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Impact of Urbanization Growth on Land Surface Temperature using remote sensing and GIS: A Case Study of Gujranwala City, Punjab, Pakistan

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Abstract: Globally, urban temperature is gradually increasing day by day. The prominent climatic condition called Urban Heat Island (UHI), is rising especially in the rapidly developed cities. Gujranwala a city of Punjab, Pakistan is experiencing fast urbanization which has led to ultimately increase in the observable UHI. The objective of recent study is to determine the effects of increasing urbanization on surface temperature and vegetation cover by different techniques of remote sensing and GIS. For this purpose, different time series of Landsat images were selected through which land surface temperature and NDVI (Normalized Difference Vegetation Index) has been calculated and urban heat island effect is analyzed. It is found that built-up areas have high temperature as compared to vegetative areas. Surface radiant temperature has increased up to 8 ˚C in Gujranwala due to urbanization. There is negative correlation between NDVI and LST. Economic activities in study area have decreased the vegetated parts leading to an increase in surface temperature and change in urban microclimate.

Keywords: LST, NDVI, urban heat island, geographical information system, remote sensing.

Introduction

Change in land use, land cover and economic activities affect the climate change in cities and around the cities. There are various causes which are responsible for urban/rural temperature variation like change in the physical physiognomies of the area (thermal capacity, albedo, heat conductivity), like reinstatement of vegetation by concrete and asphalt, change in the rate of evapotranspiration, change in the radioactive fluctuations due to complex geometry of high-rise buildings and streets and anthropogenic heat expulsions (Dousset and Gourmelon, 2003).

The most overbearing problem in urban zones is increase in surface temperature. When vegetative areas are converted in constructed areas, it affects the surface temperature by maximum absorption of solar radiation, evaporation rates, heat storage, dissenting wind and significant changes in the near-surface atmospheric conditions of the cities (Weng, Lu and Schubring 2004). The urban heat island (UHI) or surface urban heat island (SUHI) event is described as higher air temperature built in urban areas as compared to rural areas (Sobrino et al., 2013).

Vegetation is a vital element of global environment. It modifies the ecosystem through water preservation, terrestrial soil constancy and atmospheric circulation. It also helps to sustain a balance of ecosystem prominently. Rapid expansion leads to the declination of vegetation areas in cities. Topographic changes include loss of forest lands, diminishing of agricultural lands, expansion of impervious surface of the area, extension of barren land because of the built-up area (Kumar et al, 2012). These are contributing factors which increase the urban heat island (UHI) in urban areas (Takeuchi et al, 2010).

In the human history, urbanization increased when the modification of land started with the growth of population and economic activities. It has a great influence on climate. By construction of buildings or roads etc. urban areas normally absorb the higher solar radiation, and have a greater conductivity plus thermal capacity, as a result more heat is stored throughout the day and released in the night time, Consequently, urban areas tend to experience comparatively higher temperature as compared to its adjacent pastoral areas. This warm air alters and aggregates through excess heat discharged from transportation and industry, inner-city houses which is responsible for the expansion of UHI (urban heat island). The temperature variance between the rural and urban areas are normally moderate, close to 2 to 3 ºC, but sometimes increases to several degrees when urban, climatic and geographical conditions look promising for the UHI to develop (Mather, 1986).

Landsat 7 ETM+ and 8 OLI/TIRS are extensively utilized to observe the land use alterations, and build models to monitor the biophysical features of the earth's surfaces. The thermal band of the Landsat imagery is accomplished to originating the LST (land surface temperature). To control the climate condition, a model can be built by calculating the radiation budget (Mallick et al. 2008). The information about land surface temperature is very important to sort out many issues related to climate and earth sciences such as human-environment interactions, urban climatology and global environmental change. Earlier scholars (Weng, 2001; Elsayed, 2003; Alavipanah et al, 2007; Susca et al, 2011 and Choi et al., 2012) used the remotely sensed images for instance Landsat images to consider the land usage and land consumption changes

& produce land use map and land surface temperature map. Some researchers studied the influence of land use/land cover change on surface temperature of land (Carlson, 2000; Chen, 2006 and Xiao, 2007) that was found to be positively correlated between land use/ land cover and LST. More or less studies assessed the association between the vegetation abundance and land surface temperature (Weng et al., 2014), Various vegetation indices for example fractional vegetation cover (FVC) and normalized vegetation index (NDVI) were used to signify the vegetation profusion. The results confirm the negative correlation between NDVI and land surface temperature (Owen et al., 1998). In the present study, the main focus is to highlight the fact of notable decrease of vegetative areas due to rapid urbanization which affects the urban microclimate and increases the surface temperature.

