Int. J. Adv. Multidiscip. Res. (2019). 6(7): 39-44

International Journal of Advanced Multidisciplinary Research
ISSN:2393-8870
www.ijarm.com
DOI:10.22192/ijamr Volume 6, Issue 7-2019

Research Article

DOI: http://dx.doi.org/10.22192/ijamr.2019.06.07.005

Agroforestry as a Solution Elicited from the Connection between Land Surface Temperature and Spectral Indices in Mymensingh, Bangladesh

Tarulata Shapla
Department of Agroforestry & Environmental Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh

Keywords

LST,
NDVI,
NDBI,
Landsat 8 OLI/TIRS,
Agroforestry.

Abstract

The current investigation assessed the relationship between the Land Surface Temperature (LST) in terms of vegetation and built-up indices in the Mymensingh district during the winter season using Landsat 8 OLI/TIRS. The lowest LST indicated in the study has been found within areas where vegetation was the highest/most dense while the highest LST was found in areas with increasing built-up. It was also found that LST-NDVI (R^2 = 0.74) and LST-NDBI (R^2 = 0.99) possess a negative and positive correlation respectively thus showing that the applied methods show efficient techniques to monitor and correlate the LST with the spectral indices. Although the phenomena of urbanization cannot be stopped entirely, however, it can be controlled through proper planning and stricter policies which can ensure adequate living for all the residents along with a balanced ecosystem. As a consequence of growing urbanization, there exists serious stress on vegetation therefore, the application of agroforestry technology on a large scale can ensure better living and improve socio-economic conditions.

Introduction

The earth has turned into an urban planet. Though urban takes up a small fraction of the total global land area, it holds more than 54% of its population. It has also been said that the urban population is expected to grow by over 2 billion by 2050 (United Nations, 2014). As a fundamental aspect of the climate, Land Surface Temperature (LST) drives the turbulent heat fluxes and outgoing long wave radiation at the interface between the atmosphere and land which is why it is commonly used for drought monitoring, soil moisture estimation and so on (Anderson et al., 2011). In fact, on several time scales, the LST exerts control over the energy partitioning into latent and sensible heat fluxes and is a strong indicator of trends in surface warming from climate change (Schneider and Hook, 2010).

To monitor almost all fields within the science domain, geospatial technology can be considered a useful modern method. By employing the spectral signature of land surface materials under various regions of wavelengths, satellite sensors such as Landsat have a significant role in determining the changes in the specific characteristics of these materials (Chen et al., 2006). The retrieval of LST from Thermal-Infrared (TIR) data provides spatial measurements that are continuous and can examine the thermal heterogeneity of the earth's surface along with the impact on surface temperatures as a result of natural and human-induced changes (Jin and Dickinson, 2010). Besides, a widely used spectral index in LST estimation is the Normalized Difference Vegetation Index (NDVI) which shows the condition and abundance of the green vegetation cover and biomass.

Moreover, the Normalized Difference Built-up Index (NDBI) is also invariably used in LST studies and provides information on the extent of urbanization and the land cover change with the higher values suggesting the existence of a more impervious surface and vice versa.

While regional and global climate changes can have an impact on changing the climate of the urban surface, urbanization is an evident aspect of human alteration of the natural landscapes and climate (Fan et al., 2017). Urbanization, the anthropogenically induced change in surface fluxes, not only increases the concentration of atmospheric greenhouse gasses and land use and land cover change but is also a key factor in driving the formation and evolution of urban climates. The rise in urban areas results in a major decrease in the vegetation cover which not only increases the LST but also results in the Urban Heat Island (UHI). Several studies have found that places have experienced the UHI effect a decade earlier than the global average (Briber et al., 2013; Carreiro et al., 2009). Unplanned urbanization also poses a major threat to the overall ecosystem and the environment.

As modern practices destroy natural flora and the local micro-environment, this results in more natural hazards thus, in order to bring back the ecological equilibrium, agroforestry can act as a critical solution as it stands next to forestry (Haque et al., 1996).

By definition, agroforestry is an agroecological approach to tackle complex problems of interactions between the woody perennial and other productive components of agriculture (Haque et al., 1996). The International Council for Research in Agroforestry (ICRAF) also made it clear that agroforestry is effective in unstable climatic events. This study aims to inform of the present situation of the land surface temperature as a result of climate change to propose nature-based solutions in terms of agroforestry for urban planners.

