Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 13, Issue 1, January 2022: 2155-2165

Application of thermal remote sensing and GIS for LST monitoring of Laghman Province

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Abstract

Remote sensing is a science that collect and interprets the information regarding an object which has been located remotely. Thermal RS and GIS permit us to collect and analyse the land surface temperature. The LST is a major sign of the energy stability at the land surface, and measurements of LST are essential for lots of meteorological, hydrological, and biogeochemical investigations. This paper describes the technique in order to regain the LST from Landsat-8-OLI/TIR Thermal Infrared sensor (TIR) of Laghman province 06th Aug 2017 and 03rd Aug 2019 and compare its result with each other. The consequence explains some increases in urban areas as well as differences at LST in the area. The virtue of this study display that no similar study was accomplished to determine the LST changes, in Laghman province. The result has described that Max and Min temperature was found (-4.6 C and 37.68 C) at 6th Aug-2017 and (2.03 C and 38.05C) at 3th Aug-2019 respectively. In 6th Aug-2017 the Max Temperature is (0.37 C) lower than the Max Temperature in 03th Aug-2019, and at the same time, the Min Temperature is (6.635C) lower, which shows fast worming during two years in the mentioned area. This method is an efficient way to calculate the LST of remote areas where aren't gourd monitoring stations.

Keyword: Landsat_8, Laghman, Land Surface Temperature, Remote sensing monitoring, NDVI.

Introduction

Remote sensing is the science for collecting and interpreting information on targets (object or areas) without being in physical contact with them, it employs electromagnetic energy in the form of radio waves, light, and heat as a means of detecting and measuring target characteristics. RS gathers information about the earth form a distance usually from a variety of platforms, such us satellites, airplanes, remotely piloted vehicles, held-hand radiometers or bucket trucks. They have dissimilar devices, counting sensors, film and digital cameras and video recorders (Shanmugapriya. P et al, 2019) Recently RS has extended from an experimental to an operational stage. Rise of earth observation satellites, new developed tools and techniques, and using of data for new applications has been incredible, (Mahmoodi.S, 2019). . It also applicable for considerate the spatiotermporal land cover changes respected to the basic features in terms of the surface radiance and emissivity data,(Orhan. Osman et al, 2014).

Thermal remote sensing (TIR)is a branch of RS which discuss with the acquisition, processing and interpretation of data attained mainly in the thermal infrared area of the electromagnetic spectrum. The TIR measure the radiations 'send out' from the surface of the object, as it is different to optical RS. (Prakash, 2000). LST is an important factor in earth surface processes, mostly to know the energy exchange balance among the Earth and the atmosphere on any scale (regional and global). Hence, knowing and monitoring the dynamics of LST and its relation to human-induced changes are serious for modelling and expecting environmental changes, (Wubet, 2003; Ilyas, 2019). Estimate of LST from RS data is applicable on the world, new satellites TIR data appropriate for studying urban thermal environment are designated by high spatial variability including Landsat TM, ETM+, and ASTER have good temporal resolution. Recently some of TIR sensors can offer LST measurement at high spatial resolution; due to low temporal resolution their use in urban climate studies is limited because of no image data at night time (Weng et al, 2014).

Air temperature is the first descriptor terrestrial environmental conditions on the earth and is involved in many significant ecological process such as actual and potential evapotranspiration, radiation or species distribution. As per many research in the global, experts have assumed that the Land surface air temperature is raised at almost 0.6 C in the 20th century and the increase of temperature was highest in 1990s (Rahachandra, 2012). The annual temperature rising is higher in Afghanistan, based on available climate data and regional climate model which's developed in 2016, Under the optimistic (RCP 4.5) scenario shown, Afghanistan displays a trend of heating up 1.5 C up to 2050, monitored by a period of stability and will increase around 2.5 C up to 2100. In the same time (RCP8.5) scenario shown most warming 3C up to 2050 and 7 C up to 2100. Based on both scenarios there is regional changes with higher temperature increases based on altitude; in the central highland and Hindukush, heating among 2010 up to 2050 will be at interval between 1.5 C to 1.7 C; matched to the base period 1976-2005, whereas in the low land the growth range is 1.1C to 1.4 C, (NEPA, 2017). .

