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Estimation Land Surface Temperature & NDVI from Landsat-9 Thermal Infrared Data Using Single Window algorithm Method of Al- khoms District, Libya

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Abstract

Estimation Land Surface Temperature (LST) from Landsat satellite imageries has been shown to be a very effective in the estimation of environmental protection, ecology, and climatic models. Land Satellite (LANDSAT) Data has given more direction using techniques of remote sensing and Geographic Information System (GIS) to study the land processes. This research work was intended to evaluate the LST and the associated land cover parameters viz; land surface emissivity (LSE), Brightness Temperature (BT), and normalized difference vegetation index (NDVI). The study focused on the estimation of LST with NDVI over district Al-Khoms, Libya, using the means of remote sensing and GIS techniques (Raster functions and Raster calculation).The used data acquired from LANDSAT 9 satellite data on May 2020, thermal Bands (10 & 11) . Several algorithms have been suggested to extract LSTs from Thermal Infrared (TIR) data using different band configurations. These algorithms can be roughly classified into four types: single- window, split-window, multichannel, and machine learning methods. The results of this study presented that surface temperature was high in the barren areas while it was low in the vegetation cover areas. As the Single Window algorithm uses both OLI and TIRS bands, the results are feasible to calculate NDVI, LSE, TB and LST with appropriate accuracy of the study area..

الملخص :

لقد ثبت أن تقدير درجة حرارة سطح الأرض من صور الأقمار الصناعية (لاندسات) فعال في تقدير حماية البيئة والأنظمة البيئية والنماذج المناخية. وقد أعطت بيانات أقمار لاندسات مزيدًا من الطرق باستخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية لدراسة التفاعلات التي تحدث على الأرض. الهدف من هذا البحث هو تقييم درجة حرارة سطح الأرض ومعايير الغطاء الأرضي المرتبطة بها والمتمثلة في؛ قدرة سطح الأرض على انبعاث الطاقة الحرارية، درجة حرارة السطوع أو الاشعاع الذي يصدره جسم ما ومؤشر الفرق النباتي القياسي. ركزت الدراسة على تقدير درجة حرارة سطح الأرض مع مؤشر الفرق النباتي في منطقة الخمس، ليبيا، باستخدام وسائل الاستشعار عن بعد وتقنيات نظم المعلومات الجغرافية (تعديل الصور وتنفيذ العمليات الرياضية). تم الحصول على البيانات المستخدمة من بيانات قمر لاندسات 9 الصناعي في مايو 2020، النطاقات الحرارية (10 و11). تم اقتراح العديد من الخوارزميات لاستخراج درجات حرارة سطح الأرض من بيانات الأشعة تحت الحمراء الحرارية باستخدام تكوينات نطاق مختلفة. يمكن تصنيف هذه الخوارزميات إلى أربعة أنواع: خوارزمية النافذة الواحدة (الوصول الى بيانات متعددة من خلال نقطة واحدة)، وخوارزمية النافذة المقسمة (تستخدم لتحسين سهولة الاستخدام)، وخوارزمية القنوات المتعددة (لجمع البيانات من مصادر متعددة)، وخوارزمية طرق تعلم الالة (أساليب وتقنيات مختلفة للتعلم). أظهرت نتائج هذه الدراسة ارتفاع درجة حرارة السطح في المناطق القاحلة وانخفاضها في مناطق الغطاء النباتي. ونظرًا لاستخدام خوارزمية النافذة الواحدة، فإن النتائج قابلة للتطبيق لحساب مؤشر الغطاء النباتي ومؤشر الانبعاث ومؤشر السطوع ومؤشر درجة حرارة سطح الأرض بدقة مناسبة لمنطقة الدراسة.

1. INTRODUCTION

At a global and regional level, remote sensing and GIS techniques offer a distinctive approach to acquiring information on Land surface temperature (LST), land surface emissivity (LSE), and normalized difference vegetation index (NDVI) [1]. LST is the temperature of earth crust through the process of absorption, reflection and refraction of the radiation from the sun. Past studies has revealed that LST plays a crucial role in a broad range of scientific investigations, including those related to the environment and global change. The importance of LST is being increasingly acknowledged, as changes in temperature have a significant impact on various alterations occurring on the Earth's surface[2]. It is a key parameter for calculating highest and lowest temperature of a specific area. Medium spatial resolution data, such as that from the LANDSAT 9 and SPOT are suitable for land cover or vegetation mapping at regional local scale. Landsat 8 & 9 Thermal Infrared Sensor (TIRS) produced by the US Geological Survey as geographically tagged image file format (GeoTIFF).