Study Area

The Mymensingh district, as part of the Mymensingh division, extends between 24°15' and 25°12' N and 90°04' and 90°49' E (Figure 1) with a total area of 4395 km^2. The district had a cumulative population of 5,110,272 in 2011 which is significantly higher than the 4,489,726 in 2001. The rural population and the urban population was at 4,312,145 (84.38%) and 798,127 (15.62%) respectively (BBS, 2015). The temperature in the area rises at the end of January and the highest temperature can be recorded between February to mid-March. According to BBS 2015, the average annual temperature in the district varies from a maximum of 33.3°C to a minimum of 12.0°C accompanied by an annual average rainfall of 2174 mm. Mymensingh city is also known for its rapid urban growth since the 1980s.

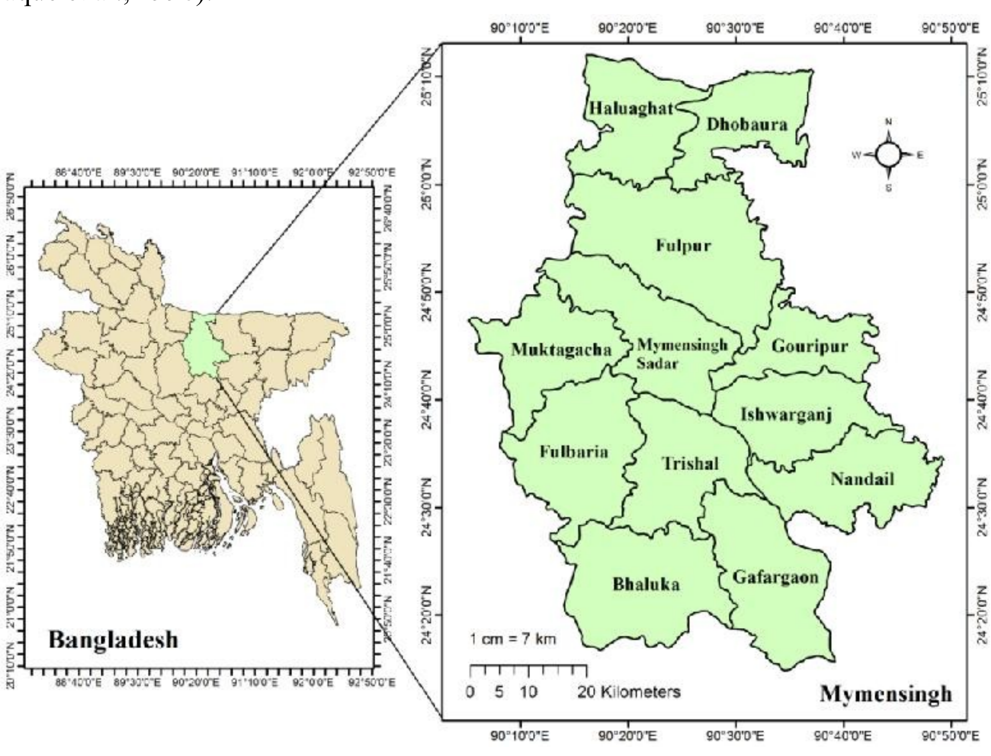

Figure 1: Location map of the study area showing the Mymensingh district highlighted in the map of Bangladesh

Methodology

Acquired from the USGS Earth Explorer, the band 10 of the Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) Level 1 satellite data used in this study was converted to spectral radiance using the radiance rescaling factors in the metadata file through equation (1). As the USGS recommended that users refrain from depending on the band 11 data in quantitative analysis such as the retrieval of surface temperature values due to the larger calibration uncertainty, only band 10 was used in this study.

$$L_\lambda = M_L Q_{cal} + A_L \qquad (1)$$

Where, L_λ corresponds to the spectral radiance; M_L and A_L stand for the band-specific multiplicative scaling factor and additive rescaling factor respectively and Q_{cal} is the quantized and calibrated pixel values of Digital Numbers (DN). Afterwards, using equation (2), the spectral radiance was converted to brightness temperature:

$$B_T = \left[{K_2}\Big/{\mathrm{In}\left(\frac{K_1}{L_\lambda}+1\right)} \right] - 273.15 \qquad (2)$$

