

Original Research Article

Land Surface Temperature Analysis of Kigali City

Abstract

This paper entitled land surface temperature analysis in Kigali city is established to analyze the change in temperature due to the cover in place and inform everyone to take care of land cover. The study was conducted in Kigali city by using land sat image of 2015.

Method

The modification and transformation of land cover in a city affect an evapotranspiration process, storage, and emission of the heat in the urban environment. Therefore, to retrieve Land surface temperature in Kigali City was done by calculating at satellite brightness from TOP radiance, calculating land surface emissivity from the proportion of vegetation, finally to convert at satellite brightness temperature to land surface temperature. Land cover detection was done by analyzing Landsat 8 OLI-TIRS using supervised classification technique in the help of ERDAS imagine 2014 software; NDVI and NDBI were calculated by using argis10.3 and finally shape file of Rwanda administrative boundary was used to delineate the study area boundary.

Results and discussion

The correlation between numerical values of LST, NDBI, NDVI and overlapping of land cover to LST map show that there is an increase in land surface temperature with an increase of NDBI and there is a decrease when NDVI increase. Then by overlapping LST to land cover of Kigali city shows that where vegetation is not concentrated imprecate the increase of land surface temperature.

Conclusion

The study of land surface temperature distribution in Kigali city results in informing the urban planners, urban designers and policymakers for successful mitigation measures of temperature increase by improving the land cover and landscape.

Key word Land Surface Temperature, NDVI, NDBI, Land cover, Land surface emissivity

1. Introduction

Urban area in Rwanda is defined as a built up agglomeration which exceeds 20 km² and has a population more than 10000 inhabitants, resulting in a population density more than 500 persons/km², City is with at least 200000 inhabitant [1]. Finally urban areas are built up areas with a considerable amount of man-made infrastructure and population, mainly depend on service based income rather than agricultural

based occupations [2]. From the above statement vegetation land cover are being converted to the impervious surface by man-made activities and the Land surface temperature changes according to the cover present in the area.

Urban heat island is a phenomenon that the Land surface temperature in urban areas is apparently higher than in rural areas [3], [4, 5]. Land use and land cover (LULC) change associated with urbanization is an essential cause of global change and often results in remarkable urban heat island effect, which will influence the regional climate and socioeconomic development [6].

The modification and transformation of land cover over the time in a city affects evapotranspiration process, storage and emission of the heat in the urban environment.

Therefore, to retrieve Land surface temperature in Kigali City, land cover detection was done by analyzing Landsat 8 OLI-TIRS using supervised classification technique in help of ERDAS imagine 2014 software; NDVI and NDBI were calculated by using argis10.3; finally, the shape file of Rwanda administrative boundaries was used to get the study area boundary.

Understanding of how patterns of land development and land use spatial distribution affect the formation of urban heat islands can inform urban design and planning practices, and lead to successful mitigation of temperature extremes [7].

1.2. Study area description

*Kigali City is the capital city of Rwanda. **Kigali City** has an administrative area of 730km² which includes a mix of urban and rural land uses. Its coordinate is (1.9706° S, 30.1044 ° E), its elevation is 1567 m and roughly located in the center of the country. It has three districts named Nyarugenge, Kicukiro and Gasabo; population of kigali city is 1318000 million.*