LANDSAT 8 & 9 data was successfully launched on 6 May 2020, and organized into orbit with two sensors; (1) the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). OLI collects data at a 30m spatial resolution with nine spectral bands located in the visible (VIS), near infrared (NIR), and the shortwave infrared (SWIR) spectral regions. (2) TIRS senses the TIR radiance at a spatial resolution of 100m with two spectrally adjacent thermal bands (band 10 and band 11) with thermal characteristics[3]. Various algorithms have been improved to extract LST from Landsat 8 & 9 data. Single-channel methods and split window methods are among the commonly employed algorithms for obtaining LST from satellite TIRS data [4] . Due to the greater calibration uncertainty associated with band 11, the study used band 10 data for the single-channel algorithm. More information about Landsat program can be found on the web of http://landsat.gsfc.nasa.gov

Eldeeb, Abdelatif (2020) “Estimation of Land Surface Temperature of Al-Jfara District, Libya using [1]
Landsat 8 TIRS & OLI data”, The Forth International Conference for Geospatial Technologies – Libya GeoTec 4, Tripoli, Libya, 3 – 5 March 2020

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2. STUDY AREA

The district of Al Khoms is geographically located in the northwest area of Libya, bordering the Mediterranean Sea. It lies between 32° 39' 3.4236" N latitude and 14° 16' 4.4364" E longitude, covering a total area of approximately 1197 km2. It is located about 120 km (74.5 mi) east of Tripoli along the coast and has an estimated population of around 202,000. The elevation of Al Khoms is approximately 16.811 m above mean sea level. (Figure 1 shows the study area).

3. OBJECTIVE

The objective of the study is to estimate LST using the NDVI through the following steps:

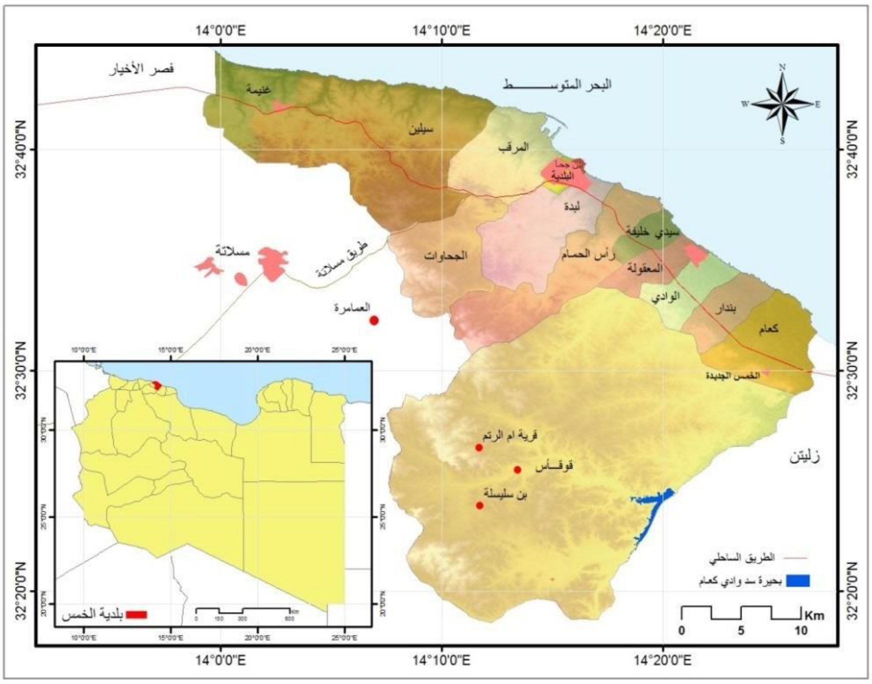
1- Calculate Normalized Difference Vegetation Index.

2- Convert TIRS band data to TOA spectral radiance.

3- Calculate Atmosphere Brightness Temperature using the TIR data.

4- Estimate the land surface emissivity using either a single- channel or split-window method.