Where, B_T refers to the top of atmosphere brightness temperature (˚C), L_λ corresponds to the spectral radiance and K_1 and K_2 stand for the band-specific thermal conversion constant. Spectral emissivity is a key factor considered during the LST calculation which was calculated using the NDVI-based method. At first, the NDVI was derived using equation (3) with bands 5 (NIR) and 4 (Red) of the Landsat 8 where the values of the NDVI image in this study were used to calculate the Proportion of Vegetation (P_{veg}) using equation (4).

$$NDVI = (NIR–RED/NIR+RED) \qquad (3)$$

$$P_{veg} = [(NDVI-NDVI_{min})/(NDVI_{max}–NDVI_{min})]^2 \qquad (4)$$

Where, the $NDVI_{min}$ and $NDVI_{max}$ refer to the minimum and maximum values from the NDVI images respectively. Using equation (5), the land surface emissivity (ε) was derived.

$$\varepsilon = 0.004 \text{ x } P_{veg} + 0.986 \qquad (5)$$

Where, P_{veg} refers to the proportion of vegetation. And lastly, the LST was derived using equation (6).

$$LST = \frac{B_T}{1 + ((\lambda\sigma B_T)/(hc))\mathrm{In}(\varepsilon)} \qquad (6)$$

Where, LST is the land surface temperature (˚C), B_T is the top of atmosphere brightness temperature (˚C), λ is the effective wavelength, σ is Boltzmann's constant (1.38×10^{-23} J/K), h is Plank's constant (6.626×10^{-34} Js), c is the velocity of light in a vacuum (3.00×10^{-8} m/s) and ε is the emissivity. Furthermore, the NDBI was calculated using equation (7) with bands 6 (SWIR 1) and 5 (NIR) as follows:

$$NDBI = (SWIR\ 1\text{- }NIR/SWIR\ 1+ NIR) \qquad (7)$$

Results and Discussion

It can be seen from figure 2 that the areas where the temperature ranges from 24.4°C to 31.5°C are also the corresponding areas where the NDBI values are the highest. It is also worth noting that the corresponding areas are on the lower spectrum of the NDVI. From figure 2(b), the sub-districts with regions having the highest temperature (25.9°C to 31.5°C) include Haluaghat, Dhobaura, Mymensingh Sadar, Muktagacha, Fulbaria, Bhaluka and Gafargaon. Areas with temperatures on the lower end include Fulpur, Gouripur, Ishwarganj and Nandail.

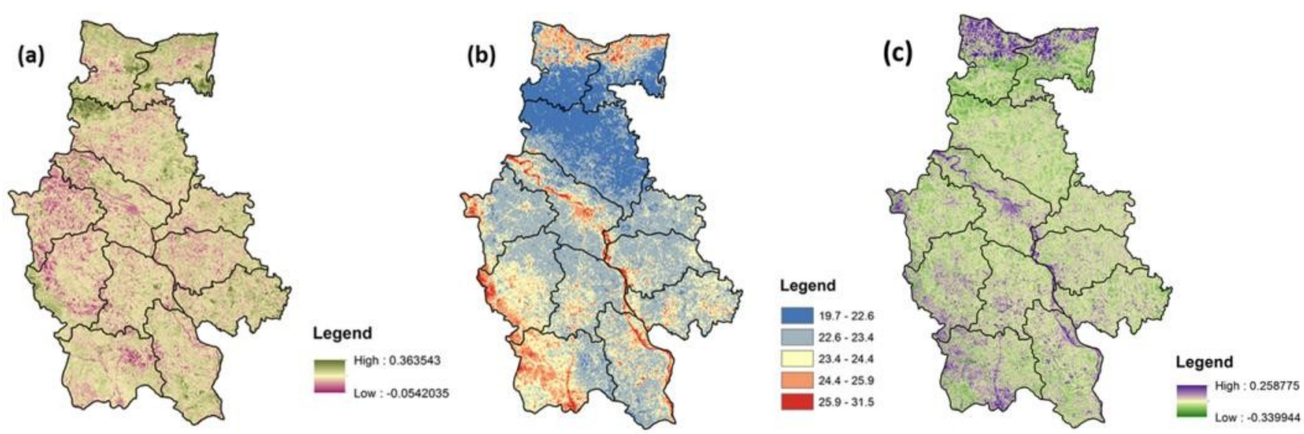

Figure 2: a) NDVI b) LST (˚C) and c) NDBI maps of the study area in February 2017 using Landsat 8 OLI and TIRS