The main objective of this paper is to describe the technique for LST analysis on the data from Landsat-8 of 06 Aug 2017 and 03th Feb 2019, in Laghman province and LST changes monitoring during 3 years. We consider that the service described in the article would be highly valuable for those who is teaching and studying the land thermal environment using Landsat images and the student which involved in meteorology field.

Study area:

The Study area for LST monitoring has designated Laghman province. Laghman province is located between (LAT, $34^o 31^ι N$) and ($LANG, 69^o 12^ι E$) at altitude of 772 m above the sea level (Figure 2). It is surrounded by Koner province to east, Kapisa and Kabul provinces to west and Noristan and Panjsher provinces to north and Nangarhar province to south. Laghman province contains of several land covers containing water, developed urban, barren land forest, shrub land, cultivated area, roads, building, high mountains, and divided on five districts. Laghnan province with high mountain area, has arid climate with a dry summer and snowy winter on the mountain portion. In 1964.

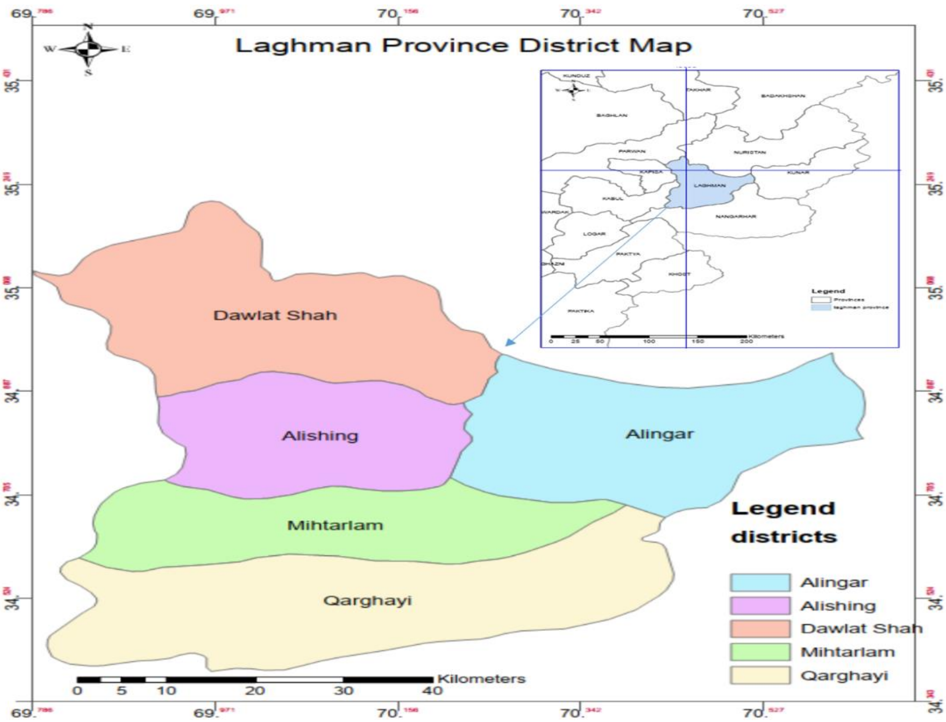


Figure 1. Study area, Laghman Province.