Study Area

Geographically, Gujranwala lies between 32˚9′ to 32˚24′ N and 74˚11′ to 74˚24′ E in Punjab province (Fig, 1). Total land area of district Gujranwala covers 3,622 km^2. The northern side of Gujranwala has river Chenab beyond which the river Gujarat is located. Total population of Gujranwala district is 5,014,196 (Table 1) (Pakistan Bureau of statistic, 2017). According to the Koppen classification, Gujranwala has hot semi-arid climate. Its temperature reaches 27-40˚C during summer (June to September). The winter season starts with November and ends in March and the temperature ranges between 5-19 ˚C during winter season. The temperature can drop to an average of 7C˚ in the coldest months (Nov to Feb). Average annual rainfall in study area is about 872 mm (PMC, 2017).

Table 1. Urbanization in Gujranwala.

Census Years	Population	Change
2003	*3,844,000	1,170,169
2017	5,014,196	
*Estimated		

Source: Pakistan Bureau of statistic 2017

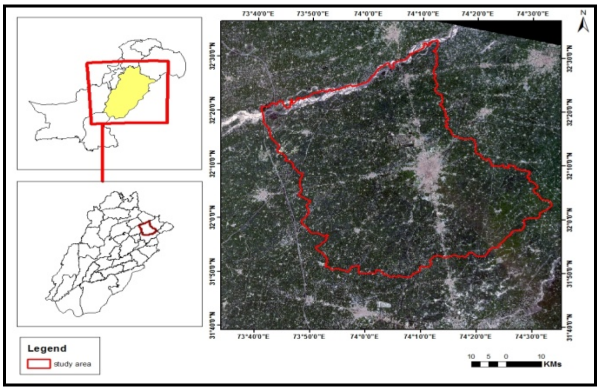

Fig. 1 Landsat 8 OLI/TIRS image of the study area.

Materials and Methods

Data Collection

Cloudless Landsat satellite data of 2003 and 2018 were downloaded for this study and protrude on the Universal Transverse Mercator (UTM) projection coordination and pre-processed. The information of the satellite data used in study is shown in Table 2. Figure 2 provides a detailed description about the data sources and methodology that are used in the current research.

Table 2. Details of Landsat data collected.

Date of images	Satellite / sensor	Resolution	Reference system/path/row
12-03-2003	Landsat 7 ETM+	60 meters	WRS/149/38
29-03-2018	Landsat 8 OLI/TIRS	60 meters	

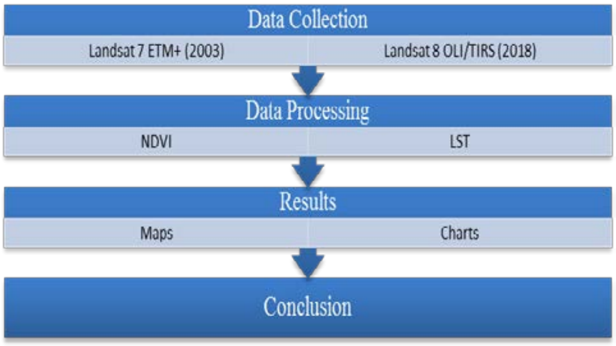

Fig. 2 Flow chart of Image Processing.

Estimation of NDVI

NDVI is an index obtained from visible band and near infrared band of the electromagnetic spectrum satellite data. The Normalized difference vegetation index is used for several influential studies (Holm, 1987; Pettorelli, 2005; Anbazhagan, 2014). NDVI is the best tool to calculate the strength and amount of vegetation on the selected surface. For this purpose, satellite data are used to calculate the reflectance ratio to originate the compactness of vegetation indices.

NDVI = (NIR –RED) / (NIR + RED) (Equation **No.1)**

Universally, RED and NIR are the DN value of red band and Near-infrared respectively.

Usually, vigorous vegetation throws back a greater part of the near-infrared and absorb most of the visible light. Scant vegetation or unhealthy reflects less near-infrared and more visible light region. In contrast bare soil moderately reflects the infrared and red parts of electromagnetic spectrum (Lillsand, 2009) and the appearing outcomes will be zero. The normalized value is between 1<=NDVI<= -1 to account the differences in radiance and surface gradient. In present study, NDVI results are derived from the Landsat TM, ETM+ and OLI/TIRS images for the years of 2003 and 2018.