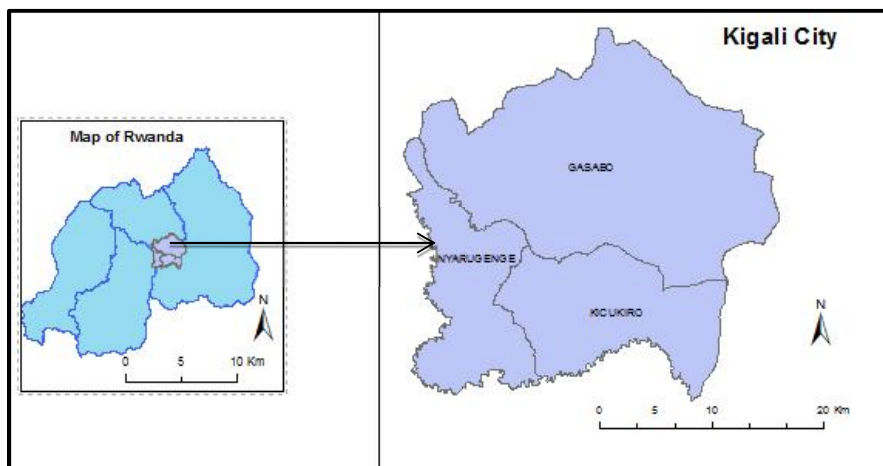
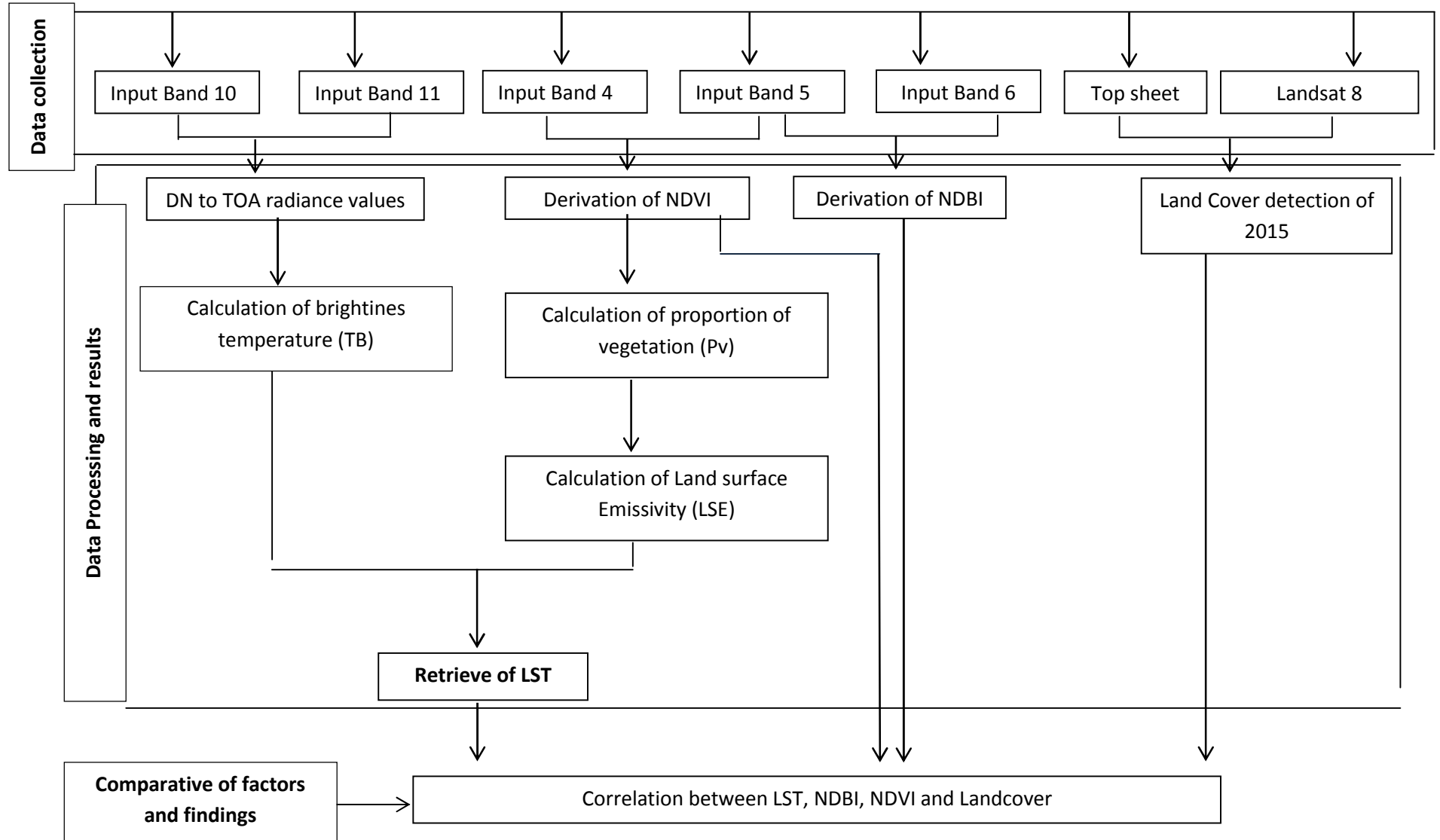


Figure1: study area map

1.3. Data and Methods

To carry out this research, Landsat 8 OLI/TIRS data are widely used, shape file of Rwanda administrative boundaries, Landsat visible and near infrared bands at 30 m resolution are capable of capturing signals of land cover and vegetation properties, while thermal bands at 60 m resolution are sensitive to surface temperature. By using ERDAS Imagine 2014 and Argis 10.3 software for pre-processing and processing. Finally for analysis zonal statistics tools from Arcgis was used.

