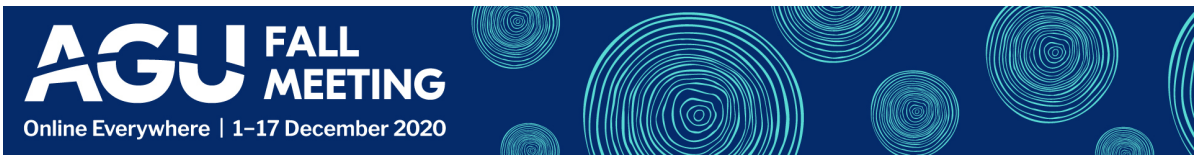
Urban Green Space and Land Surface Temperature in Lucknow

Ravi Verma, Pradeep Kumar Garg

Indian Institute of Technology Roorkee, Roorkee- 247667, Uttarakhand, India

PRESENTED AT:



URBAN GREEN SPACE (UGS)

As described by Urban Atlas code 14100 “The green urban areas include public green areas used predominantly for recreation such as gardens, zoos, parks, and suburban natural areas and forests, or green areas bordered by urban areas that are managed or used for recreational purposes.” (Egorov et al., 2016).

Green spaces show a significantly low temperature because the amount of heat stored within urban vegetation is significantly reduced through transpiration (Agnihotri, 2018). Depending on the person’s gender, age, and discrete predilections variations in configurations of green spaces, built environment, and topographical aspects in the proximity of a person’s residence may deliver different scenarios (listed below) for physical schemes and mental restoration (Egorov et al.,2016).

a) Comprehensions of green space accessibility and quality

* Greenness, quantified by Normalized Difference Vegetation Index (NDVI)

* Density or percentage of green space by area

* Proportion of green space or greenness within a precise range from residence

* Size of green space

b) Neighbourhood

* Proximity to an urban park or geographically designated green space

* Buffers of different sizes of greenery around different built-ups.

c) Built-up Area

* Height of built-up

* pockets of built-up accumulation in different sizes

* Dispersal of built-up land in various directions

LAND SURFACE TEMPERATURE (LST)

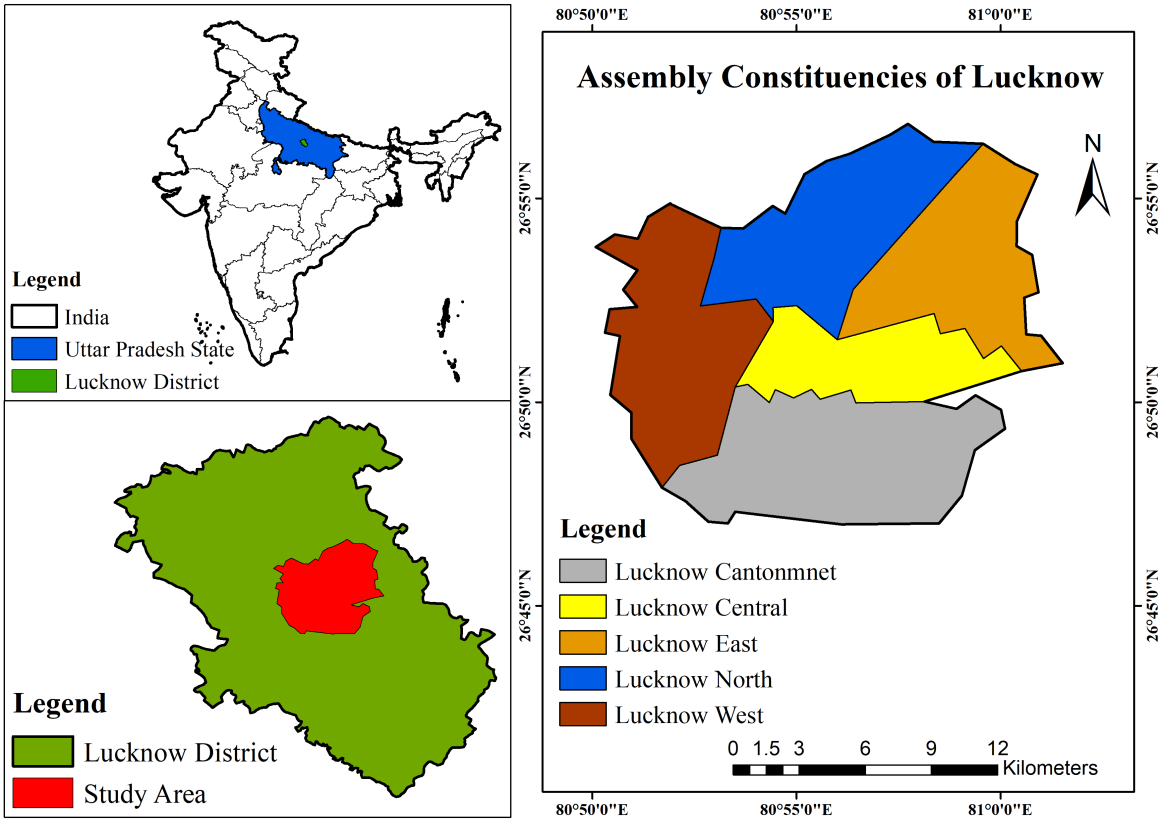
Many studies have tried to establish the relationship between urban spaces and LST instead of relating differences between urban and rural LST. Qualitative and quantitative, both models have been used for establishing relationships between urban green spaces (UGS) and LST in existing research studies.NDVI can be used to estimate greenness and relation temperature both (Lo and Faber, 1997). The recovery of emissivity for LST estimation from thermal infrared (TIR) remotely sensed data requires the radiative-transfer equation applied to a certain wavelength in the TIR region, from a theoretical point of view (Sobrino et al., 2008).