Fig-1



5- Estimate LST using BTand the estimated land surface emissivity.

7- Calculate the area for different temperature ranges.

4. MATERIALS AND METHODS

4.1 Data Used

Landsat 9 belongs to the series of Landsat satellites operated by NASA (National Aeronautics and Space Administration). The data of Landsat 9 is available in USGS (United States Geological Survey) Earth Explorer website at free of cost. Satellite data over Al Khoms region of May 2020 has been acquired in this study. Several algorithms have been developed to extract LST from Landsat 9 data. The study was used single-channel method to retrieve LST from satellite TIRS data. TIRS band 10 was used to estimate brightness temperature and bands 4 and 5 were used to create Emissivity and NDVI of the study area. Landsat 9 runs metadata of the bands (thermal constant, rescaling factor value etc.), which can be used for computing such as LST. Bands, Wavelength and Resolution of Landsat 9 are as shown in Table-1

***Table 1: Band properties of Landsat** 9*

Bands	**Wavelength (micrometers)**	**Resolution (meters)**
Band 1 – Ultra Blue (coastal/aerosol)	0.435 – 0.451	30
Band 2 - Blue	0.452 – 0.512	30
Band 3 - Green	0.533 – 0.590	30
Band 4 - Red	0.636 – 0.673	
Band 5 - Near Infrared (NIR)	0.851 - 0.879	15
Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
Band 8 - Panchromatic	0.503 - 0.676	30
Band 9 - Cirrus	1.363 - 1.384	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	30
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	30

The USGS provides data in the GeoTIFF with Metadata format. Following file that ends with "_MTL.TXT" were used for calculation;

• Radiance Add Band 10 = 0.10000

• Radiance Mult Band_10 = 0.0003342

• K1 Constant band 10 = 774.8853 • K2 Constant Band 10 = 1321.0789

4.2 Software's Used: Arc GIS Version 10.8

4.3 Methodology

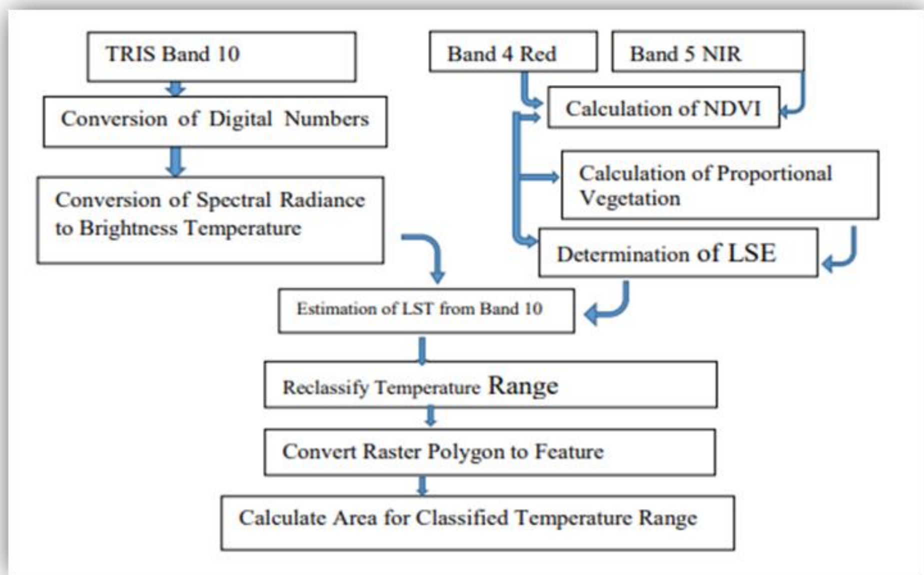


Fig – 2: Flowchart

4.3.1 PROSSES

i. Top of Atmosphere (TOA) Radiance: The initial stage involves converting the DNs to radiance using rescaling factors[5].