Input Data

The contribution data set of this article contains satellite data of three different years; In this article, we exploit three images of landsat-8 OLI/TIR at 6^{th} August 2017 and 03th August 2019, which cover the study area to expedite evaluation of LST. The images are in Geo-Tiff format and downloaded from USGS site, the could cover area of images include 0.2%, and 2.58% respectively**.**

Methodology

Laghman the eastern province of Afghanistan is divided on 5 districts. this study covers (Qarghayi, Mihtarlam, Alishing, Alingar and Dawlat shah districts). Dawlat shah, Alishing and Alingare districts located in mountain area but the other two districts have low land and most of agricultural area. In order to obtain and compare the LST of this mountain area though remote sensing data, the split window method has selected, therefore it his required to apply the below methodology step by step at all images:

I. Atmospharic correction: Satellite data pre-proccessing contain of radiometric calibration atmospheric correction TM/ETM bans 3 and 4 (Serban Cristina, Maftei Carmen, 2011)**.** Correction of Top of Atmosphere (ToA) in infrared band 10 and band 11 of landsat-8 TIR, band-6 in landsat-7 ETM+ and Landsat- OLI in multi-band in order to decrease the errors of energy reflected from target on the land surfaces to the sensor when getting the data containing weather topoghrapy, termperature, and angle of incidiency,

$$L_\lambda = M_L \times Q_{cal} + A_L \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where: L_λ, ToA spectral radiance ($\frac{W}{m^2 sr\ \mu m}$). M_L, Band specific multiplicative rescaling factor (Table 1). Q_{cal}, OLI/TIR image bands. A_L, Band specific additive rescaling factor (Table 1).

Table 1. Rescaling Factor, **(** Laosuwan et al,2017; USGS,2019):

Rescaling Factor	Landsat-8 OLI/TIR	
	Band_10	Band_11
$\mathbf{M_L}$	0.0003342	0.0003342
$\mathbf{A_L}$	0.1	0.1

II. Conversion to top atmosphere brightness: TIRS bands data can be changed from spectral radiance to ToA brightness temperature using the thermal constant provided in metadata file, and using below formula to calculate TB for Landsat-8 OLI/TIR band 10 and 11, (Serban Cristina, Maftei Carmen, 2011);

$$TB = \frac{K_2}{\ln(\frac{K_1}{L_\lambda + 1} + 1)} \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Which; K_1 and K_2 are calibration or thermal conversion constants for TIR bands (Table 2), L_λ, is ToA spectral radiance. In case to find the result on Celsius (C), the absolute temp is correcting to add the absolute zero (-273.15), (Laosuwan et al, 2017). ;

$$TB = \left[\frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}\right] - 273.15 \ldots\ldots\ldots(3)$$

Table 2. Thermal constants, (USGS,2019):

Satellite	Thermal Constant	Band Ten	Band Eleven
Landsat-8 OLI.TIR	K1	774.8853	480.8883
	K2	1321.0789	1201.1442

III. NDVI Analyze: Normalized Difference Vegetation Index (NDVI) has obtained from the ratio of variation and subtotal of reflection of visible light band, red band and NIR band from the targets on the ground surfaces. Its outcome is between -1 and +1 which depends to earth surface land use and land cover. The NDVI of water surface is less than zero, Barren land is among zero up to 0.1 and the NDVI the land with plant covered is 0.1, (Laosuwan et al, 2017). . NDVI of this study is determined through equation (4) using landsat-7 ETM visible red (0.63-069µm) and NIR band (0.76-0.9 µm) and equation (8) using landsat-8OLI/TIR visible red (0.64- 0.67µm) and NIR band (0.85-0.88µm) bands, (Orhan et al, 2014);

$$NDVI = \frac{NIR - RED}{NIR + RED} \ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

IV. Fractional Vegetation Cover (FVC): in order to analyze the (FVC) in the area, the NDVI values would be involved in calculation conducted by equation (5) for Landsat_7 ETM+ band six and Landsat_8 OLI/TIR band ten and eleven, (AlSultan Sultan. et al, 2005) ;

$$\mathrm{FVC} = \left(\frac{NDVI - \mathrm{NDVI}_{Min}}{\mathrm{NDVI}_{Max} - \mathrm{NDVI}_{Min}}\right)^2 \ldots\ldots (5)$$