Using TIRS images of Landsat- 8 data acquired, LST maps are prepared for Lucknow city using radiative transfer equation with the NDVI emissivity estimation (Sobrino et al., 2008). Satellite-based thermal infra-red (TIR) data is directly linked to the LST through the radiative transfer equation. LST for study area is calculated in steps listed as below:

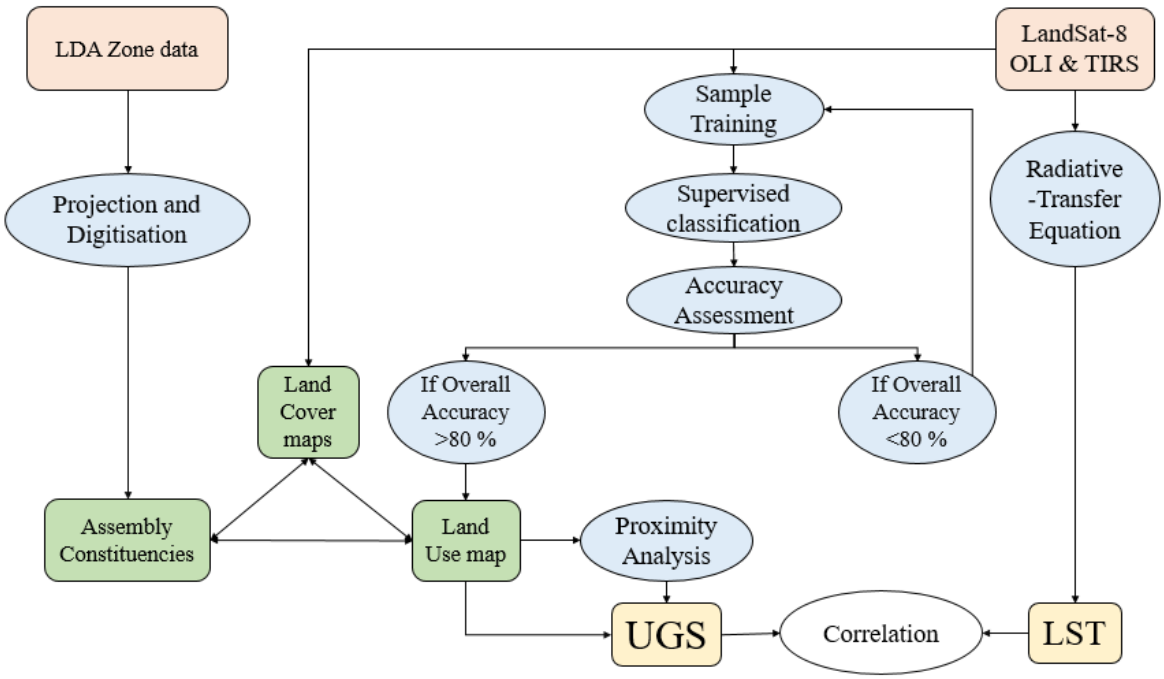
1. Calculation of surface reflectance values for Red and NIR band (band 4 & 5 of Landsat-8 OLI) for using it in NDVI retrieval for study area by using Multiplicative and additive factor for reflectance, which will then be used in calculation of Vegetation Cover (P_v) and calculation of surface radiance values for SWIR and TIRS band (band 6, 10 & 11 of Landsat-8) for using it in calculation of LST by radiative transfer equation through metadata file of downloaded satellite images.
2. Calculation of Emissivity, e is done by NDVI (Considering NDVI < 0.2 for Pure Soil pixels, and NDVI > 0.5 for Pure veg pixels and using values of factors for Landsat-8 Band 10, e_s = 0.9668, e_v = 0.9863 and Landsat-8 Band 11, e_s = 0.9747, e_v = 0.9896)(Yu et al, 2014)
3. Calculation of LST through the Radiative Transfer equation, which is obtained by rearranging Planck's law.

$$LST = c_1/(\lambda_T M * ln[c_2/(([\![\lambda_T M]\!]^5) * (ToA_R ad - UWR - (\tau * (1-e) * DWR))/(\tau * e))])$$

