2010 and 2017, in 2010 LST of the study area ranged between 29° C and 38° C. Where in 2017 LST of the study area ranged between 35° C and 46° C. That means the rate of change in LST was (20%) in high (LST) and (24%) in low (LST) from 2010- 2017. The figure also shows that the increase in temperature was in the same areas where degradation and decline of vegetation.

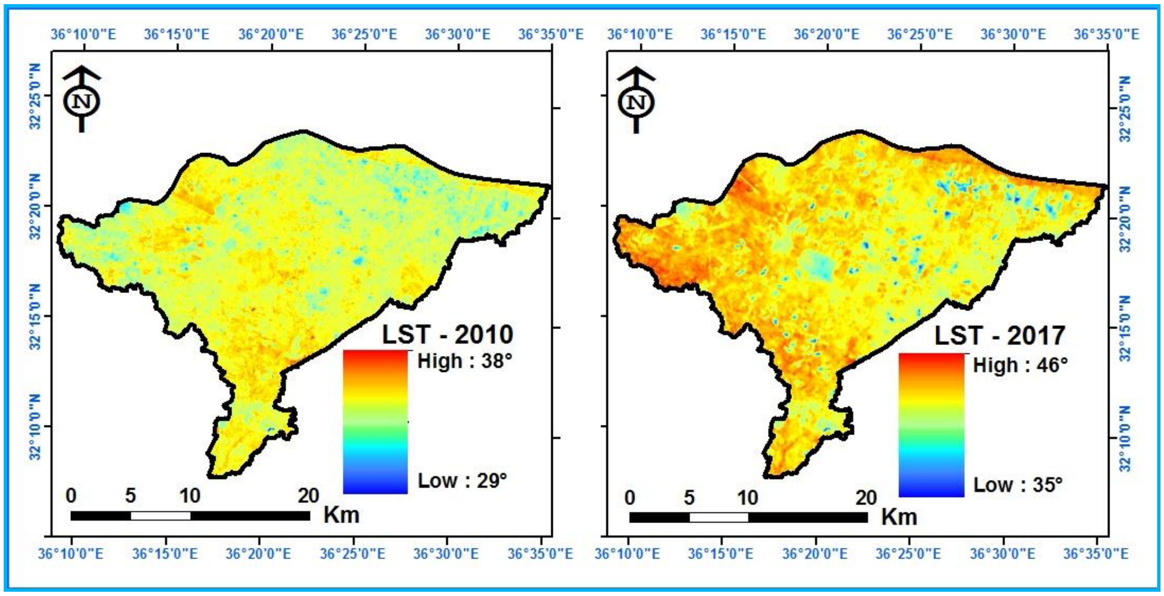

Figure (5). Land Surface Temperature (LST) (2010 – 2017)

Water Supply Vegetation Index *(WSVI)*

Figure (6) show the change of Water Supply Vegetation Index (WSVI) from 2010-2017. The height of (WSVI) in 2010 in the west and the east of the study area, while the exact contrast was in 2017. This is an indication that the region has become drought area due to degradation and decline of vegetation and high temperature.