V. Land Surface Emissivity (LSE): The LSE value in study area is analyzed through equation (6) by following the FVC values for Landsat_7 ETM+ band six and Landsat_8 OLI/TIR band ten and eleven;

$$\mathrm{LSE} = \varepsilon_s(1 - \mathrm{FVC}) + \varepsilon_v \times \mathrm{FVC} \ldots\ldots (6)$$

In above equation, ε_s is soil emissivity value and ε_v is vegetation emissivity value of corresponding bands (Table 3),

It can be estimated according to the following equation (7) as well, (Mohamadi. Baha, et al, 2019). ;

$$\mathrm{LSE} = 0.004 \times PVC + 0.986 \ldots\ldots (7)$$

Table 3. Emissivity values, **(** Laosuwan et al,2017; USGS,2019) **:**

LSE	Band Ten	Band Eleven
$\boldsymbol{\varepsilon_s}$	0.971	0.977
$\boldsymbol{\varepsilon_v}$	0.987	0.989

VI. Land Surface Temperature (LST): To obtain the LST of planned area, below formula is applicable;

$$\mathrm{LST} = \frac{TB}{[1 + \left(\lambda \times \frac{TB}{C_2}\right) \times \ln(LSE_{Mean})]} \ldots.\ldots.\ \ldots (8)$$