LST Estimation from Satellite Data

Surface temperature is a universal, non-defind term describing combined temperature of intact objects present on the land. Several researchers utilized defined measurement on satellite data to calculate the LST (Chander, 2003; Chander, 2009; Srivastava, 2010; Sheela, 2011). The Land surface temperature was calculated from the TM, ETM+ and OLI/TIRS thermal infrared band (band 6, band 6.1 and band 10 and 11) with spatial resolutions of 30m, 60m and 60m respectively. Initially, the DN values were changed to spectral radiance by using equation 2.

$L\lambda = gain*DN + offset$ (Equation No.2)

In the next step, the spectral radiance value was converted to temperature by equation 3

$T = K2/\ln(K1/L\lambda+1)$ (Equation No.3)

Table 3. Thermal band calibration constants.

Constant	Landsat ETM+	Landsat OLI/TIRS
K1	666.09	774.8853 band 10 480.8883 band 11
K2	1282.71	1321.0789 band 10 1201.1442 band 11

Source: NASA

In the last step, temperature which was in Kelvin was converted to Celsius (C˚) through equation 4.

$T(C^{\circ}) = T(K) - 273.15$ (Equation No.4)

Results and Discussion

The main objective of present study was to detect the changes in vegetation cover and land surface temperature due to urbanization in Gujranwala area. The values of NDVI and LST was obtained for the years of 2003 and 2018.

Effect of Urbanization on Vegetation

NDVI is one of the best extensively used index which can analyze the satellite data and monitoring of vegetation cover. The pixels value of NDVI varies between -1 and +1. Higher values of NDVI specify the healthier and richer vegetation. There is observable change in vegetation cover (Fig 3, 4).

In 2003, the maximum value of NDVI was 0.626, minimum value is -0.386 and mean value 0.12. The NDVI 2018 shows that the maximum value was 0.583, minimum value was -0.163 and mean value was 0.21. (Table 4 &Fig 7). It is observed that in these two years, negative values of Normalized difference index were found in the central portion of the research area which specifies the nonappearance of vegetation or little flora cover.

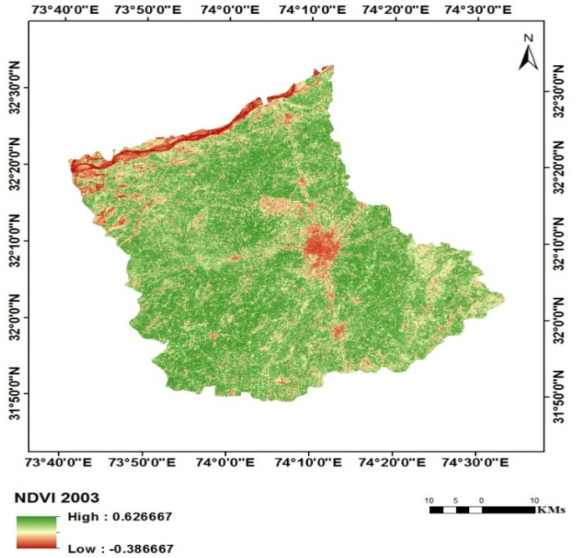

Fig. 3 NDVI derived from LANDSAT 8 OLI/TIR for the year 2018.

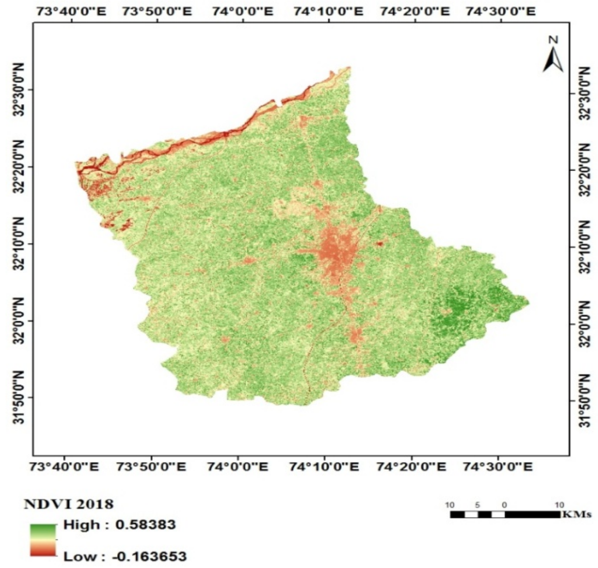

Fig. 4 NDVI derived from LANDSAT ETM+ for the year 2003.

