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Impact of Land Cover on Land Surface Temperature

A Remote Sensing Perspective

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ABSTRACT*: Heat Island Effect is a phenomenon where the temperature of urban areas grows warmer than the surrounding rural areas. Rapid urbanization has led to the increase in Urban Heat Islands due to the changes in vegetated land cover and deforestation. These influences are evident from the increased land surface temperature (LST). The study is aimed to explore the influence of landuse/landcover on the variations of land surface temperature, using the techniques of Remote Sensing. The study area chosen is Kannur district, which is one of the most urbanized districts of Kerala. The study reveals that there is strong negative correlation between LST and Normalised Difference Vegetation Index (NDVI). The study also shows thatLST is proportionate to the percentage of urban areas. The study concludes that introduction ofvegetative patches in the land cover, can be effective in alleviating the heat island effect.*

KEYWORDS: Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Remote Sensing, Urban Heat Island (UHI), ArcGIS

1. INTRODUCTION

Human activities after Industrial revolution had substantial environmental impact and resulted in issues like global warming and deforestation. Rapid increase of land temperature is one of the most immediate and obvious effects of global warning. According to temperature analysis conducted by NASA's Goddard Institute for Space Studies (GISS) the average global temperature has increased by about 0.8oC since 1880 (Global Change, 2019).

NASA researchers studying urban landscapes have found that the intensity of temperature in acity depends on the ecosystem and regional climate. Scientists first discovered the phenomenon called 'heat island effect' in 1800's when they observed cities growing warmer than surrounding rural areas. The urban heat island can raise temperatures within cities as much as 5oC than the surrounding rural areas (Donald Rapp, 2014). Unplanned and rapid development of urban areas lead to faster runoff from land and the cooling effects of water and landscape are reduced. This also leads to less evapotranspiration. Trees also provide shade, a secondary cooling effect in urban landscapes. Studies show that deforestation and change in vegetation cover has direct influence onland surface temperature and a consistent negative correlation exists between greenness and Land Surface Temperature (Friedman, 2015). Examination of the linkage between urban development and satellite derived land surface temperature provide a theoretical model of the dynamics of an urban thermal environment which is useful for urban planning and decision making (Deb, Kant, & Mitra, 2015).

Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) can be consideredto be basic indices to study the urban ecological and thermal environment using low cost and moderate spatial resolution imageries (Yue, Xu, Tan, & Xu, 2007). Therefore, this study tries to investigate this phenomenon of increase in land surface temperature and tries to answer the research question: "How and to what extend the change in landuse affect the land surface temperatures of a region?'

2. STUDY AREA SELECTION

Kannur is located in the state of Kerala along the west coast of India, between 11o40'23"N - 12o17'58"N and 75o10'7"E -75o56'23"E. Kannur district is bounded by Kasargod district to the north, Kozhikode district to the south and Wayanad district to the southeast, Western Ghats to the east and the Arabian sea to the west. Figure 1 shows the extend of Kannur District with a the study area of 2790 km2 (DTP-Govt of Kerala, 2011)

Kannur District falls under the warm humid climatic region of India and a rare humid tropical monsoon climate under the Koppen climate Classification (Am). The average low temperature varies from 21.5oC to 25.6oC and the average high temperature varies from 29.6oC to 34.4oC. The annual average rainfall of the area is 3320 mm with 111 average rainy days (IMD, 2015). Kannur is a highly urbanized area in Kerala, with more than 50% of its residents living in urban areas with a population of 2,32,486 (Das & Laya, 2016). This was the most urbanized district in Kerala in 2001.