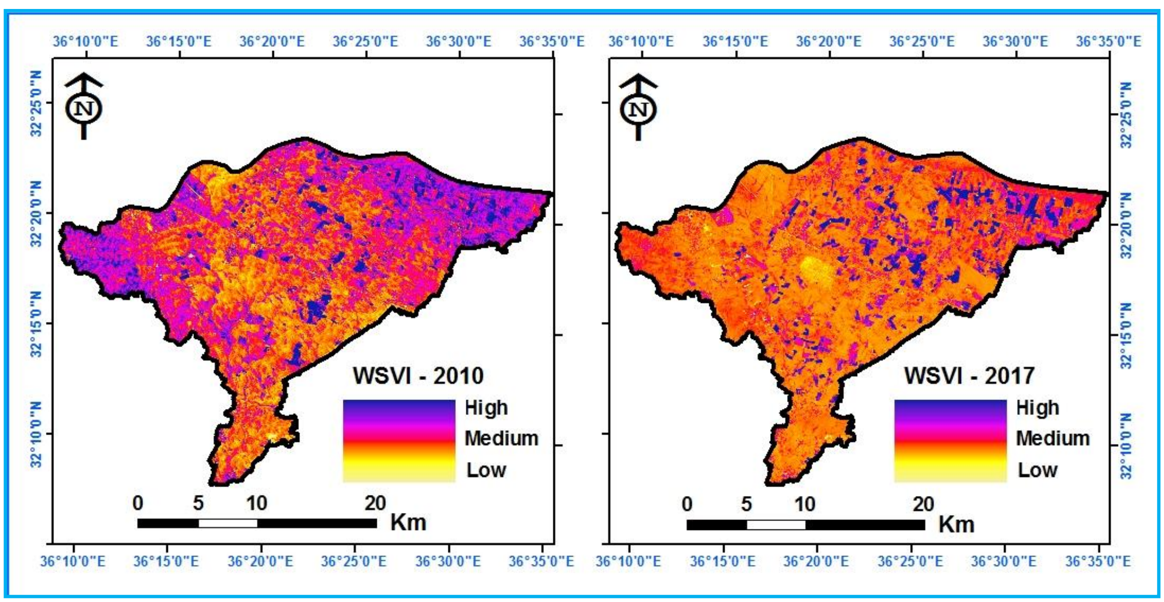

Figure (6). Water Supply Vegetation Index (WSVI) in the study area

Spatial correlation between LST and the other indicators

The correlation coefficient is an equation that is used to examine the relationship between thermal behavior and Other Indicators were used in this study and the strength of this correlation by analysis of data.

Relationship between *LST and NDVI*

The correlation between NDVI and LST are negative, it means that where NDVI is lower have higher LST. Table (3) shows the LST and NDVI values at 24 locations within the study area, these locations were observed on a field by a GPS with geographical coordinates system (degree minute second) and WGS 84 / UTM, in order to find the correlation between the indicators were used in the study area, based on the values of NDVI and LST in the same locations was observed on the study area after adding coordinates of locations on satellite images. The highest LST values were recorded at 38 ° C in 5 different locations in the study area, and the lowest values (negative) of NDVI are (-0.000651, -0.00016, -0.000651, -0.000578, and -0.000721) was located in the same locations that were recorded the highest values of LST. And where NDVI is higher values (0.002218 and 0.002182) has lower LST (28 ° C and **29** ° C. So, the correlation between LST and NDVI is depicted in figure (7), It is shown that the NDVI is negatively correlated with LST, and R^2 = 0.7076.

Table (3) LST and NDVI measurements

EAST	NORTH	LST	NDVI	EAST	NORTH	LST	NDVI
36°16'57.811"	32°19'52.035"	37	-0.00034	36°16'27.553"	32°18'22.374"	38	-0.000651
36°20'30.491"	32°12'29.547"	28	0.002218	36°19'44.708"	32°13'47.489"	38	-0.000578
36°16'12.719"	32°20'22.427"	36	-0.000391	36°21'30.4"	32°17'0.25"	38	-0.000721
36°21'56.316"	32°21'44.523"	31	0.000752	36°12'24.425"	32°18'49.413"	32	-0.00028
36°15'34.919"	32°20'43.783"	38	-0.00016	36°24'50.075"	32°17'51.009"	29	0.002182
36°17'26.503"	32°19'55.653"	33	-0.000458	36°24'52.577"	32°17'51.474"	29	0.002248
36°31'58.811"	32°20'58.4"	33	0.000162	36°24'49.951"	32°17'49.652"	29	0.001970
36°24'55.665"	32°17'52.974"	29	0.001793	36°15'40.841"	32°19'7.94"	30	0.002633
36°9'28.282"	32°18'11.245"	33	-0.000097	36°15'49.411"	32°19'4.633"	29	0.001500
36°24'53.414"	32°17'50.008"	29	0.001832	36°15'43.46"	32°19'11.388"	33	0.001534
36°16'27.553"	32°18'22.374"	38	-0.000651	36°17'25.378"	32°19'52.444"	32	-0.000503