Where, λ, is wavelength or emitted radiance (Table. 4). $C_2 = h * \frac{c}{s} = 1.4388 * 10^{-2}\ mK = 14388\mu mK$. h, plank's constant$= 6.626 * 10^{-34}\ js$. S, is Boltzmann constant$= 1.38 * 10^{-23}\ j/K$. C, is velocity of light $= 2.988 * 10^{8}\ m/s$, (USGS, 2019):

Table 4. Canter of wavelength (λ) of Landsat bands, **(** Laosuwan et al,2017; USGS,2019)**:**

Satellite	Band	$\boldsymbol{\lambda(\mu m)}$
Landsat_8	10	10.8
Landsat_8	11	12

VII. Usage of GIS for clips of each district form Laghman provice LST image, and analysis of any district statistical partameters such as Min, Max, Mean and Standurd deviation at indicated period.

VIII. Comparson of LST tempertures vulues based on remote sensing data analyzed results in order to determine the changes of LST during three different years.

Work flow Chart:

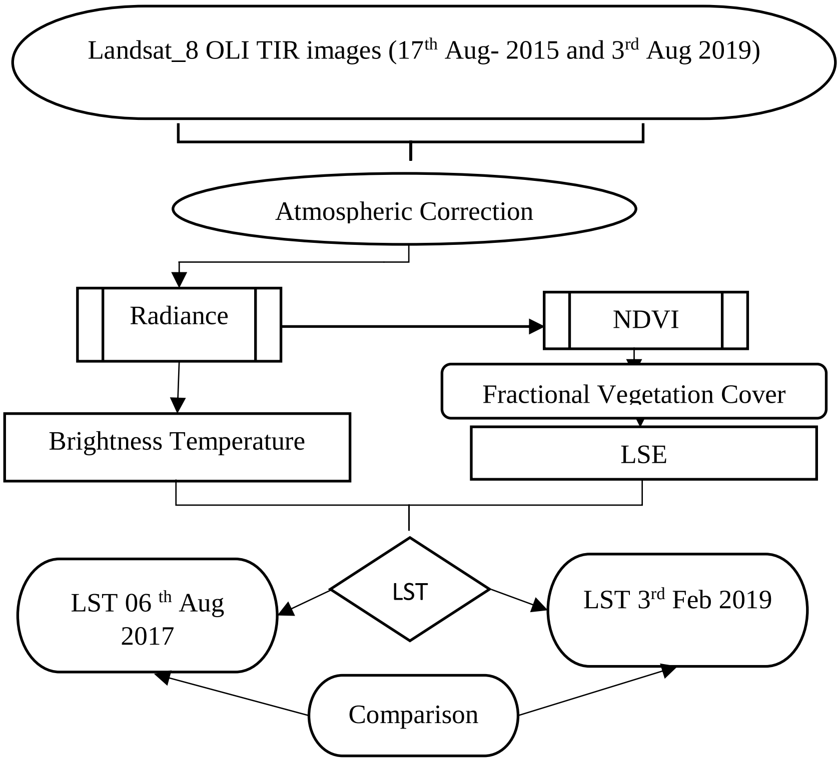
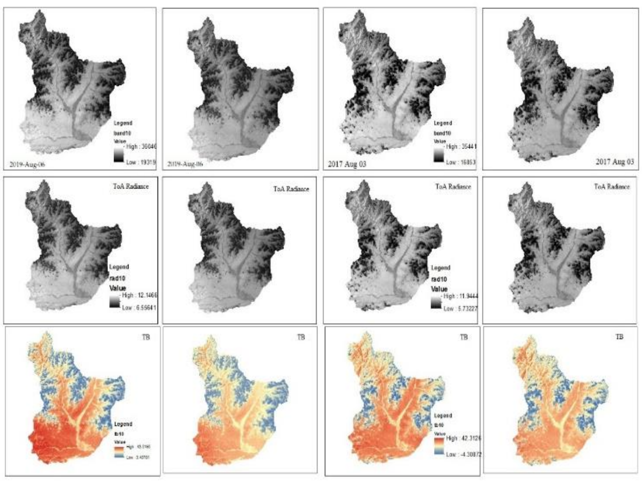


