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RESEARCH ARTICLE

STUDY OF CLIMATE VARIABILITY OF SARGODHA, PAKISTAN USING SATELLITE DERIVED TEMPORAL LAND SURFACE TEMPERATURE AND ITS COMPARISON WITH GROUND DATA

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ABSTRACT

Sargodha city has a weather of utmost temperature in the summers and calm cold in the winters. Comparative study of Sargodha ground temperature which is the part M. Phil research was initiated by using thermal infrared (TIR), near infrared (VNIR), and detectable bands of Landsat metaphors with ground based instruments being measured by Pakistan Meteorological Department (PMD) to ascertain the variation of results. The validation of remote sensing data was found within ±5°C.The study was conducted to contribute to enhance the scientific evidence about rising of global temperature and increase of deforestation by materialistic inspection. The Landsat data for the month of October of years 2000, 2005, 2011 and 2015 was used and compared with ground station data. The results of the study show that the temperature of the land surface increased gradually from30°C in 2000, to 33°C in 2005 and34°C in 2011, but there was irregular decrease of temperature found in 2015 for the reasons required to be further investigated. The increase of temperature is attributed to the reduction of agricultural land and increase of developed area in Sargodha that lead to disturb the energy balance.

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INTRODUCTION

The application of Remote sensing techniques in climate studies including land and sea surface temperature play pivotal role since early seventies. The remote sensing techniques in climate change are applied to observe the change in average temperature and precipitation of long-term weather that helps to confirm the inference of increase of temperature during last century. Global warming phenomenon has been widely confirmed with this technique. In the present study, remote sensing technique has been used for the weather data of the Sargodha city of Pakistan and results affirmed the belief that global average temperature has increased to 0.76°C during current century (Ghous,2015).The purpose of the study is to trace the relationship of urbanization with climate change by using the periodical Land sat thermal band data of Sargodha, a central Punjab agricultural city of Pakistan to estimate the Land Surface Temperature (LST). Sargodha is confined between 32°3'N to 32° 7'N and 72°38'E to 72°43'E (Figure 1) and worldwide famous for the good quality production of citrus fruits specially oranges.

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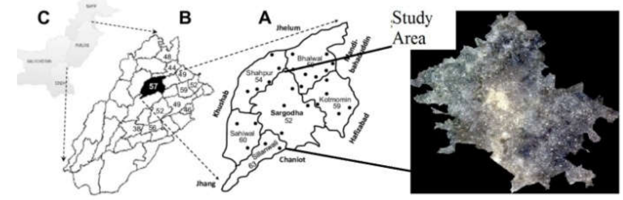

Figure 1. Illustration of study area, A part of Sargodha located in B provice of Punjab C in Pakistan.

With the rise of sun, solar radiation starts heating up the ground and reflected back radiation heats up the air above its. Holmes & Dingle (1965) inferred that as a result of change in rural and urban ratio, macroclimate conditions are affected vertically as compared to horizontally. Single channel algorithm has been recognized very effective for the assessment and mapping of various parameters like LST or forestry. The results of the study conclude that the surface temperature of Sargodha is linearly increasing as in other parts of the world. The satellite derived data for the period 2000 to 2015, show that the mean LST gradually raised from 30°C in 2000, to 33°C in 2005 and further one degree Celsius in 2011 and dropped to 25 °C in 2015. The results further depict that Sargodha is also being affected by the Global Warming phenomenon.

MATERIAL AND METHOD

In order to determine the relationship between urbanization and climate change and estimation of LST, selective Landsat thermal band data for 15 years from 2000 to 2015 was obtained for Sargodha. To attain the resolution of the study, Landsat metaphors acquired for; 20th October 2000, 2nd October 2005, 3rd October 2011 and 6th October 2015.
The month of October for imagery was chosen because it is transitory month with mild temperatures. However, due to bare land cover, the temperature of mountains and soil is relatively higher. LST is computed temperature of the surface of the Earth recorded by the remote sensing instrument installed on Landsat satellite platform by using high climate radiance or transition with single channel algorithm technique as defined by Sun et al (2003) as under;

$$T_S = \gamma I_\varepsilon(\psi_1 L_{sen} + \psi_2) + \psi_3 + \delta$$

as the Landsat satellite series 1-7 have only single channel thermal band. However, in present study, imagery of Landsat-8 are also used that have multichannel thermal bands with in10 to 12 µm wavelength called split window (SW), therefore, for its analysis, the SW algorithm developed by Sobrino et al (2004) as mentioned below was used on ERDAS Imagine 2014 an image analysis software and thematic maps were produced using ESRI ArcGIS 10.3.