NDVI of 2018 indicates the lowest NDVI value in the central portions which is due to increase of urbanization in the study area.

Effect of Urbanization on Land Surface Temperature

LST was obtained from satellite images of three different years (Figs. 5, 6). In Landsat ETM+ 2003, the estimated values of LST indicate a maximum of 35.4 ˚C and minimum of 15.6 ˚C with mean of 25.5 ˚C. In Landsat OLI/TIRS 2018, LST values were calculated for maximum temperature 43.5˚C, minimum temperature 21.9 ˚C and mean temperature 32.7 ˚C. The calculated temperature and range of LST for two different years have been shown in Table 4. The LST maximum and minimum values are graphically exemplified in Figure 8. In the study area, high temperature can be observed in central portion because this area is more developed in terms of infrastructure than surrounding area. Temperature record obtained from Pakistan Meteorological Department (PMD) temperature also justifies the results. Figure 9 shows the graphical representation of mean value of NDVI and LST of study area.

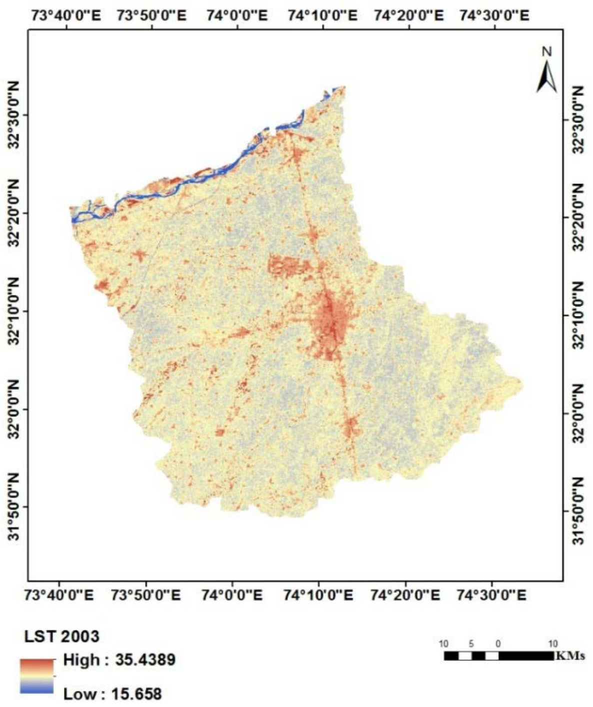

Fig. 5 Land surface temperature (Celsius) gradient derived from Landsat ETM+ 7 for 2003 data.

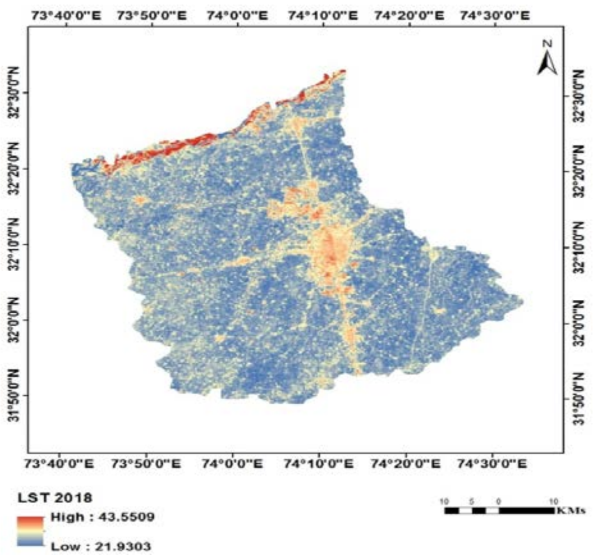

Fig. 6 Land surface temperature (Celsius) Gradient derived from Landsat 8 OLI/TIRS for 2018 data.

Table 3. Satellite derived NDVI index, LST and calculated Range.