STUDY AREA AND METHODOLOGY

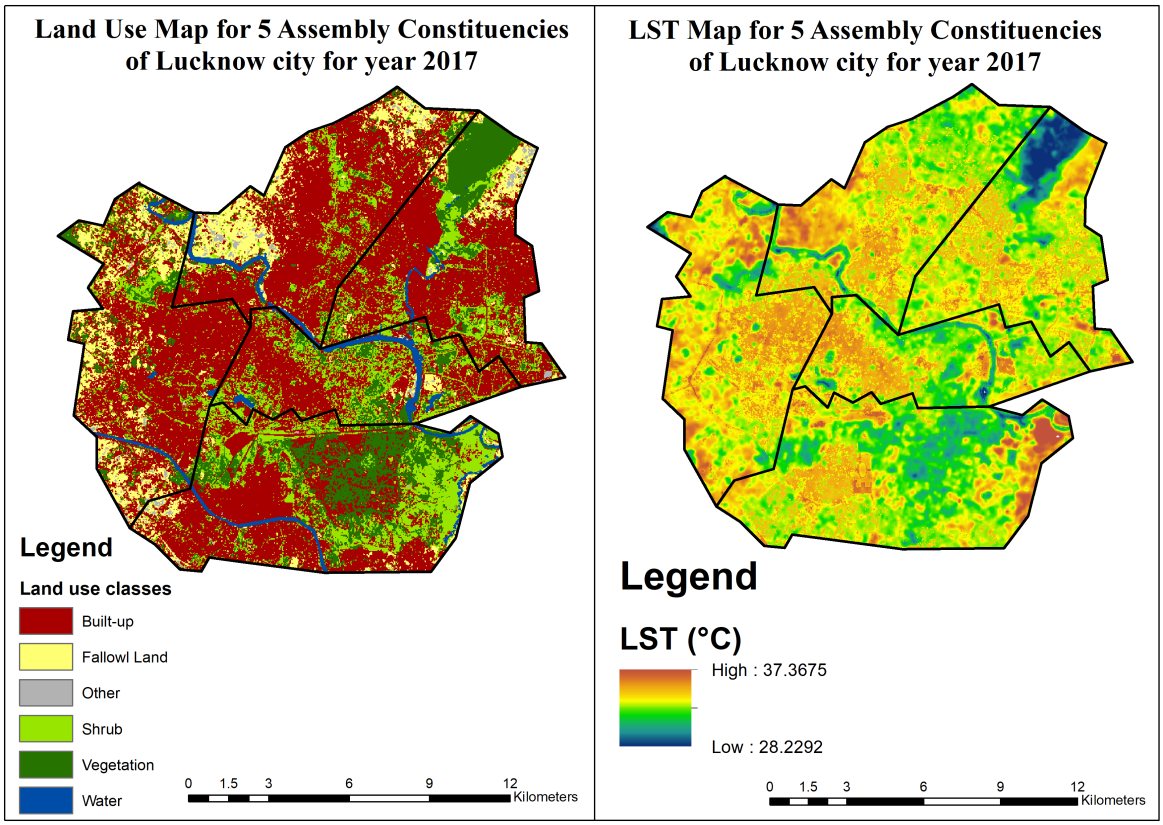


The study area falls in Lucknow Parliamentary constituency which is comprised of 5 Assembly constituencies (ACs) named Cantonment (Cantt.), Lucknow Central (LC), Lucknow East (LE), Lucknow North (LN), and Lucknow West (LW). River Gomti passes through almost all of 5 ACs in between of study area.