$$T_s = T_i C_1(T_i - T_j) + C_2(T_i - T_j)^2 + C_0 + (C_3 + C_4 W)(1-\varepsilon) + (C_5 + C_6 W)\Delta\varepsilon$$

However, before using the SW algorithm, atmospheric correction, instrumental noise, decoupling, top of atmosphere reflectance and comparison of temperature revival from MIR by TIR were sorted out separately as mentioned Munoz & Sobrino, (2003) and Wan et al (1996). Top of atmospheric (TOA) radiance was computed using Coe et al (2003) algorithm reproduced as:

$$L\lambda = \left(\frac{L_{max} - L_{min}}{DN_{max}}\right) * Band + L_{min}$$

Where, Lλ is the top of atmospheric (TOA) Spectral Radiance measured in watts/m^2 sradµm, maximum and minimum spectral radiance of bands are denoted in the above formula as L_{max} and L_{min} respectively. For brightness temperature, TOA is determined using following well known algorithms.

$$T_{B_{10}} = \left\{\frac{K_2}{\ln\left(\frac{\varepsilon K_1}{Irr adianceB_{10}} + 1\right)}\right\} - 272.15$$

$$T_{B_{11}} = \left\{\frac{K_2}{\ln\left(\frac{\varepsilon K_1}{Irr adianceB_{11}} + 1\right)}\right\} - 272.15$$

The relationship between NDVI and LST was established and the materialistic change in temperatures of Sargodha was examine by computing standard deviation. Finally, the results were validated with the ground weather station data of Sargodha for the same 15 years duration obtained from the Pakistan Meteorological Department.

RESULTS AND DISCUSSIONS

The Sargodha located in central Punjab, Pakistan has varying topographic features with exposed hillock known as Kirana (Kazmi, 1964) with a nature of unfossiliferous Precambrian met a sediments and metavolcanics (Naseem & Sohail, 2011).

Table 1.The average statistical values of LST data as computed from imagery

Year	Satellite temperature (^{0}C)		
	Maximum	Minimum	Mean
2000	38	25	30
2005	37	27	33
2011	38	27	32
2015	30	22	24

Table 2.Comparison of the ground and satellite data

Year	Temperature (^{0}C)	
	Ground Observatory	Satellite data
2011	36.1	38
2015	35.5	30

The Kirana hill locks are spread over Sargodha and Chinniot districts and are sporadically covered with wild and invasive mesquite shrubs that has tendency to grow even in shallow soil (Platt, 2015). Sargodha is selected because it represents well populated with agricultural fields that are irrigated with river water through canal network. The complexity of the area made it difficult to describe climatologically. Climate vary due to; incoming short wave solar radiations, temporal change in composition of atmosphere, and change in land surface ratio (Ghous, 2015).Any change in the heat budget of incoming or outgoing radiation cause the changes in the climate. The ground data of Sargodha that was obtained from Pakistan Meteorological Department show that the average high temperature is 42 °C mostly recorded in the month of June whereas, the average low temperature drops to freezing point that is mostly observed during the month of January (Figures 2 & 3).