Years	NDVI			LST		
	Maximum	**Minimum**	**Range**	**Maximum ˚C**	**Minimum ˚C**	**Range ˚C**
2003	0.626	-0.386	0.12	35.4	15.6	25.5
2018	0.583	-0.163	0.21	43.5	21.9	32.7

Table 4. PMD observations on Land Surface Temperature and Annual rainfall.

Years	Temperature		Rainfall
	Maximum ˚C	Minimum ˚C	Annual Average (mm)
2003	32	14	167
2018	38	20	145

(Source: PMD, Pakistan Meteorological Department)

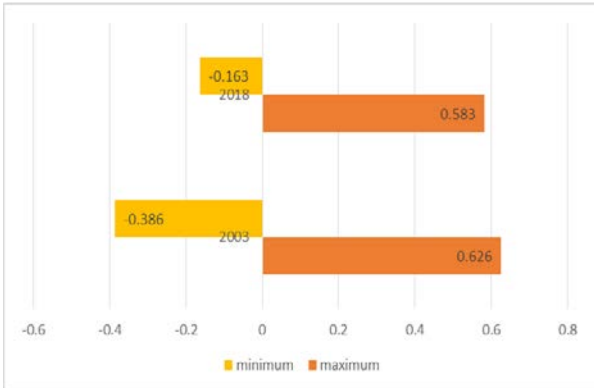

Fig. 7 Minimum and maximum value of NDVI during 2003 and 2018.

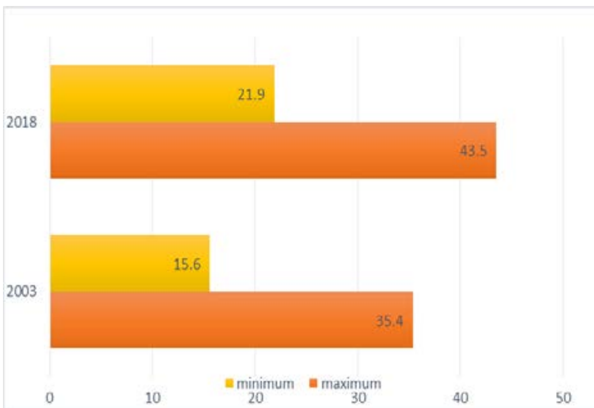

Fig. 8 Maximum and Minimum values of LST during, 2003 and 2018.

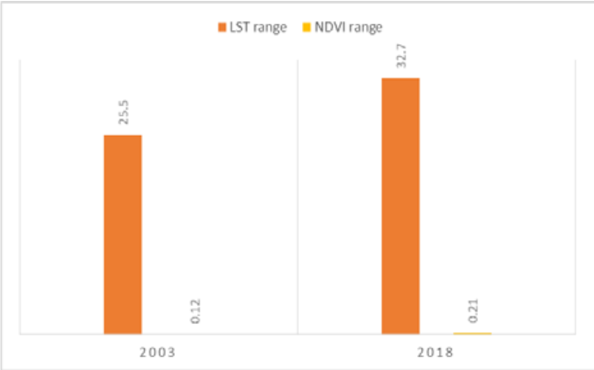

Fig. 9 Mean values of NDVI and LST during 2003 and 2018.

Conclusion

The calculated NDVI and LST values reflect the effects of urban growth on study area. An increase in surface temperature is due to industrial growth, different types of economic activities, settlement, reduction of flora covers and unexpected climatic changes. NDVI value is found negative in developed parts of study area. Fundamentally the NDVI and LST are the best applications to know the temperature of the area and NDVI confirms the findings of the study. Results illustrate that there is a negative correlation between LST and NDVI. Less vegetation cover reflects the increase in surface temperature and vice versa. The central portion shows the higher emissivity value as buildings, settlements and surface of soil have an impact on the temperature. Satellite data supplement the results of areas where ground-based observations of temperature (stations of PMD) were recorded. The results show an asymmetrical pattern of temperature and vegetation in study area. This work has ultimately served as an eye-opener to some hidden facts about the hazardous impact of urbanization on LST and vegetation cover. Present study will give an optimistic approach for future and will support progressive applications.

References

1. Alavipanah, S. K., Saradjian, M., Savaghebi, G. R., & Komaki, C. B. (2007). Land surface temperature in the yardang region of lut desert (iran) based on field measurements and landsat thermal data. *J. Agri. Sci. Techno.*, **9**, 287–303.