Figure 2. Work Flow chart,

Results and discussion

The outcomes of performed adjusting the value of (ToA) reflectance in bands ten and eleven of landsat_8 TIR, to decrease the errors of the energy coming back from the target on the land surface to the data record sensors surrounding evironement which have shown in (Figure 3).



Figurer 3. Atomospheric corection of Landsat_8 TIR bands of study area at 06th Aug-2017 and 03thAug-2019.

Based on equeations (4,5 and 7) the NDVI, FVC and LSE values are estimated for both landsat images respectivly, the results of NDVI of panned area shown a maximum of 0.54 , a mean of -0.11, a minimum of -0.14 and Std Dev of 0.06 and the results of FVC indicated a maximum of 0.99 and a minimum of $3.90e^{-013}$ and the results of LSE indicated a maximum of 0.99 and a minimum of 0.98 at 06^{th} Aug-2017 and the results of NDVI indicated a maximum of 0.61 , a mean of 0.3, a minimum of -0.18 and Std Dev of 0.02and the results of FVC indicated a maximum of 0.99 and a minimum of 1.073269e014 and the results of LSE indicated a maximum of 0.99 and a minimum of 0.986, Figure 4.

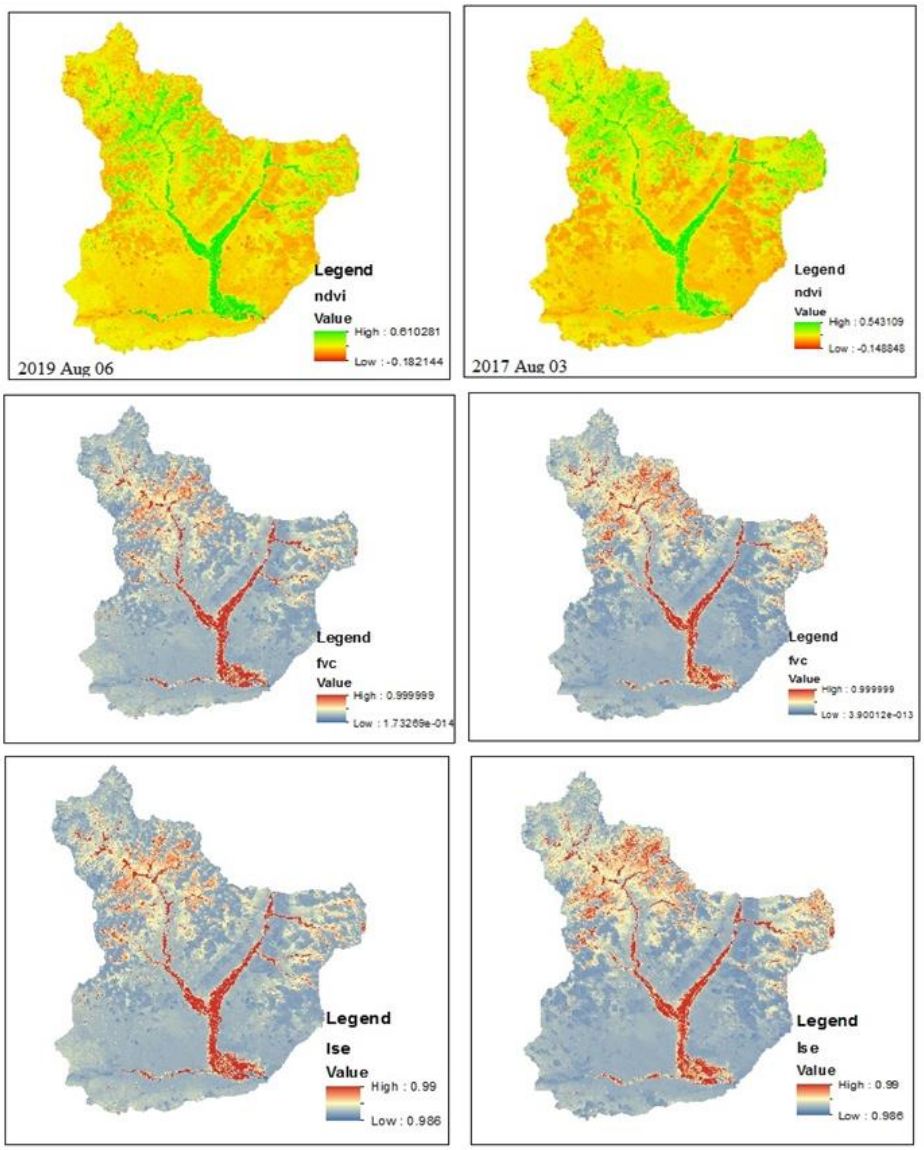


Figure 4. NDVI, FCV and LSE changes from 2000 un till 2015.