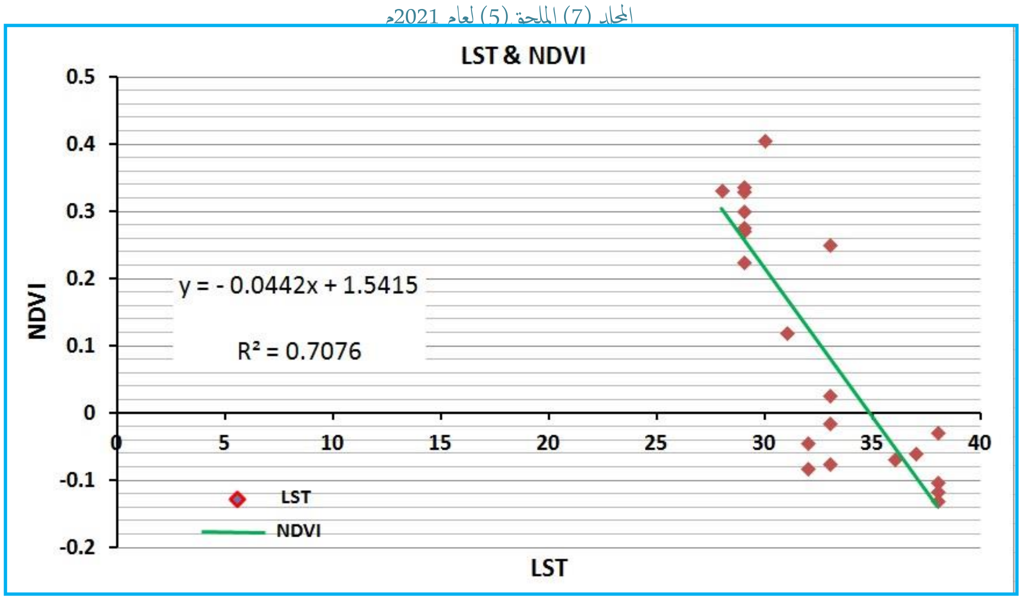

Figure (7). Correlation between LST and NDVI

Relationship between *LST and WSVI*

The correlation between WSVI and LST is negative also, it means that where WSVI is lower has higher LST and where WSVI is higher have lower LST. Table (4) shows the LST& WSVI values at 24 locations within the study area, these locations were observed on a field by a GPS with geographical coordinates system (degree minute second) and WGS 84 / UTM, In order to find the correlation between the indicators were used in the study area, based on the values of WSVI and LST in the same locations was observed on the study area after adding coordinates of locations on satellite images. The highest LST values were recorded at 38 ° C in the study area, and the lowest values (negative) of WSVI were located in the same locations that recorded the highest values of LST. And where WSVI is higher values have lower LST (28 ° C and **29** ° C). So the correlation between LST&WSVI is depicted in figure (8), It is shown that the WSVI is negatively correlated with LST. $R^2 = 0.7017$.

Table (4) LST and WSVI measurements

EAST	NORTH	LST	WSVI	EAST	NORTH	LST	WSVI
36°16'57.811"	32°19'52.035"	37	-0.00034	36°16'27.553"	32°18'22.374"	38	-0.000651
36°20'30.491"	32°12'29.547"	28	0.002218	36°19'44.708"	32°13'47.489"	38	-0.000578
36°16'12.719"	32°20'22.427"	36	-0.000391	36°21'30.4"	32°17'0.25"	38	-0.000721
36°21'56.316"	32°21'44.523"	31	0.000752	36°12'24.425"	32°18'49.413"	32	-0.00028
36°15'34.919"	32°20'43.783"	38	-0.00016	36°24'50.075"	32°17'51.009"	29	0.002182
36°17'26.503"	32°19'55.653"	33	-0.000458	36°24'52.577"	32°17'51.474"	29	0.002248
36°31'58.811"	32°20'58.4"	33	0.000162	36°24'49.951"	32°17'49.652"	29	0.001970
36°24'55.665"	32°17'52.974"	29	0.001793	36°15'40.841"	32°19'7.94"	30	0.002633
36°9'28.282"	32°18'11.245"	33	-0.000097	36°15'49.411"	32°19'4.633"	29	0.001500
36°24'53.414"	32°17'50.008"	29	0.001832	36°15'43.46"	32°19'11.388"	33	0.001534
36°16'27.553"	32°18'22.374"	38	-0.000651	36°17'25.378"	32°19'52.444"	32	-0.000503