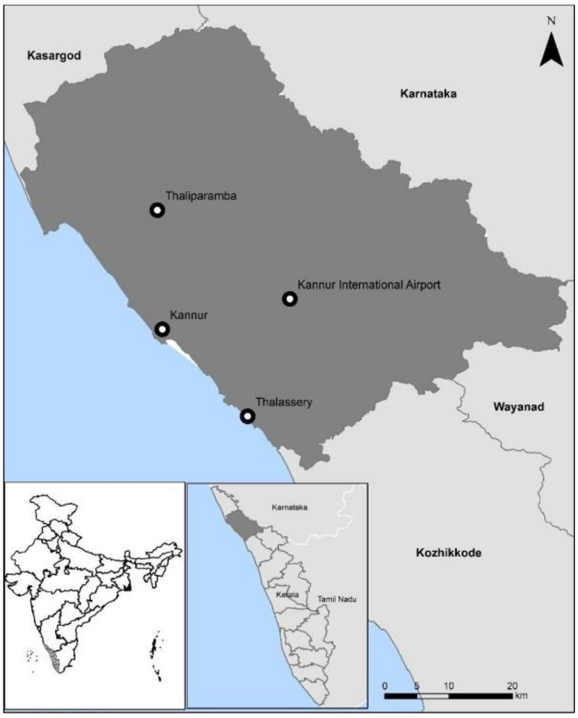

Figure 1 Extend of Study Area

3. METHODOLOGY

The methodology was adopted from a similar studydone by Chaithanaya et.al in 2017 (Chaithanya, Binoy,& Vinod, 2017). QGIS and SAGA GIs is used to carry outthe study. Framework of the methodology adopted inthis study is illustrated in Fig 2. Descriptions of each stage is provided in the following sections.

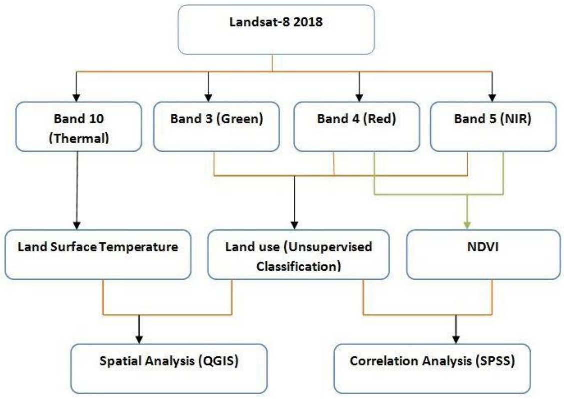

Figure 2 Methodology Framework

3.1. Satellite image acquisition from USGS

The Landsat 8 image of 28 November 2018 was downloaded from USGS website (USGS, 2018) with cloud cover less than 10% as shown in Fig 3. TheLandsat 8 Satellite payload consists of two science instruments: Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). These two sensors provide seasonal coverage of the global landmass at a spatial resolution of 30 meters. TIRS images are obtained in band 10 and 11. The projected coordinatesystem is WGS84/UTM 43 N.

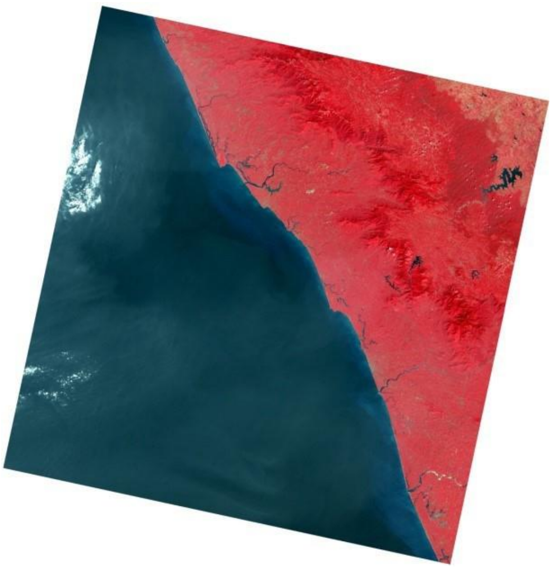

Figure 3 Landsat 8 image

Preparation of District boundary

DIVA-GIS is a free computer program for mapping and geographic data analysis. DIVA-GIS helps to make maps of the world, or of a very small area, like state boundaries, etc. DIVA-GIS also provide free spatialdata for the whole world that can be used in DIVA-GIS or other programs. The district boundary of Kannur district was downloaded from the DIVA –GIS website (Hijmans et al., 2004)

The district boundary downloaded from DIVA-GIS was overlaid on the image downloaded from USGS. The study area under consideration was clipped from the image with respect to the district boundary and a map was created.

3.2. Landuse Classification

The landuse landcover map of study area is shown in Fig 4. The proportion of various landuse is shown in Fig 5. The unsupervised classification was done using Band 3, Band 4 and Band 5.