Goward et al., (2002) found that the LST-NDVI correlation, irrespective of any season, was negative and that the value of the correlation coefficient was inversely related to the surface moisture content. This has also been shown in the present study (Figure 2a and 2b) where the regions with lower NDVI values show higher LST values and vice versa. As the NDVI values tend to be higher over mixed vegetation in comparison to other land cover types, the lower NDVI values that are seen scattered throughout the southern part of the district (Figure 2a) can be partly attributable to urban expansion which can lead to the loss of vegetation. Although LST varies in both temporal and spatial features, a drastic increase in LST is mostly observed in urban areas (Zhang et al., 2016). This is evident in figure 2 (b and c) where the areas with high built-up can be seen having the highest temperatures.

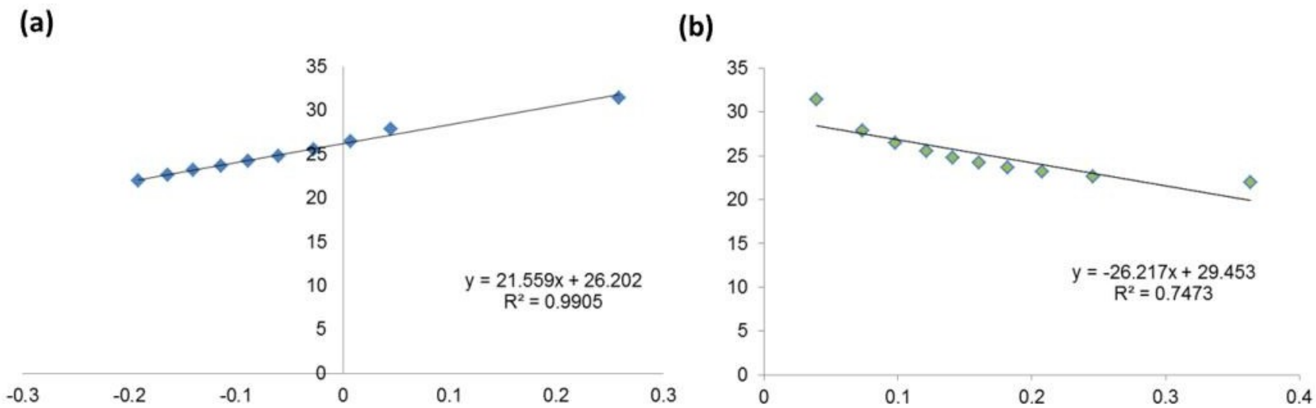

Figure 3: Correlation between a) NDBI and LST b) NDVI and LST.

Figure 3 shows the relationship between the two spectral indices and the LST where the independent variable for figure 3(a) and figure 3(b) is the NDBI and NDVI respectively and the dependent variable for figure 3 (a and b) is the LST. A strong positive correlation is seen in figure 3(a) with an R-squared value of 0.9905 suggesting how urbanization/built-up is contributing to increased surface temperature. Besides that, a moderate negative relationship is observed in figure 3(b) with an R-squared value of 0.7473 suggesting that vegetation could play a key role in reducing surface temperatures.