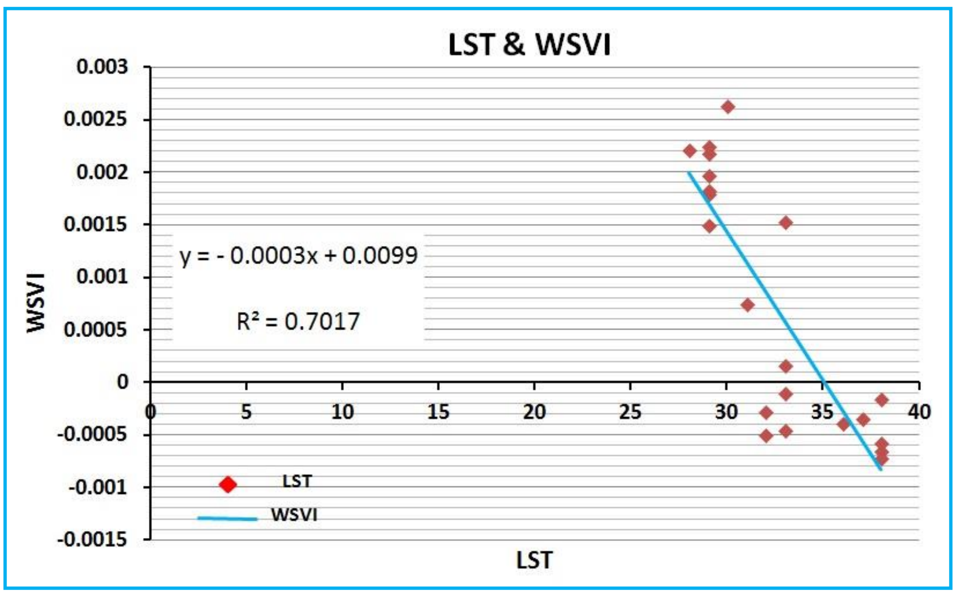

Figure (8). Correlation between LST and WSVI

Table (5). The results of Correlation between the previous indicators

	LST&NDVI	LST&WSVI
R	-0.8412	-0.8376
R^2	0.7076	0.7017
Correlation	Negative	Negative

Based on the above analysis in this study, we came to the following conclusion.

1. Space technology is one of the most important methods for continuous monitoring and understanding trajectories of change on the earth's surface.
2. Three indices were employed in order to change detection and understand the Spatio-temporal distribution of drought in order to understand the most affected areas.
3. The analysis showed a negative change in most of the study area.
4. (28%) decrease in vegetation cover from (2010 to 2017).
5. (20%) increase in high (LST) and (24%) in low (LST).
6. Decrease in Water Supply Vegetation Index from.

Recommendations

Time series analysis for drought monitoring is recommended in order to warnings of timely to the farmers.

Results of this study can contribute to monitoring the onset of drought as an early warning system.

Policymakers in Jordan are invited to investigate and assess drought regions through space technology applications in Royal Jordanian Geographical Center (RJGC).

References

1. Akhtari, R. Bandarabadi, B. (2008). Spatio temporal patterns of drought in North East of Iran.
2. Albert, J. Peters, Elizabeth A. WalterShea, Lel J.I., Andres Vliia, Mlchael Hayes, Mark, D. Svoboda, (2002). Drought monitoring with NDVI-based standardized vegetation index.
3. Anja Klisch And Clement Atzberger, (2016). Operational Drought Monitoring In Kenya Using MODIS NDVI Time Series.
4. Asian Development Bank, (2014). Space technology and Geographic Information Systems Applications in Asian Development Bank projects. Mandaluyong City, Philippines: Asian Development Bank

5. Brian Wardlow, (2009). Remote Sensing and Drought Monitoring An Overview, Options for Mali, and Future Directions.

6. Hatfield J.L., Gitelson A.A. and Schepers J.S, (2008). Application of spectral remote sensing for agronomic decisions. Agronomy J. 100:117 - S-131.

7. Heim, R.R., Jr. A review of twentieth-century drought indices used in the United States. B Am. Meteorol. Soc. 2002, 83, 1149–1165.

8. Joshua John Henik, (2012). Utilizing NDVI and remote sensing data to identify spatial variability in plant stress as influenced by management. Iowa State University.

9. Luke, J. Wersinger, J. Jianshen, S. Kopalle, D. (2001). Remote sensing applications from the Alabama Space Program

10. Murad, H. Islam, S. (2011). Drought assessment using remote sensing and GIS in North-West region of Bangladesh. 3rd International Conference on Water and Flood Management (ICWFM).

11. NASA. (2000). Measuring Vegetation (NDVI&EVI).

12. Prata, A. J., Caselles, V., Coll, C., Sobrino, J. A., ., & Ottlé, C. (1995). Thermal remote sensing of land surface temperature from satellites: Current status and future prospects.

13. Pinter Jr. P.J., Hatfield J.L., Schepers J.S., Barnes E.M., Moran M.S., Daughtry C.S.T., and Upchurch D.R. (2003). Remote sensing for crop management. Photogrammetric Engineering and Remote Sensing. 69:647 664.

14. Rouse, J. W., Haas, R. H., Schell, J. A., & Deering, D. W. (1973). Monitoring vegetation systems in the great plains with ERTS.

15. Sobrino, J.A.; Jiménez-Muñoz, J.C. Minimum configuration of thermal infrared bands for land surface temperature and emissivity estimation in the context of potential future missions. Remote Sens. Environ. 2014, 148, 158–167

16. Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of the Environment, 8, 127-150.

17. Xijie LV. (2013). Remote Sensing, Normalized Difference Vegetation Index (Ndvi), And Crop Yield Forecasting.