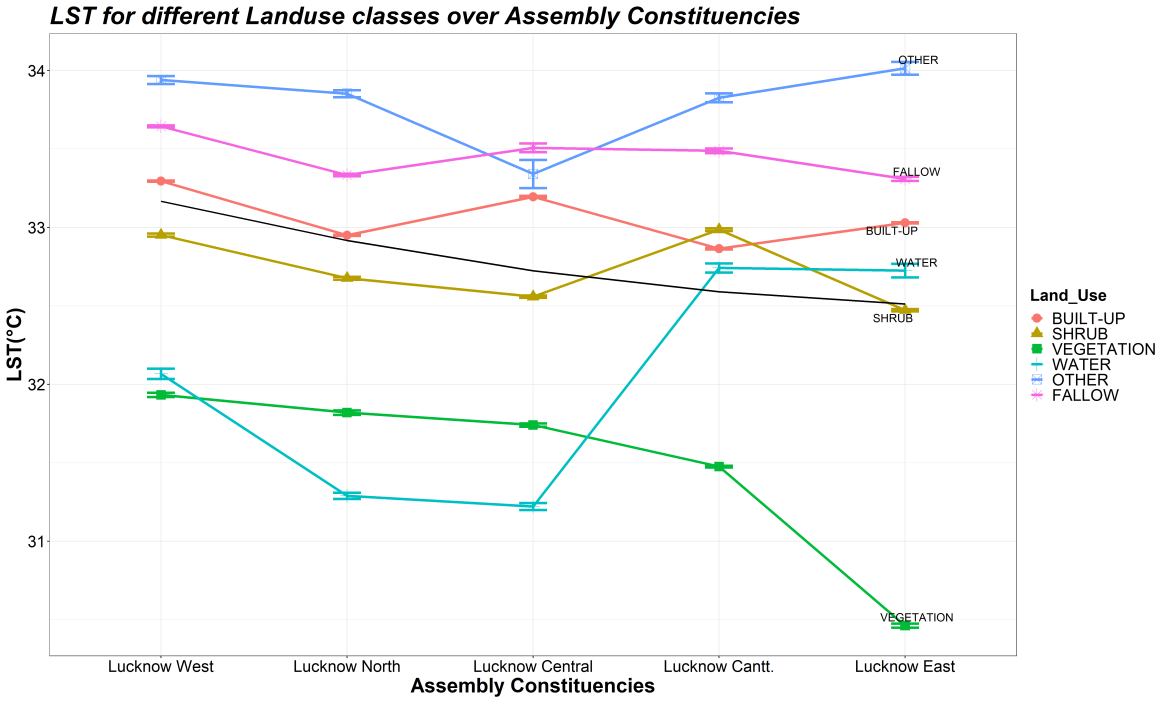


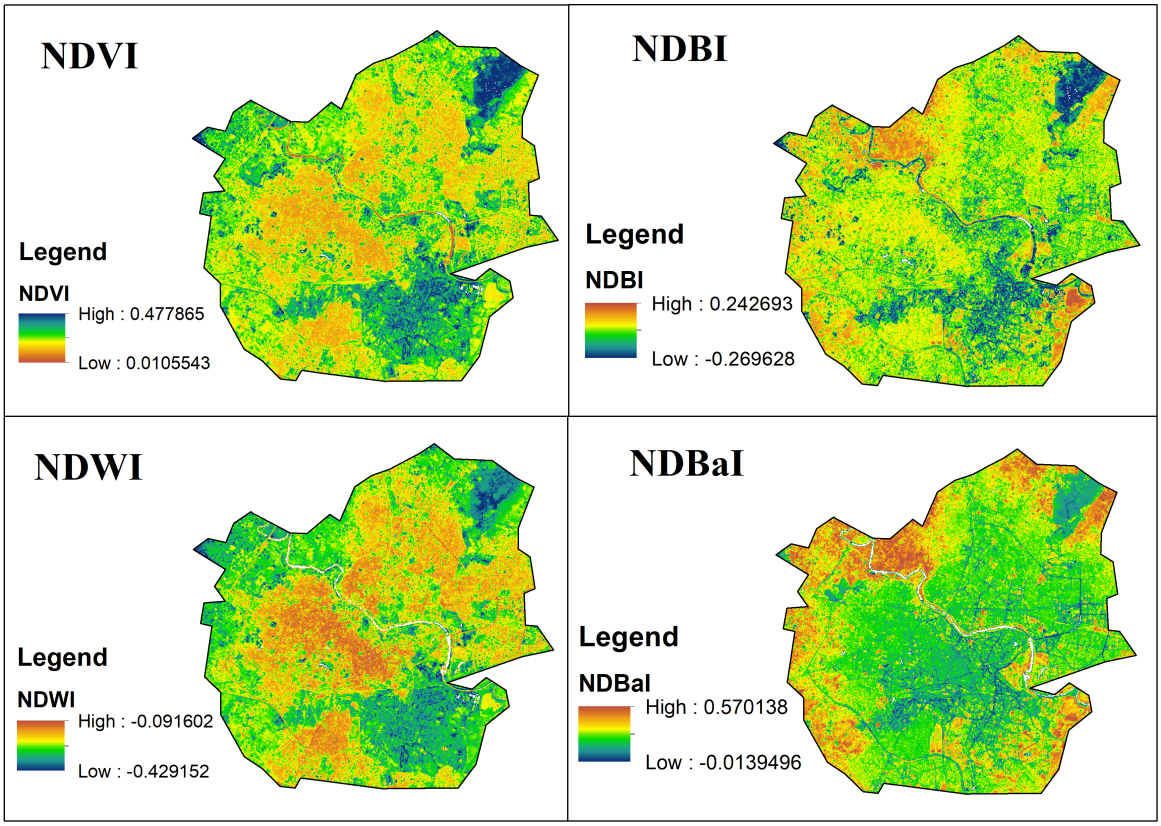
Built-up and Vegetation (vegetation + shrub) class pixels are separated form classified map using raster calculator. Same pixels are converted to point shapefiles and then point density is generated for each of pixel in 250m radius neighbourhood, as both properties affect green indices in its own way. Landsat-8 OLI band 3, 4 & 5 images acquired on May, 2017 falling over study area is used for classification of various land use classes (vegetation, built-up area, water bodies etc.) and land cover (NDVI, NDWI, NDBI & NDBaI) in study area using hybrid approach Maximum Likelihood supervised classification method.