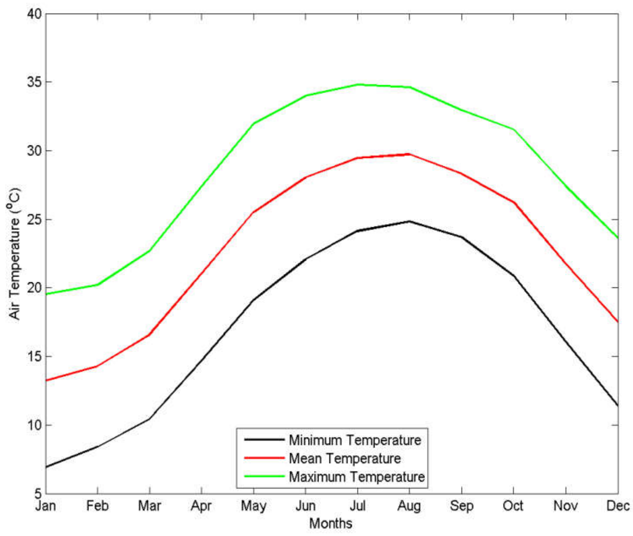

Figure 2 Mean monthly temperature of Sargodha as recorded by PMD.

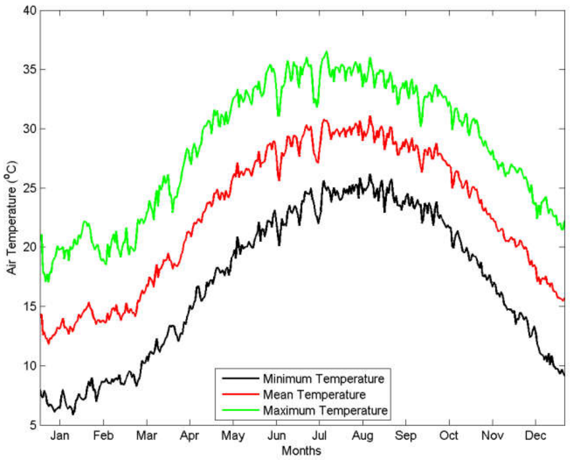

Figure 3.Daily mean temperature of Sargodha as recorded by PMD

The annual average precipitation in the Sargodha is observed as 30.4 cm due to semi-arid climate, however, spatial distribution pattern with in Sargodha is quite variable that make varying impact on the agricultural yield. The normal wind speed on daily bases has been recorded as 4 km/h. The spatial distribution of LST that was computed from Landsat-7 ETM+, imagery of20th October 2000 (Figure 4) indicates the variation of temperature between 25^{0}C and 38^{0}C, with mean value of 30^{0}C.Thematic map of the imagery highlights the agricultural fields with lower temperature (25^{0}C to 29^{0}C) and barren land with mountains as well as developed areas including roads with high temperature(33^{0}C to 38^{0}C).However, the areas with cultural features like houses have comparatively low temperature then the mountainous areas (31^{0}C to 33^{0}C).

The LST map of 2ndOctober 2005 (Figure 5) shows 37^{0}C and 27^{0}Cbeing the highest and lowest with mean 33^{0}C.The imagery of October 2011 (Figure 6) does not show any significant variation from LST of October 2005, with the exception that it is low at some places. However, thematic map of LST as computed from the imagery of October 2015 (Figure 7) indicates the abnormal decrease of temperature from earlier years imagery. Comparison of the data shown in Table 1 and plotted as bar graph in figure 8indicate that the LST is progressively rising, whereas, 2015 imagery (Figure 7) depicts the lower values (the highest temperature30^{0}C and the lowest 22^{0}C with 25^{0}C as mean). The graphical comparison (Figure 8) of a selected pixel indicates that temperature has an increasing trend from 2000 to 2011 but dropped in 2015. During these 11 years, the computed temperature rise is 3 ^{o}C. The increase in temperature might be the result of conversion of agricultural fields in to urban areas in addition to the global warming. The result of the analysis were compared with the data recorded at ground meteorological observatory even though imagery pixel size is 60 x 60 m for Land sat- 7 ETM+ TIR while ground data represent the temperature for less than 1 m^2. Before utilization of ground data, thermal uniformity experiment of the meteorological observatory at Sargodha airport was carried out and then results were compared with satellite data. The result of the comparison between vegetation area and built up area as shown in figure 9 indicates that during recent past, Sargodha has vigorously changed from rural to urban with the boom of real state business That reduced the farm land area resulting in imbalance of energy. The increase in number of housing colonies created heat island to contribute in increase of atmospheric temperature. The ground verification of satellite thermal data for the years 2011 and 2015 with the meteorological observatory at Sargodha as recorded by PMD (Table 2), indicates that results are within 3%.