$L\lambda = ML * Qcal + AL$ (1)

Tania Kleynhans, Aaron Gerace, Matthew Montanaro, Christopher Kanan. (2017) Predicting Top-of- [5] Atmosphere Thermal Radiance Using MERRA-2 Atmospheric Data with Deep Learning

Where Lλ is the TOA spectral radiance (Watts/ (m2 * sr * μm)), ML is the Radiance multiplicative Band (No.), Qcal is the Quantized and calibrated standard product pixel values (DN), and AL is the Radiance Add Band (No.)

ii. Top of Atmosphere (TOA) Brightness Temperature: Using the thermal constant values provided in Meta data file, the Top of Atmosphere (TOA) brightness temperature can be derived by converting spectral radiance [6].

$$BT = K2 / \ln (k1 / L\lambda + 1) - 272.15$$

Where BT is the Top of atmosphere brightness temperature (°C), Lλ is the TOA spectral radiance (Watts / (m2 * sr * μm)), K1 is the K1 Constant Band, and K2 is the K2 Constant Band.

Iii: Normalized Differential Vegetation Index (NDVI). NDVI is calculated with the following expression: NDVI = (NIR-Red) / (NIR+Red) (3) Where RED is the DN values from the RED band, NIR is the DN values from Near-Infrared band [7].

iv: Land Surface Emissivity (LSE): LSE is the average emissivity of an element of the surface of the Earth calculated from NDVI values [8].

$$PV = [(NDVI - NDVI\ min) / (NDVI\ max + NDVI\ min)]^2$$

Where PV is the proportion of vegetation, NDVI is the DN values from NDVI Image, NDVI min is the minimum DN values from NDVI Image, and NDVI max is the maximum DN values from NDVI Image.

$$E = 0.004 * PV + 0.986$$

Where E is the Land Surface Emissivity, and PV is the proportion of vegetation.

[6] Oguz, H. (2016a) Automated Land Surface Temperature Retrieval from Landsat 8 Satellite Imagery: A Case Study of Kahramanmaras – Turkey. In R. Efe, I. Curebal, A. Gad & B. Toth (Eds.), Environmental Sustainability and Landscape Management (pp. 598- 604). St. Kliment Ohridski University Press, Sofia.

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v: Land Surface Temperature (LST): LST is the radioactive temperature, which calculated using Top of atmosphere brightness temperature, Wavelength of emitted radiance and LSE [9]. LST = (BT / 1) + W * (BT / 14380) * ln (E)

Where BT is the Top of atmosphere brightness temperature (°C), W is the Wavelength of emitted radiance, and E is the Land Surface Emissivity [10].

5. RESULT AND DISCUSSIONS

NDVI maps identify areas of green space in urban areas. They are useful for a wide range of applications, including monitoring vegetation growth and health, detecting changes in land cover, and assessing the impact of environmental factors such as climate change. The findings of this study have shown that the NDVI value ranged between -0.21 to 0.55. They were lower in the mid dry season as well as in the proportion of vegetation (PV) . (see Figure 3, 4).

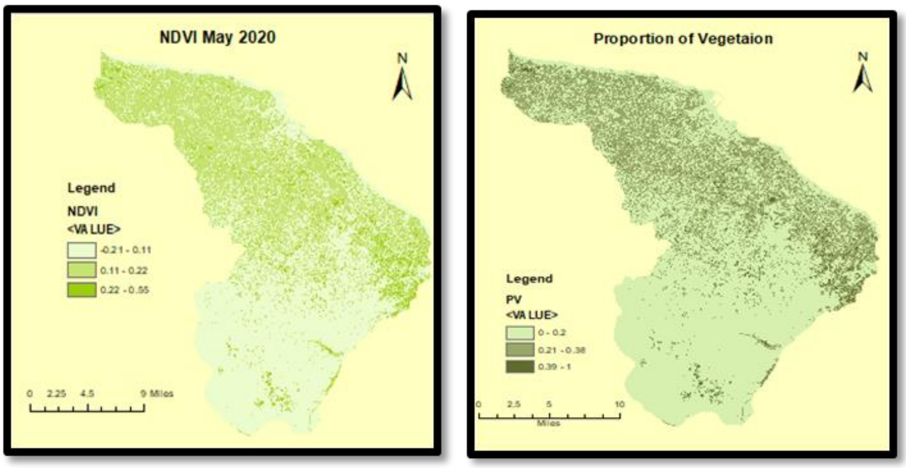

Fig – 3 & 4

Brightness temperature (BT) map is used to represent the temperature of the Earth's surface that measured by remote sensing platforms. It is typically derived from TIR data acquired by Landsat 9. BT map can be displayed using a color scale, where warmer temperatures are represented by orange colors and cooler temperatures by