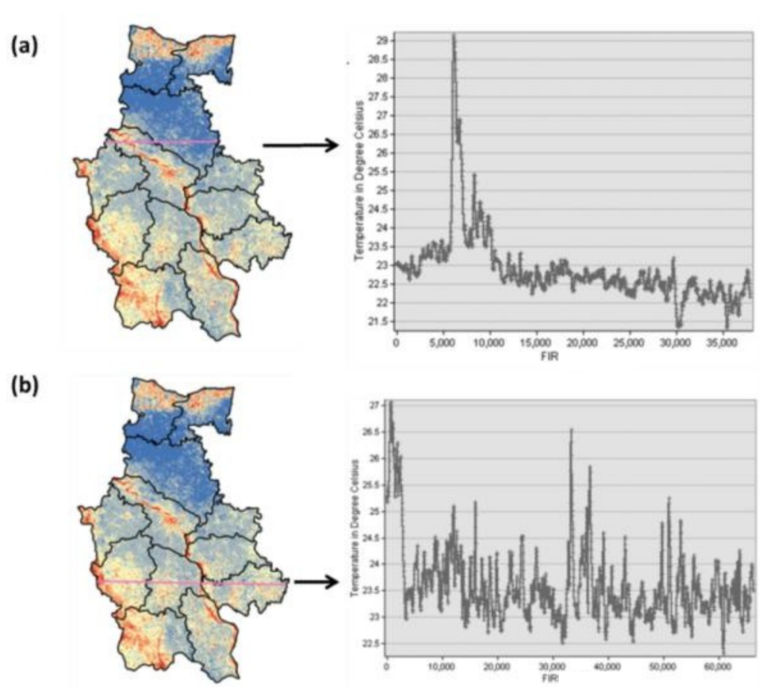

Figure 4: Cross profile generated with respect to the LST in Mymensingh during February 2017.

The combined pressures of uncertain and adverse climatic conditions and over exploitation have led to the degradation of ecosystems (Haque, 1996). With fewer areas falling under the lower end of the LST scale (<22.5°C) as seen in figure 4, agroforestry, as a promising technology, can make the environment much more favorable for precipitation, lowering water loss through evapotranspiration and keeping the micro-environment cooler through the absorption of water from deep soil (Haque et al., 1996). In different regions of the world, several agroforestry systems are being practiced. Some of the agroforestry systems are old and retain their form to a large extent while others have been modified considerably over the years. As a matter of fact, agroforestry systems are related to various ecological factors and can be classified based on important ecological parameters (*i.e.*, climatic, edaphic and physiographic) (Haque et al., 1996). Based on climate, agroforestry systems can be classified into temperate, tropical, sub-tropical, subalpine and alpine (Huxley, 1983). For instance, sub-tropical agroforestry systems consist of vegetation in suitable climatic conditions (agroforestry practices in the sub-tropical regions including Bangladesh). To check further deterioration in the environmental conditions, massive afforestation and appropriate agroforestry programmes should be taken up without delay (Haque, 1996). In fact it has been found that shaded surfaces through vegetation and trees can be 20–45°F (11–25°C) cooler than the peak temperatures of unshaded materials thus, evapotranspiration, alone or in combination with shading, could be useful in decreasing peak temperatures by 2–9°F (1–5°C) (Akbari et al., 1997; Kurn et al., 1994).

Conclusion

The climate around urban areas generally varies from its rural countryside as urban tends to be more polluted, warm, and less windy which leads to the understanding that the increase in temperature will be experienced to a larger extent in urban areas due to climate change. The rising urban temperatures will affect the development of the species community as a result of limited water and nutrients. In this study, the lowest LST values have been found in areas indicating dense vegetation through the NDVI index while the highest LST values were found in areas indicating dense built-up through the NDBI index in the Mymensingh district. Through the inverse relationship between vegetation and LST, it can be inferred that nature-based solutions have a key role to play and can create a sustainable habitat for the future. Depending on the climatic and socio-ecological contexts, vegetation in various forms can also contribute to various degrees of climate adaptation. To protect the physical environment from further degradation, appropriate agroforestry programmes can be adopted through the active participation of all kinds of agencies, farmers and residents. It is hoped that this study will bring light to the current situation in the Mymensingh district in regards to rising temperature as a result of climate change to help the urban planners and policymakers make better decisions for a more sustainable and eco-friendly place.

References

Anderson, M.C., Kustas, W.P., Norman, J.M., Hain, C.R., Mecikalski, J.R., Schultz, L., Gonzalez-Dugo, M.P., Cammalleri, C., d'Urso, G., Pimstein, A. and Gao, F. (2011) Mapping Daily Evapotranspiration at Field to Continental Scales using Geostationary and Polar Orbiting Satellite Imagery. *Hydrology and Earth System Sciences*, **15**, 223-239

Akbari, H., Kurn, D.M., Bretz, S.E. and Hanford, J.W. (1997) Peak Power and Cooling Energy Savings of Shade Trees. *Energy and Buildings*, **25**,139–148.