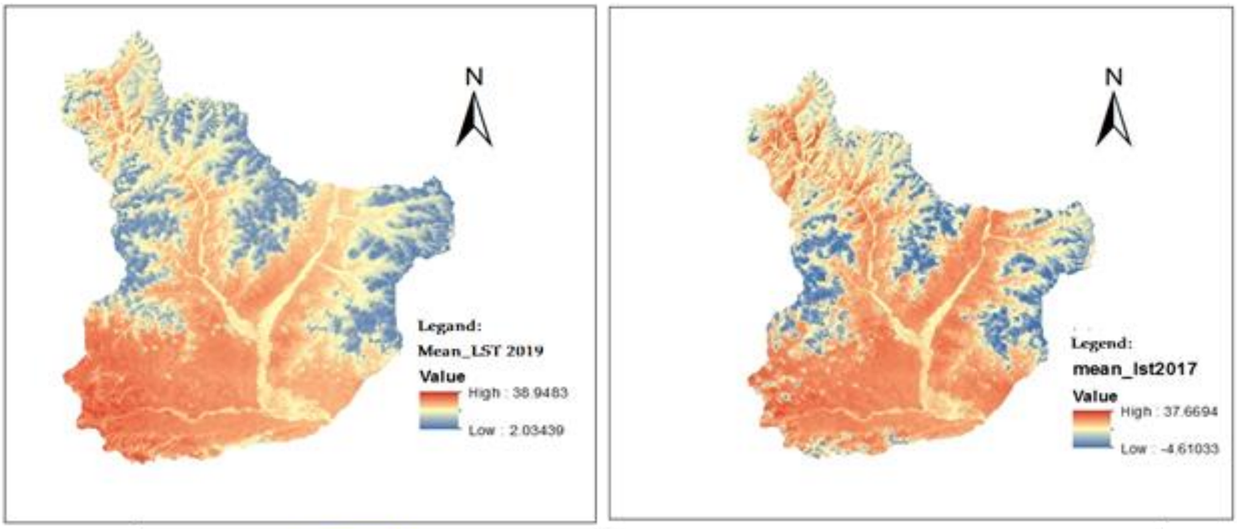


Figure 5. Land Surface Temperature changes from 2017 un-till 2019.

The Analysis of LST has perfomed by split window method which incldues; Culculation of brightness tempretue by equation (2); LST by equation (10) and mean of LST through equation (11), using thermal band of Landsat_8 TIR. And it's results is included in (Figure 5). The statistical paramters of LST is extracted for five involved districts and included in (Table 5), but for all study area is shown in (Figure 6).

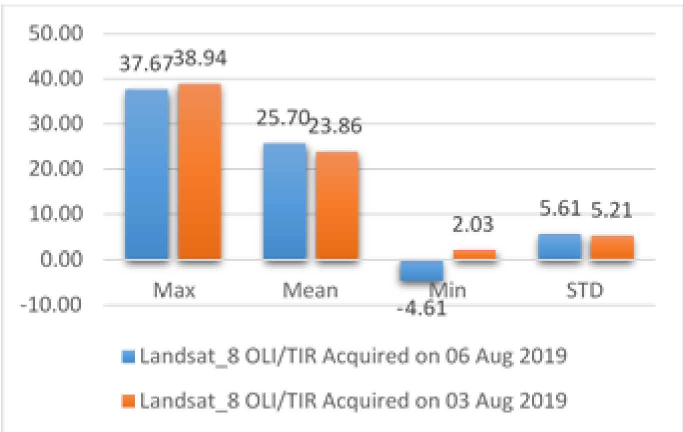


Figure. 6. Statistical parameters of LST at 2017 and 2019.

The Studay area LST results images are clssified according to temperature interval (6C), in order to find the area of specific temperature class at respected date 06th Aug-2017 and 03th Auge 2019, to detertermine the LST variation on the land surface. The LST immages and statistical parameters comparing shows that the LST of Study area have some changes to space and time repctively, i.e in 2017 year, the range of LST is between (-4.6 C and 37.66 C) but it has chaged to (2.03 C and 38.95 C) in 2019. The mean teperature in 2017 is (25.70 C), it is reached to (23.86 C) in 2019 which shows (1.84 C) decreases in 2 years (0.92 C/year) at mentioned date. The results quantities is more differ with the qauntitity mentioned in NEPA report (1.5 C to 1.7C in 30 years), The quantity ot LST changes in Laghman city not meets with global warming mean level in 20th century. Meawhile, statistical comparaing of the area percnetage to its temperature class interval has many alterations to time, Based on five LST classes, one class is depends to nagative temperature under zero degrees and four classes are refer to positive temperature in 2017, but in 2019; all classes area covers posative temperature, (Figures 7).