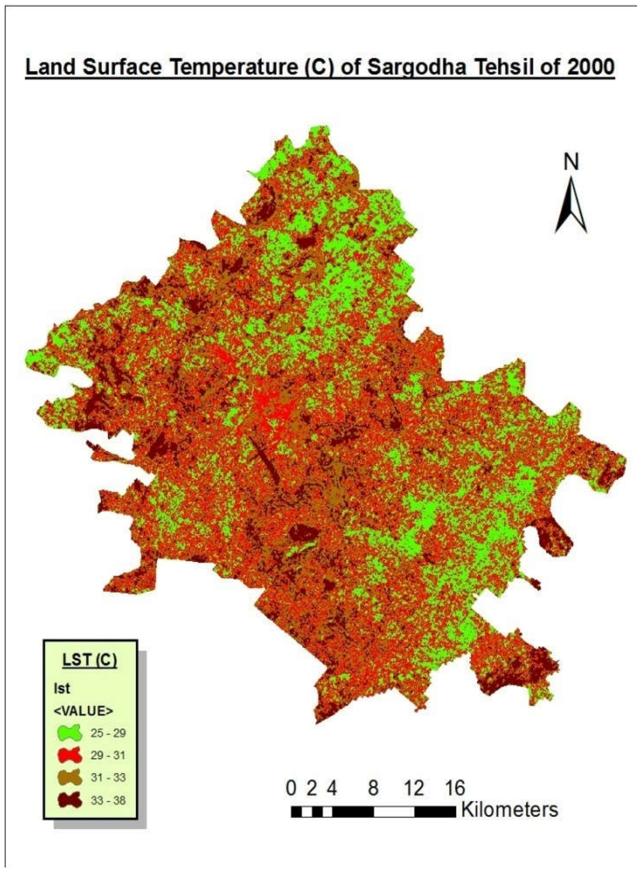

Figure 4.The result of LST analysis of landsat-7 ETM+, dated 20th October 2000

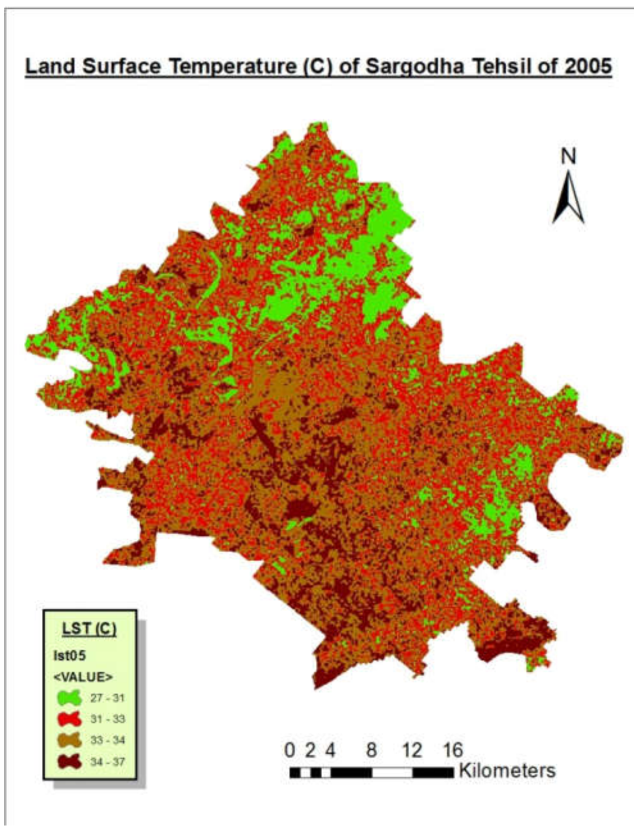

Figure 5.The result of LST analysis of landsat-7 ETM+, dated 2nd October 2005.