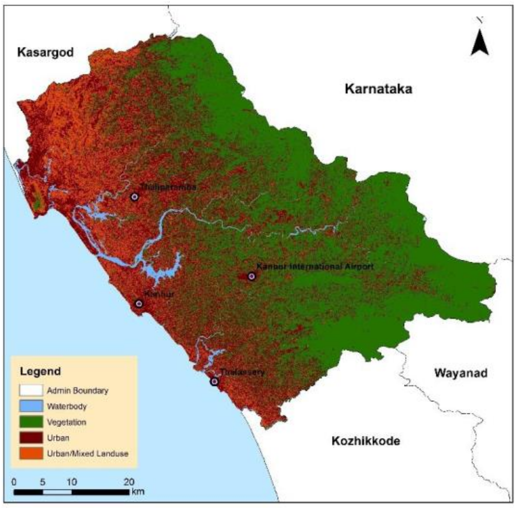

Figure 4 Landuse/Land cover map

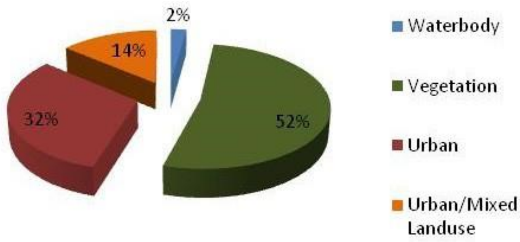

Figure 5 Area wise landuse break-up

3.3 Calculating Brightness Temperature

Land surface temperatures (LST) were derived from Landsat band 10 images as shown in Fig 6. The percentage of area under each temperature range is shown in Fig 7.

3.4 Calculating Normalized Difference Vegetation Index

Landsat allows for the derivation of the Normalized Difference Vegetation Index (NDVI) value which measures the greenness of vegetative cover. The NDVI Image of the study area is created in SAGA GIS as shown in Fig 8.