2. Anbazhagan, S., Dasgupta, S. and Jothibasu, A. (2014). Monitoring of drought using remote sensing data in uppar odai, sub-basin, Tamil Nadu, and India. *Int. J. Ear. Sci. Eng.*, **7** (03), 930-937.

3. Choi, H., Lee, W., Byun, W. (2012). Determining the effect of green spaces on urban heat distribution using satellite imagery. *Asi. J. Atmo. Environ.*, **6**, 127–135.

4. Carlson, T.N., Arthur, S.T. (2000). The impact of land use - land cover changes due to urbanization on surface microclimate and hydrology: A satellite perspective. *Glob. Plane. Chan*., **25**, 49-65.

5. Chen X. L., Zhao H. M., Li P. X., Yin Z. Y. (2006). Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes. *Rem. Sens. Environt.*, **104**, 133-146.

6. Chander, G., Markham, B. (2003). Revised landsat-5 tm radiometric calibration procedures and post calibration dynamic ranges. *IEEE Transac. Geosci. Remo. Sens.,* **41** (11), 2674-2677.

7. Chander, G., Markham, B. L., Helder, L. D. (2009). Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. *Rem. Sens. Enviro.*, **113**, 893-903.

8. Dousset, B., Gourmelon, F. (2003). Satellite multi-sensor data analysis of urban surface temperatures and landcover. *ISPRSJ Photogra*., **58**, 43–54.

9. Elsayed, I. S. M. (2009). A study on the urban heat Island of the City of Kuala Lumpur, Malaysia. *IAS. Int. Confer. Environ. Manag. Eng. Alb. Canada.*

10. Holm, A. M., Burnside, D. G., Mitchell, A. A. (1987). The Development of a System for Monitoring trend in range condition in the Arid Shrub Lands of Western Australia. *Austr. Rang. Lan. J.,* **9** (1), 14-20.

11. Kumar, K. S., Bhaskar, P. U., Padmakumari, K. (2012). Estimation of land surface temperature to study urban heat island effect using Landsat ETM + IMAGE. *Int. J. Eng. Sci. Tech..*, **4** (2), 771–778.

12. Lillsand, T. M., Kiefer, R. W., Chipman, J. W., (2009). *Remote Sensing and Image Interpretation*. 5th edition, New York, John Wiley and Sons, 753 pages.

13. Mallick, J., Kant, Y., Bharath, B. D. (2008). Estimation of land surface temperature over Delhi using Landsat-7 ETM +. *J. Ind. Geophys.,* **12** (3), 131–140.

14. Owen, T. W., Carlson, T. N., Gillies, R. R. (1998). Assessment of satellite remotely-sensed land cover parameters in quantitatively describing the climatic effect of urbanization. *Int. J. Remo. Sens.,* **19**, 1663-1681.

15. Pettorelli, N., Vik, J. O., Mysterud, A. (2005). Using the satellite-derived NDVI to assess ecological responses to environmental change. *Tren. Ecolo. Evolu.*, **20** (9), 503-510.

16. Punjab Bureau of Statistics, (2017).

17. Pakistan Metrological Center, (2017).

18. Sobrino, J. A., Carrióa, R. O., Sòriaa, J. C., Francha, B., Hidalgoa, V. C., Mattara, Juliena, Y. J., Gómezb, E., Miguelb, R., Bianchic, Paganinic, M., (2013). Evaluation of the surface urban heat island effect in the city of Madrid by thermal remote sensing. *Int. J. Remo. Sens.*, **34**, 3177–3192.

19. Susca, T., Gaffin, S. R., Dell'osso, G. R. (2011). Positive effects of vegetation: urban heat island and green roofs. *J. Environ. Pollu.*, **159** (8-9), 2119–2126.

20. Sheela A.M., Letha J., Sabu Joseph, Ramachandran K.K., Sanalkumar S. P. (2011). Trophic state index of a lake system using IRS (P6-LISS III) Satellite imagery. *J. Environ Monitor Assess.*, **177**, 575-592.

21. Srivastava, P. K., Majumdar, T. J., and Bhattacharya, A. K. (2010). Study of land surface temperature and spectral emissivity using multi-sensor satellite data. *J. Ear. Sys. Sci*., **119** (1), 67-74.

22. Weng Q. H., Lu D. S., and Schubring, J. (2004). Estimation of land surface temperature-vegetation abundance relationship for urban heat island studies. *J. Remo. Sens. Environ*., **89**, 467-483.