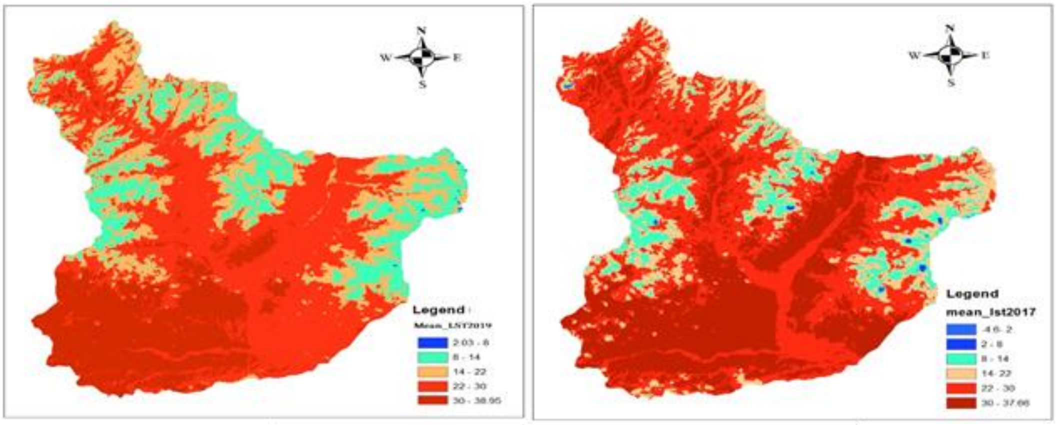


Figure 7. LST classification.

Table 5. The analysis results of LST on district level:

Satellite data	District Name	Max	Mean	Min	STD
Landsat_8 OLI/TIR Acquired on 06 Aug 2017	Qarghayi	37.10	29.39	-2.05	4.16
	Mihterlam	35.51	28.12	11.41	5.16
	Alishing	34.50	22.73	5.25	6.88
	Alingar	33.51	23.66	1.30	6.75
	Dawlat shah	37.67	24.63	-4.61	5.12
Landsat_8 OLI/TIR Acquired on 03 Aug 2019	Qarghayi	38.94	29.39	9.77	3.96
	Mihterlam	35.82	28.02	10.42	4.66
	Alishing	32.29	21.63	7.13	5.53
	Alingar	32.91	20.21	4.98	6.46
	Dawlat shah	35.49	20.07	2.03	5.45

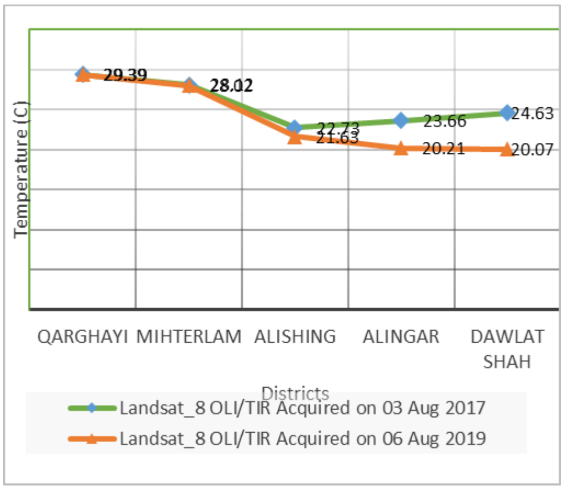


Figure 8. The result of LST on district level

Conclusion

This paper have illustrated the role and technique to retrieve the LST for the data of Landsat_8 OLI/TIR satellite Thermal Infrared bands in Laghman province five districts at 6th Aug-2017 5:55 AM and 3th Aug-2019, 6:00 AM, the statical parameters Max and Min temprature were found (-4.6 C and 37.68 C) at 6th Aug-2017 and (2.03 C and 38.05C) at 3th Aug-2019 respectivly. In 6th Aug-2017 the Maximum Temperature is (0.37 C) lower then the Max Temerature in 03th Aug-2019, and the same time the Min Temperature is (6.635C) lower, which describe fast worming during two years in Laghman province; but visversa the mean LST of 2017 year is higher, this issue depends to the varity of date and mountain area,. The LST changes in Laghman is different to space and time which hinge on to surface elevation, urbanization and population of specific area; by 2017 year, some area, which's relavent to LST class (-4 to 2 C) is availabe (Figure 7), but in 2019 it has elimenated and beside ot that the LST class (30-37C) covers large area in 2017 but in 2019 it cantain small area allocated for low land and large popultion. Base on this analyzsis the LST Statistical parameter values of study area had enormous changes at specified period.

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