RESULTS.....

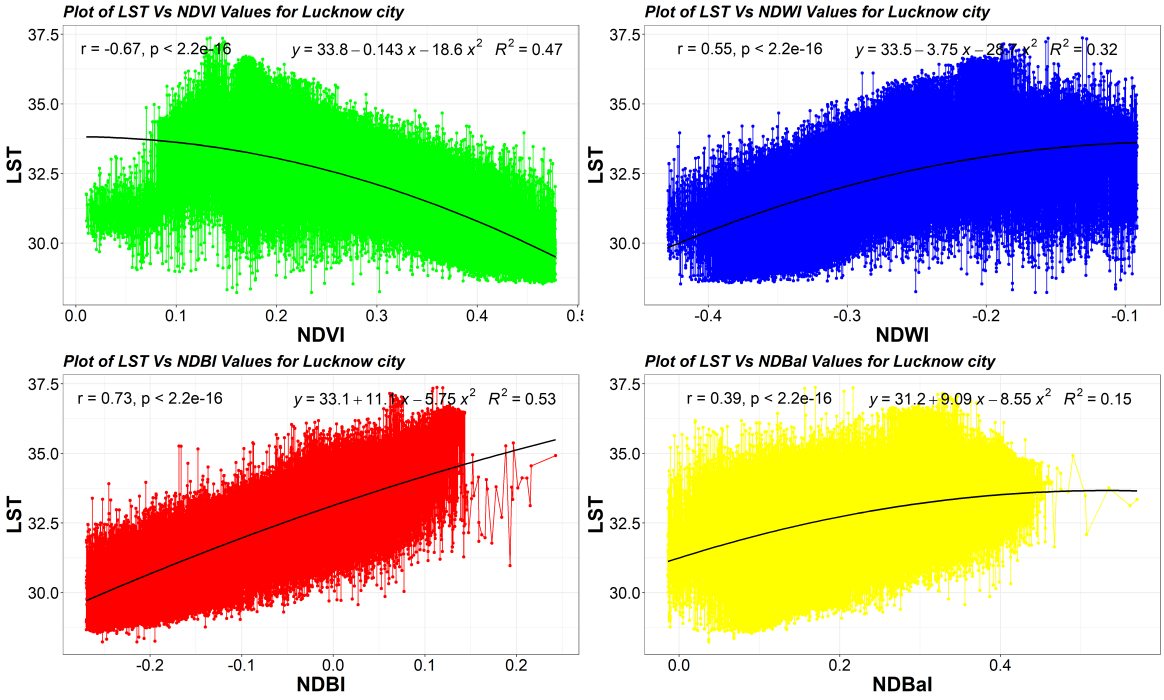


Vegetation and Water Land use class is having Lowest LST in all 5 ACs of Lucknow city.