Bangladesh Bureau of Statistics. (2015) Population and Housing Census 2011. Zila Report (Mymensingh).

Briber, B.M., Hutyra, L.R., Dunn, A.L., Raciti, S.M. and Munger, J.W. (2013) Variations in Atmospheric CO_2 Mixing Ratios across a Boston, MA Urban to Rural Gradient. *Land*, **2**, 304-327

Carreiro, M.M., Pouyat, R.V., Tripler, C.E. and Zhu, W.X. (2009) Carbon and Nitrogen Cycling in Soils of Remnant Forests along Urban–Rural Gradients: Case Studies. In *the New York metropolitan area and Louisville, Kentucky Ecology of Cities and Towns: A Comparative Approach*, Cambridge University Press, New York. pp. 308-328

Chen, X.L., Zhao, H.M., Li, P.X. and Yi, Z.Y. (2006) Remote Sensing Image-based Analysis of the Relationship between Urban Heat Island and Land Use/Cover Changes. *Remote Sensing of Environment*, **104**, 133-146,

Fan, C., Myint, S.W., Kaplan, S., Middel, A., Zheng, B., Rahman, A., Huang, H.P., Brazel, A. and Blumberg, D.G. (2002) Understanding the Impact of Urbanization on Surface Urban Heat Islands—A Longitudinal Analysis of the Oasis Effect in Subtropical Desert Cities. *Remote Sensing*, **9**, 672.

Goward, S., Xue, Y. and Czajkowski, K. (2002) Evaluating Surface Moisture Conditions from the Remotely Sensed Temperature/ Vegetation Index Measurements– An Exploration with the Simplified Biosphere Model. *Remote Sensing of Environment*, **79**,225-242.

Haque, M.A. (1996) Dryland Agroforestry. In: Haque, M.A., Ed., *Agroforestry in Bangladesh*, Joint Publication, Bangladesh Agricultural University, Mymensingh and Swiss Development Cooperation, Dhaka, 71- 84.

Haque, M.A., Bhuiya, M.S.U. and Prodhan, A.K.M. A.U.(1996) Concept, Scope and Classification of Agroforestry. In: Haque, M.A., Ed., *Agroforestry in Bangladesh*, Joint Publication, Bangladesh Agricultural University, Mymensingh and Swiss Development Cooperation, Dhaka, 10-20.

Huxley, P.A. (1983) Comments on Agroforestry Classification with special reference to Plant Aspects. In: P.A. Huxley (ed.). *Plant Research and Agroforestry*. ICRAF, Nairobi.

Jin, M. and Dickinson, R.E. (2010) Land Surface Skin Temperature Climatology: Benefitting from the Strengths of Satellite Observations. *Environmental Research Letters*, **5**, 1-13.

Kurn, D., Bretz, S., Huang, B. and Akbari, H. (1994) The Potential for Reducing Urban Air Temperatures and Energy Consumption through Vegetative Cooling. United States. https://doi.org/10.2172/10180633

Schneider, P. and Hook, S.J. (2010) Space Observations of Inland Water Bodies show Rapid Surface Warming since 1985. *Geophysical Research Letters*, **37**.

United Nations World Urbanization Prospects: the 2014 Revision, Highlights Department of Economic and Social Affairs, New York, NY, USA (2014) https://esa.un.org/unpd/wup/CD-ROM/

United States Geological Survey. Landsat 8 OLI and TIRS Calibration Notices (January 29, 2014 - Landsat 8 Reprocessing to Begin February 3, 2014).

Zhang, Y., Balzter, H., Liu, B. and Chen, Y.(2016) Analyzing the Impacts of Urbanization and Seasonal Variation on Land Surface Temperature based on Subpixel Fractional Covers using Landsat Images. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, **10**, 1344-1356.

Access this Article in Online

Quick Response Code	Website: www.ijarm.com
	Subject: Environmental Remote Sensing

DOI:10.22192/ijamr.2019.06.07.005

How to cite this article:
Shapla, T. (2019). Agroforestry as a Solution Elicited from the Connection between Land Surface Temperature and Spectral Indices in Mymensingh, Bangladesh. *Int. J. Adv. Multidiscip. Res*. 6(7): 39-44.
DOI: http://dx.doi.org/10.22192/ijamr.2019.06.07.005