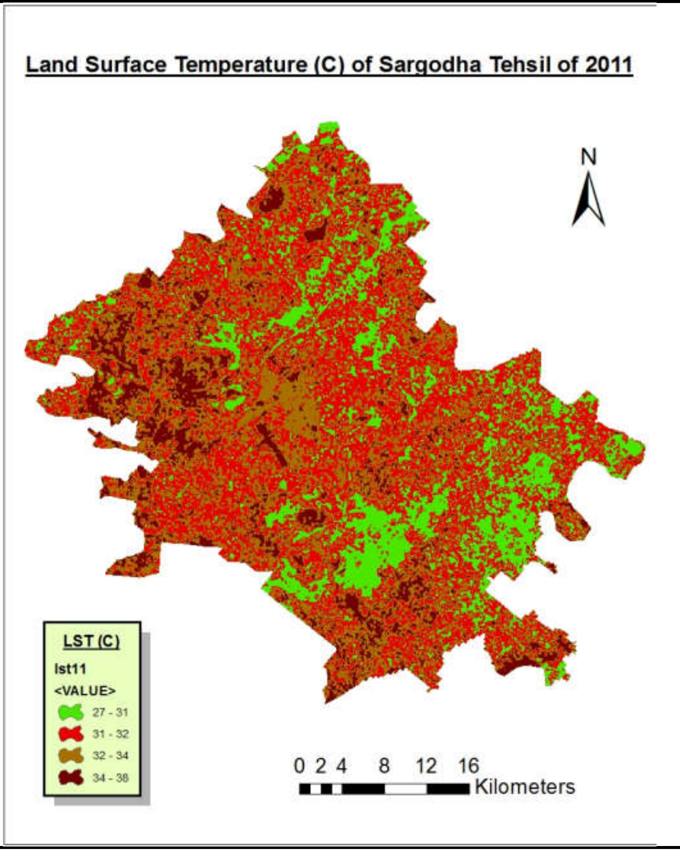

Figure 6.The result of LST analysis of landsat-7 ETM+, dated 3rd October 2011.

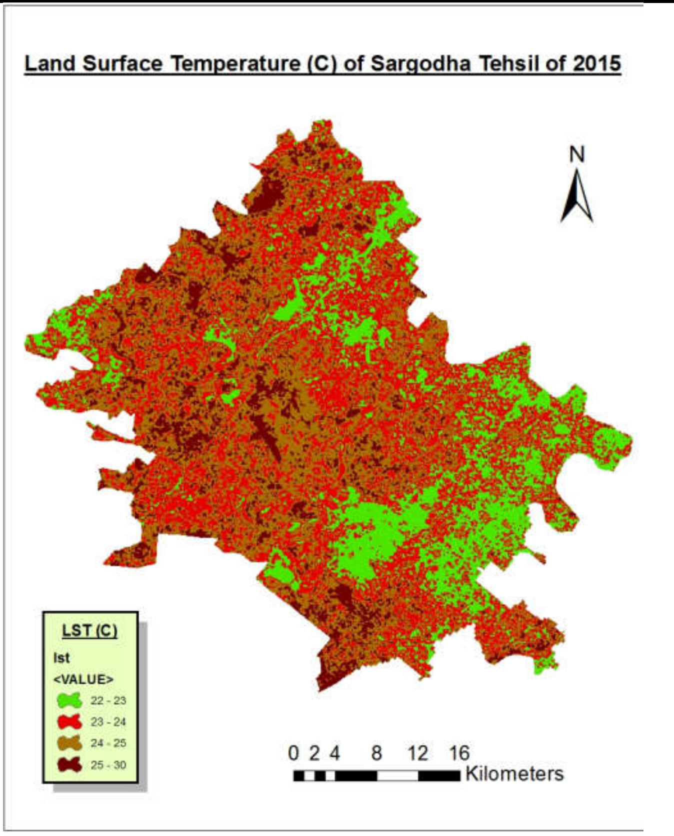

Figure 7.The result of LST analysis of landsat-8 OLI-TIRS, dated 6th October 2015.