[9] Zhao-Liang, L.; François, P.; Renhua, Z. A physically based algorithm for land surface emissivity retrieval from combined mid-infrared and thermal infrared data. Sci. China Ser. E Technol. Sci. 2000, 43, 23–33

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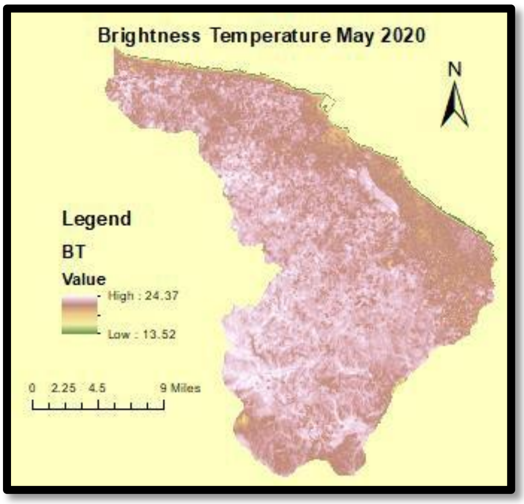
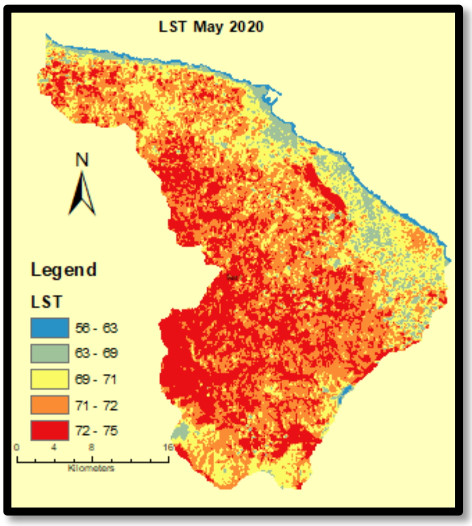


Fig – 5

green colors. However, to obtain accurate temperature measurements, we need to be corrected for atmospheric effects such as water vapor and aerosols. The BT map in the study area shows that the temperature value ranges between 22.74 to 37.89 °C as explain in Fig-5.

LST map is typically displayed as a map where each pixel represents the temperature of a small area on the Earth's surface. The temperature range is usually displayed using a color scale, where warmer temperatures are represented by red colors and cooler temperatures by blue as shown in fig-7.

Land surface map has been derived using brightness temperature and LSE. LST



Fig– 6

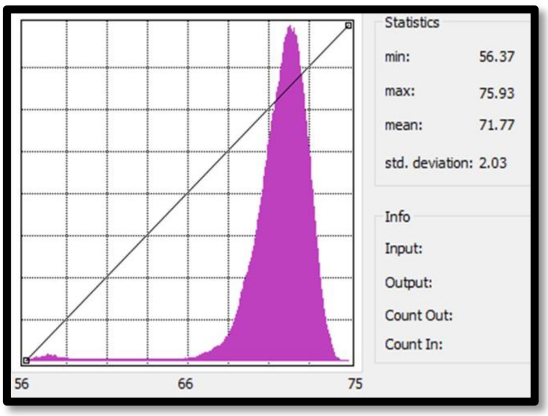


Fig – 7 Histogram of LST

temperature ranges and areas are shown Fig-6-7 and table 2 .

Table-2

S. No	Temperature (°C)	Area (Sq.km)	Percentage (%)
1	56-63	11.59	1.2
2	63-69	62.23	6.4
3	69-71	226.31	23.55
4	71-72	377.47	39.28
5	72-75	283.26	29.47

6. CONCLUSION

In this study, Single Window algorithm that uses the ensemble learning method with Landsat-9 TIR data to accurately estimate LST without the need for external input parameters. NDVI, BT, LSE, and LST of an area were derived using Arc GIS software. NDVI Map illustrate that vegetation is low in the dry season. The findings of this study have practical applications in urban planning and can provide guidance to urban planners and decision-makers on the importance of preserving and promoting urban green spaces. In addition, the land surface temperature (LST) results could be used to better understand spatial variation in temperature of the study area. This will allow city planners to incorporate sustainable measures to reduce the Urban Heat Island effec

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