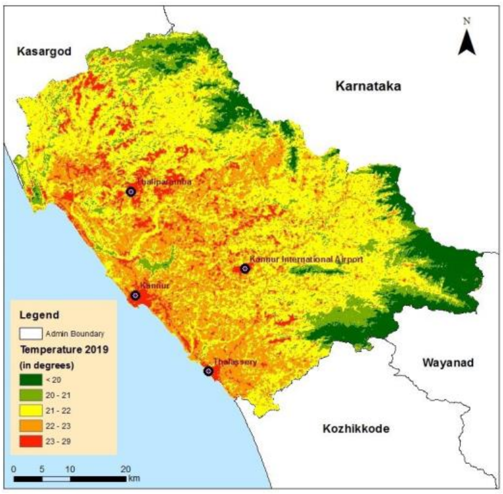

Figure 6 Land surface Temperature in 0C

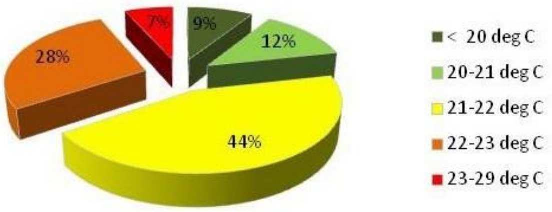

Figure 7 Percentage of Area under Temperature range

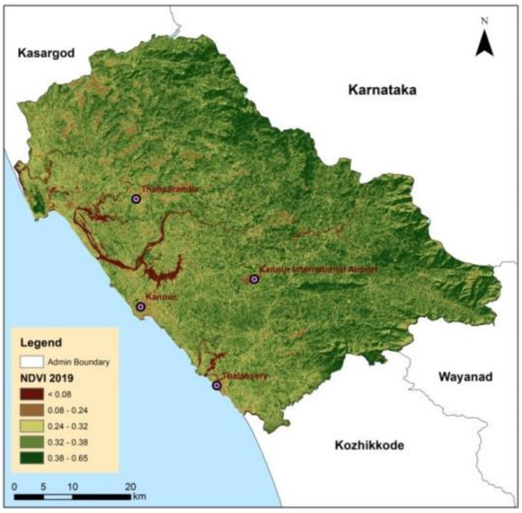

Figure 8 NDVI image

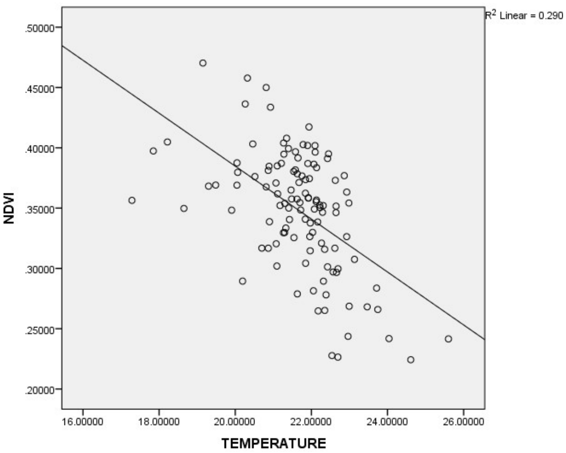

Figure 10 Relationship of LST and NDVI

3.5 Extracting Attribute Values

Regular Points were created in an interval of 5 km and was intersected with the study area in QGIS, which gave 119 random points in the study area as shown in Fig 9. The attribute values of the 114 random points were extracted from QGIS for further analysis.

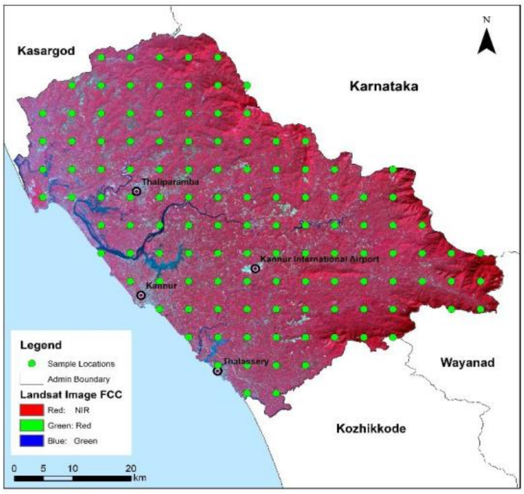

Figure 9 Map showing sample points

3.6 Analysis using SPSS

A statistical analysis of the correlation between vegetation parameters/indicators (NDVI) and the Land Surface Temperature (LST) can be significant in determining the impact of these parameters on Urban Heat Island characteristics of the region (Kumar & Shekhar, 2015). The attribute values (LST&NDVI) of 114 points were analyzed in SPSS to find out the correlation between them. The resulted correlation value -0.539 shows that the Land Surface Temperature (LST) is inversely proportional to vegetation cover.

Fig 10 shows the correlation of LST and NDVI in the study area for the year 2018. There is strong negative correlation between LST and NDVI values in Kannur District.

Table 1 Percentage of Landuse and Variations in Temperature

TEMPERATURE URBAN VEGETATION WATER

URBAN/MIXED BODY LANDUS

< 20^{0}C	0.52%	0.09%	99.30%	0.08%
20-21^{0}C	11.57%	5.99%	76.39%	6.05%
21 - 22 ^{0}C	27.22%	12.63%	57.07%	3.08%
22-23 ^{0}C	46.59%	23.16%	29.98%	2.17%
23-29 ^{0}C	76.15%	17.34%	6.23%	0.29%

4. RESULTS AND DISCUSSION

The results reinforce the initial understanding thatthe change in land use has a significant impact on the