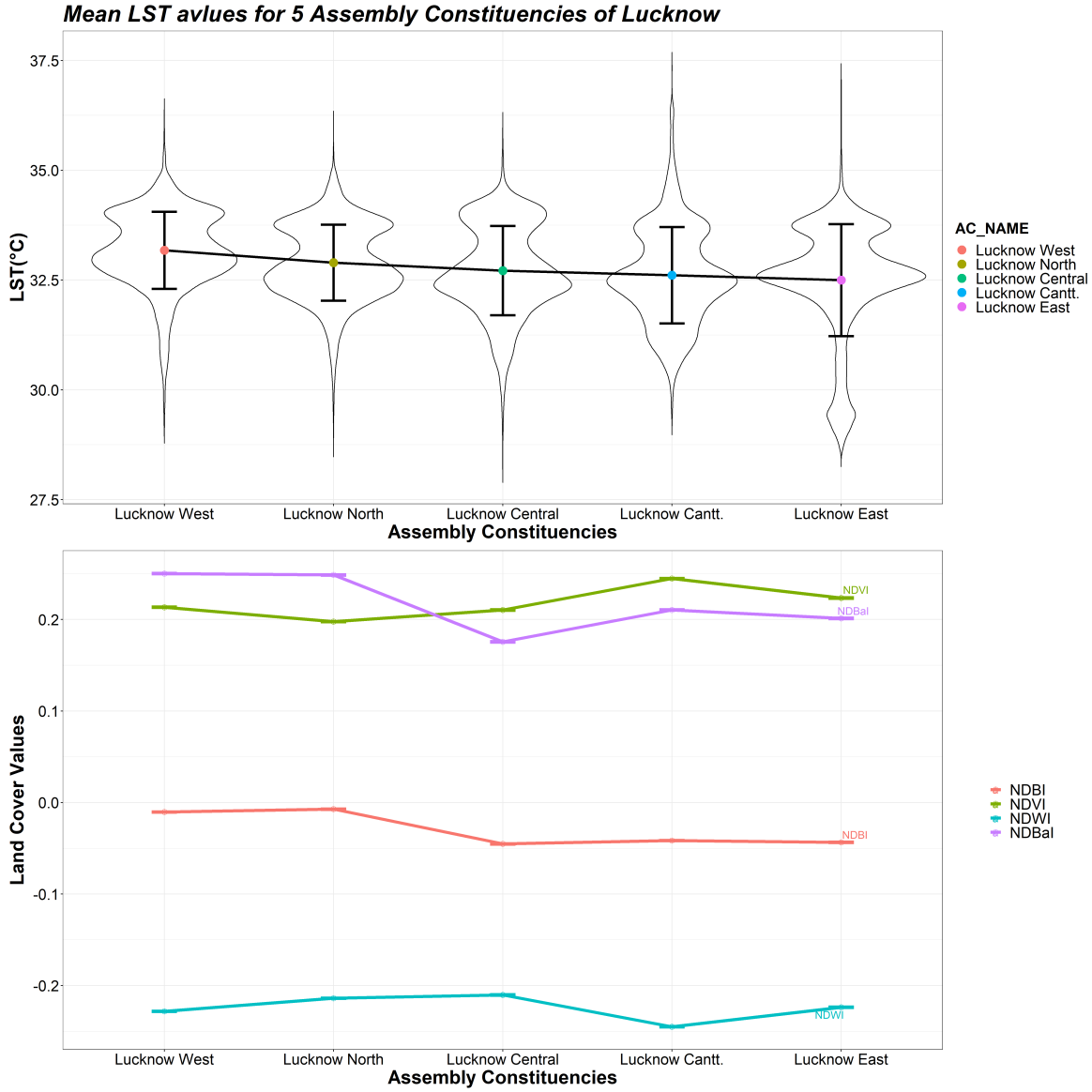




NDVI shows the best correlation with the negative trend to LST in Lucknow

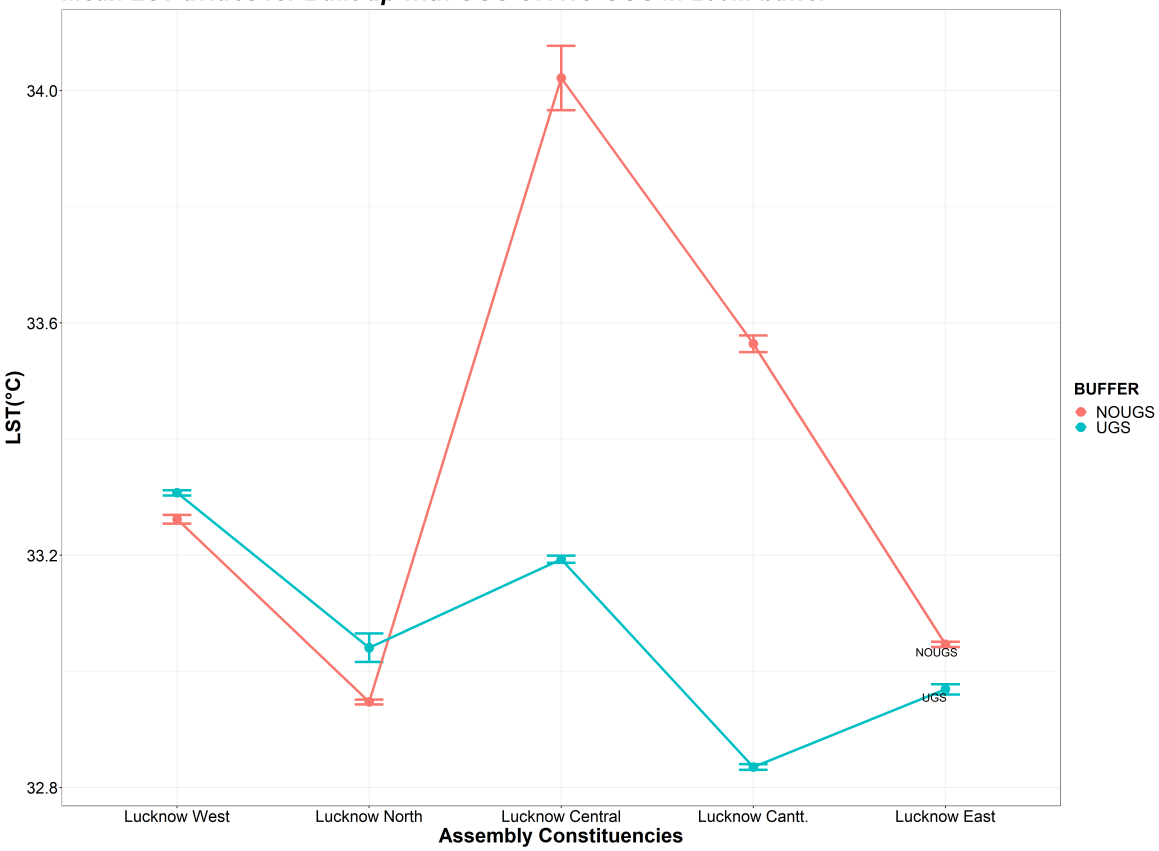


RESULTS



Built-up areas having UGS access in 250 m buffer around it, are showing a maximum of 1.5 C less temperature in Assembly constituencies of Lucknow city.