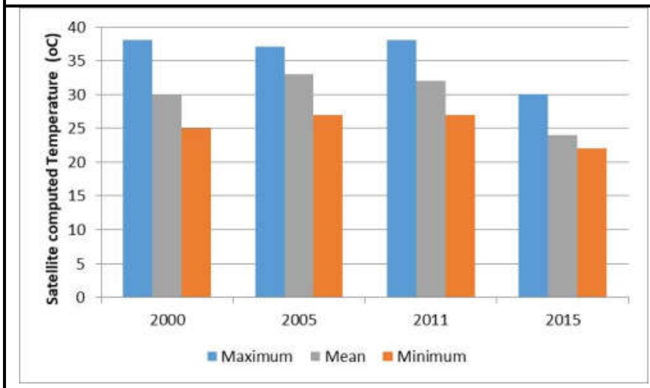

Figure 8. Graphical representation of LST retrieved from Landsat images over the period of 2000 to 2015

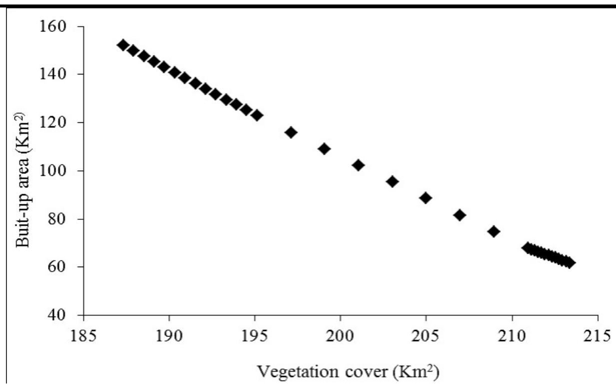

Figure 9. Relationship between built up area and vegetation cover of Sargodha for the period of 2000 to 2015.

Conclusion

Present study was devised to use the emissivity approximation in single channel systems for LST monitored from Landsat and compare it with ground temperature recorded at ground metrological observatory and found that the result obtained are useful in studying the climate of Sargodha in detail. For LST retrieval, NDVI single channel method is used because of its suitability. The accuracy of the result is good with difference of±5°C with actual ground temperature value. The precision of temperature helps to recalculate and allow to have further improvements with accurate estimation and values of atmospheric constraints and ground emissivity of every individual pixel of satellite data. LST from the satellite data is computed by using the single channel techniques and compared the results with the ground station data.

The application of geomatics method to analysis and visualize the climatic conditions of difficult terrain regions such as mountains and forests as well as agricultural fields in the present study facilitated to understand Sargodha weather. Results of the study also helped to infer that single channel algorithm is a powerful tool to assess several environmental parameters such as; land/sea surface temperature or vegetation. The results of the present study further show that the ground temperature of Sargodha is linearly increasing as in other parts of the world. The results are also in agreement with the sea surface temperature trend presented by Syed & Ahmed (2015) and analysed from satellite derived data. The results further depict that Sargodha is also being affected by the Global Warming phenomenon. It is widely acknowledged that temperature of the Earth's Surface has increased to 0.9°C since last one century.

One of the reason for global warming has been attributed to increase of greenhouse and trace gases such as chlorofluorocarbons, nitrous oxide and methane (Ahrens, 2006). The impact of global warming on rainfall pattern is not evenly distributed everywhere. Some observe more rainfall whereas, in other areas it receive less rainfall that make varied impact on the agricultural output. Another major impact of global warming is sea level riseas a result of glaciers retreat and expansion of oceans. It is estimated that sea level will rise 30 cm by the end of present century. The results of LST and SST are in agreement with each other. Sidra (2017) attributed it as one of the reasons for local atmospheric warming is urbanization of the agricultural area. Sidra (2017) further concluded that the conversion of agricultural land in to housing area can disturb the energy balance by increasing surface temperature. The impact of urbanization on climate change has alerted the stakeholders to effectively control the air pollution and by reducing the emission of gasses to the atmosphere. Adoption of alternate energy over fossil fuel will efficiently reduce the global warming as many countries have already taken the lead since 2008. The results of this research if taken in to consideration by the concerned authorities, will contribute to forecast for the control of local climate change with necessary actions.

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