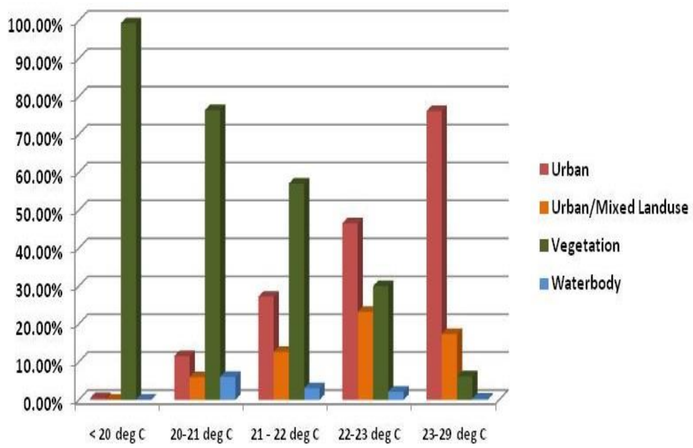

Figure 11 Percentage of landuse and variations in temperature

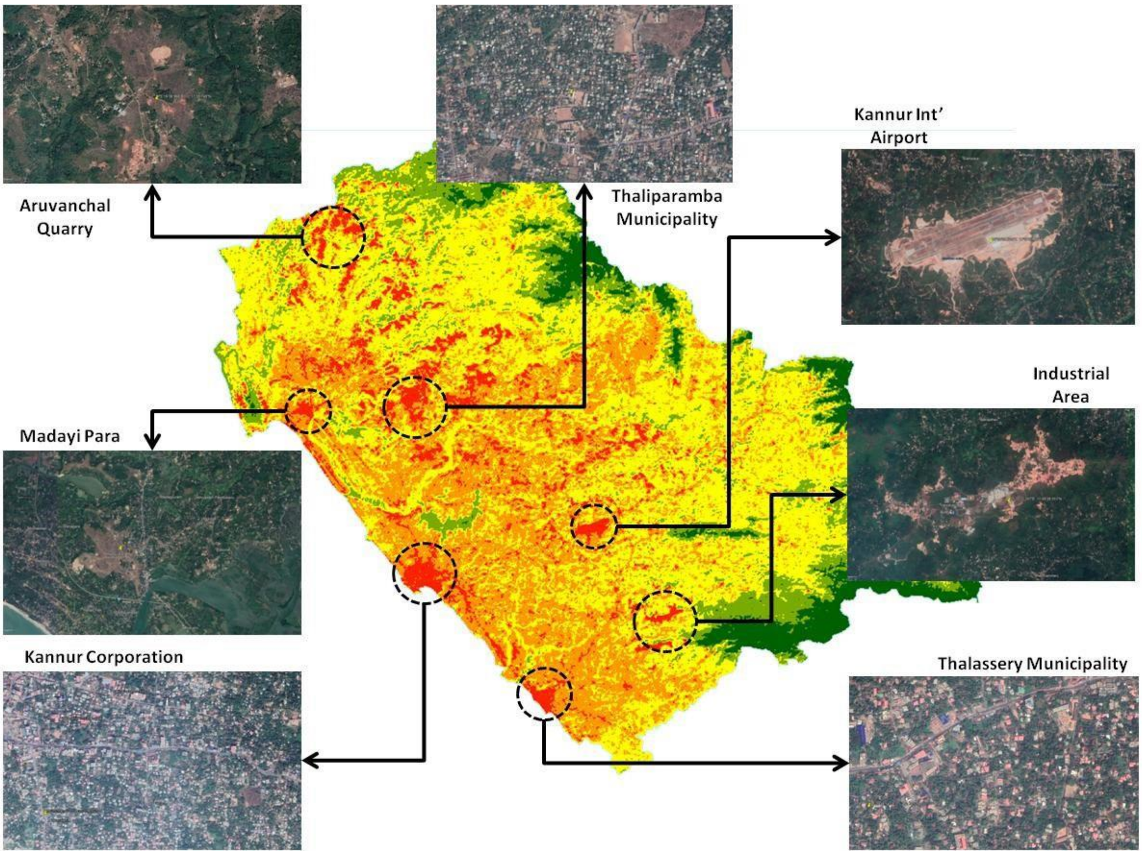

Figure 12 Identified area of visible Heat Islands

land surface temperature of an area. Table 1 and Fig 11 displays the relation between the percentage of landuse and the variations in temperature. 99.3% of areas with less than 200C are the vegetated land covers and only 0.52% of urban landuse area comes under this temperature range. At the same time, 76.15% of urban areas have a land surface temperature between 230 – 290C. Percentage of vegetated land area comingunder the highest temperature range is only 6.23%. This trend of increase in land surface temperature in urban areas clearly implies the impact of replacement of vegetated surface covers to hard land covers.

5. CONCLUSION

The study reveals that there is strong negative correlation between LST and NDVI. LST is found tobe directly proportional to the percentage of urban area and inversely proportionate to the percentage of vegetated areas. The study concludes that introductionof vegetative patches in the land cover, can alleviate the heat island effect. The impact of NDVI and LST on rainfall in highly populated and deforested areas is leftfor future research.

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