Mean LST avlues for Built-up with UGS OR NO UGS in 250m buffer



CONCLUSIONS

1. UGS is just a relative term to express nature of greenery present in surrounding, it does not quantify greenery in any terms. In its best meaning expresses a qualitative relation of pixels in surrounding about greenery accessible to it.
2. Urban green spaces have a significant cooling effect except for areas with high built-up density and low proximity to vegetation density (VDP). The range of LST for different land use classes was as significant as 1.5 °C.
3. Relation between UGS and LST is clearly evident from above graphs, which is reciprocal in nature. This reciprocity however depends on proximity to built-up/vegetation density, built-up/vegetation density around considered area and also the rise of built-up in that area.

ABSTRACT

Urban Green Spaces (UGSs) are proving to be most important part of urban area of a city. These green spaces not only provide psychological comfort to humans but also affect heat impact on city to a vast level. In a developing country like India, where urban growth is happening in a very fast and haphazard manner a little consideration is given to Green Spaces in city. Such a study has been conducted over Lucknow metro-city of Uttar Pradesh state of India. In this study, the relation between Land Use\Land Cover (LULC) and Land surface temperature (LST) has been tried to find. Using Landsat-8 OLI data (Band 3, 4 & 5) and Maximum Likelihood Classification algorithm, 6 Land Use classes are obtained, which are “Built-up”, “Vegetation”, “Shrub”, “Water”, “Fallow Land” and “Other”. In addition to these 4 Land Cover Indices namely Normalized Difference Built-up Index (NDBI), Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Normalized Difference Barren Index (NDBaI) are also generated for same areas. LST is obtained using TIRS data (Band 10 & 11) and Split Window Algorithm by Radiative Transfer Equation. Ancillary data is used for digitization of 5 assembly constituencies (ACs) of Lucknow parliamentary constituency (PC) of Lucknow district namely, Lucknow Cantonment, Lucknow North, Lucknow East, Lucknow West and Lucknow Central has been done. River and Canal passing through these areas, are also considered in Urban Green Spaces as per Urban Atlas code 14100. 250m radius buffer is generated around Built-up pixels for analysis of impact of UGSs on LST. Cantonment and East Lucknow area having highest amount of UGSs in terms of “Vegetation”, “Shrub” & “Water” pixels due to presence of Forest area in both ACs. It is found that LST is positively related with all indices except for NDVI with strong negative correlation and R^2 of 0.47 and highest R^2 of 0.53 with NDBI. Among all 5 ACs best correlation between all 4 LC and LST values is found in Lucknow East AC with $R^2 > 0.64$ for NDVI, NDWI and NDBI. Lucknow East AC is having least LST but there is very little difference between LST values of Built-up pixels having minimum UGSs present in 250m radius buffer around built-ups and Built-up pixels having no UGSs around. AC Lucknow Central is having 1 °C difference in LST values of such different Built-ups.

REFERENCES

Agnihotri, A. K. (2018). Impact of Green Spaces on the Urban Microclimate through Landsat 8 and TIRS Data, in Varanasi, India. International Journal of Environment and Sustainability, 7(2).

Alavipanah, S., Wegmann, M., Qureshi, S., Weng, Q., & Koellner, T. (2015). The role of vegetation in mitigating urban land surface temperatures: A case study of Munich, Germany during the warm season. Sustainability, 7(4), 4689-4706.

Balogun, I. A., & Daramola, M. T. (2019). The impact of urban green areas on the surface thermal environment of a tropical city: a case study of Ibadan, Nigeria. Spatial Information Research, 27(1), 23-36.

Cetin, M. (2015). Using GIS analysis to assess urban green space in terms of accessibility: case study in Kutahya. International Journal of Sustainable Development & World Ecology, 22(5), 420-424.

Egorov, A.I., Mudu,P., Braubach, M. and Martuzzi, M. (2016). Urban green spaces and health. Copenhagen: WHO Regional Office for Europe.

Gao, J., & Liu, Y. (2008). Mapping of land degradation from space: a comparative study of Landsat ETM+ and ASTER data. International Journal of Remote Sensing, 29(14), 4029-4043.

Gupta, K., Kumar, P., Pathan, S.K. and Sharma, K.P. (2012). Urban Neighbourhood Green Index: An Measure of Green Spaces in Urban Areas. Landscape and Ur- ban Planning, 105 (3): 325-335.

Gupta, K., & Sharma, K. P. (2011). Functional Assessment of Urban Green Spaces- A GIS Analysis. In 12th Esri India User Conference.

Huang, J., Lu, X. X., & Sellers, J. M. (2007). A global comparative analysis of urban form: Applying spatial metrics and remote sensing. Landscape and urban planning, 82(4), 184-197.

Lang, S., Schöpfer, E., Hölbling, D., Blaschke, T., Moeller, M., Jekel, T., & Kloyber, E. (2008). Quantifying and qualifying urban green by integrating remote sensing, GIS, and social science method. In Use of landscape sciences for the assessment of environmental security (pp. 93-105). Springer, Dordrecht.

Li, Xi., Meng, Qi., Li, We., Zhang, Ch., Jancso, Ta. and Kangli, Wu. (2016). Modelling building proximity to greenery in a three-dimensional perspective using multi-source remotely sensed data. Journal of Spatial Science, 61:2, 389-403.

Li, Xi., Meng, Qi., Li, We., Zhang, Ch., Jancso, Ta. and Mavromatis, S. (2014). An explorative study on the proximity of built-ups to green spaces in urban areas using remotely sensed imagery. Annals of GIS, 20:3, 193-203.

Liu, Yu., Meng, Qi., Zhang, Ji., Zhang, Li., Jancso, Ta. and Vatseva, Ru. (2015). An effective Building Neighborhood Green Index model for measuring urban green space. International Journal of Digital Earth, 9:4, 387-409.

Naeem, S., Cao, C., Qazi, W., A., Zamani, M., Wei, C., Acharya, B., K., Rehman, A., U., (2018). Studying the Association between Green Space Characteristics and Land Surface Temperature for Sustainable Urban Environments: An Analysis of Beijing and Islamabad. International Journal of Geo-information, 7:38, 5-29.

Nero, B.F. (2017). Urban green space dynamics and socio-environmental inequity: multi-resolution and spatiotemporal data analysis of Kumasi, Ghana. International Journal of Remote Sensing, 38:23, 6993-7020.

Nimish, G., Bharath, H. A., & Lalitha, A. (2020). Exploring temperature indices by deriving relationship between land surface temperature and urban landscape. Remote Sensing Applications: Society and Environment, 100299.

Ruangrit, V., & Sokhi, B. S. (2004). Remote sensing and GIS for urban green space analysis—a case study of Jaipur city, Rajasthan, India. Journal of Institute of Town Planners India, 1(2), 55-67.

Sekertekin, A., & Bonafoni, S. (2020). Land Surface Temperature Retrieval from Landsat 5, 7, and 8 over Rural Areas: Assessment of Different Retrieval Algorithms and Emissivity Models and Toolbox Implementation. Remote Sensing, 12(2), 294.

Schopfer, E., Lang, S., and Blaschke, T. (2004). ”A green index incorporating remote sensing and citizen’s perception of green space”.

Sobrino, J. A., Jiménez-Muñoz, J. C., Sòria, G., Romaguera, M., Guanter, L., Moreno, J., & Martínez, P. (2008). Land surface emissivity retrieval from different VNIR and TIR sensors. IEEE Transactions on Geoscience and Remote Sensing, 46(2), 316-327.

Thiloi, D., Tuan P. A., Gupta K. (2015). Development of an Index for Assessment of Urban Green Spaces at City Level. International Journal of Remote Sensing Applications (IJRSA), Volume 5, 2015.

Unal, M., & Uslu, C. (2018). Evaluating and optimizing urban green spaces for compact urban areas: Cukurova District in Adana, Turkey. ISPRS International Journal of Geo-Information, 7(2), 70.

Wang, J., Meng, B., Fu, D., Pei, T., & Xu, C. (2018). Mapping Spatiotemporal Patterns and Multi-Perspective Analysis of the Surface Urban Heat Islands across 32 Major Cities in China. ISPRS International Journal of Geo-Information, 7(6), 207.

Woldegerima, T., Yeshitela, K., & Lindley, S. (2017). Characterizing the urban environment through urban morphology types (UMTs) mapping and land surface cover analysis: The case of Addis Ababa, Ethiopia. Urban ecosystems, 20(2), 245-263.

Yang, Chaobin, Xingyuan He, Ranghu Wang, Fengqin Yan, Lingxue Yu, Kun Bu, Jiuchun Yang, Liping Chang, and Shuwen Zhang. The effect of urban green spaces on the urban thermal environment and its seasonal variations. Forests 8, no. 5 (2017b): 153.

Yang, J., Zhao, L., Mcbride, J., & Gong, P. (2009). Can you see green? Assessing the visibility of urban forests in cities. Landscape and Urban Planning, 91(2), 97-104.

Yu, X.; Guo, X.;Wu, Z. Land surface temperature retrieval from Landsat 8 TIRS-comparison between radiative-transfer equation-based method, split window algorithm and single channel method. Remote Sens. 2014, 6, 9829–9852.

Zheng, Z., Zhou, W., Yan, J., Qian, Y., Wang, J., & Li, W. (2019). The higher, the cooler? Effects of building height on land surface temperatures in residential areas of Beijing. Physics and Chemistry of the Earth, Parts A/B/C, 110, 149-156.