Flowchart Methodology



2. Data collecection and prococessing

2.1. Landsat 8 Image data

Landsat 8 OLI/TIRS image were aquired from United States Geological Survey (USGS) under clear atmospheric condition with 0% of cloud, and 30 metes of resolution. By using ERDAS Imagine 2014; 30 m resolution were enhanced to 15 m resolution into 3 steps. Step1: layer stack of band 1,2,3,4,5,6 and 7. Step 2 is resolution marge by using multispectral image and panchromatic band 8 using pan sharpening tools. Last step is to subset and get an image to be used for scientific analysis.



Figure 2: Landsat 8 of Kigali city,2015

Table 1: Landsat 8 characteristics

LANDSAT 8 CHARACTERISTICS	
Sensor ID	OLI-TIRS
Map Projection	WSG 84
UTM Zone	36 S
Path	172
Low	61
Data Acquired	07-12-15
Cloud Cover	0
Grid Cell size Panchromatic	15
Grid Cell size reflective	30
Grid Cell size Thermal	30
Resolution for visible band and infrared	30
Resolution for thermal band	30

2.2. Landcover detection

Landsat 8 OLI/TIRS, 2015 of Kigali city were used for assessing landcover detection and Landcover map were generated by using supervised classification with maximum likelihood classifier methods. the smilar pixels were grouped following the landcover and finally general images were reclassified to increase the accuracy classification.The whole process was conducted by using ERDAS Imagine 2014 and Arcgis 10.3, and the findings are presentated in the tables 2 bellow.

Supervised Classification/ Landsat 8- 2015				
Land cover	Counts	pixel size	Area (Km ²)	%
Water Body	34408	225	8	1
Vegetation	1552056	225	349	48
Built up	428781	225	96	13
Bare soil	1229270	225	277	38
Total			730	100

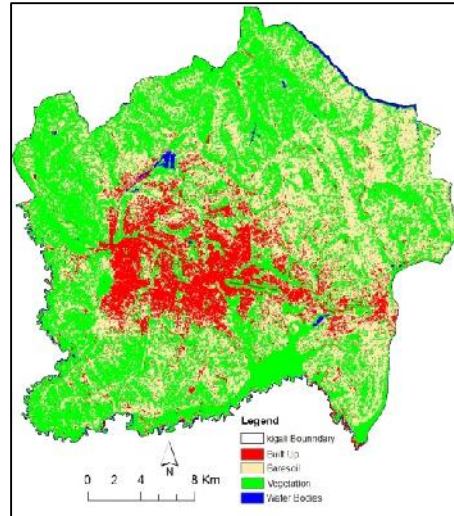


Figure 3: Land use/land cover map of Kigali City, 2015

The supervised classification shows that the vegetation occupies a big part of Kigali City followed by bare soil. Landsat 8 image used to detect land cover was acquired in July 2015 and it is dry season in Rwanda, this reflects the increase of bare soil because the crops are already harvested, vegetation and greenness decrease.

The built up land has a big implication on the increase of Land surface temperature due to the impervious material and non environment friendly construction materials used. Those impervious surfaces modify the urban air and water resource by reducing evapotranspiration and infiltration rate. Therefore, affect water table recharge and Land Surface emissivity increases; finally Urban heat Island is assisted considerably.

3. Land surface temperature (Data processing)

The procedure used to derive Land Surface Temperature from Landsat 8 OLI/TIRS, 2015 is discussed stepwise.

3.1. Step I: Determination of TOA radiance values

OLI and TIRS band data are converted to Top Atmospheric (TOA) Spectral radiance by using the radiance rescaling factors provided in the metadata file. The value of TOA Spectral Radiance was calculated by converting DN and TIRS into atmospheric Radiance by using equation 1 [8].

$$L_{\lambda} = M_L * Q_{cal} + A_L \quad \text{(equation 1)}$$

Where by:

L_{λ} = Top Atmospheric spectral radiance [watts/(m²*S rad*μm)].

M_L = Band specific multiplicative rescaling factor from metadata or Radiance Multiplier,

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

A_L = Band specific additive rescaling factor from the metadata.

3.2. Step II: Calculate at satellite brightness temperature

OLI and TIRS band data are converted from spectral radiance to Top of Atmospheric Brightness temperature using the thermal constant provided in the metadata file by following equation two [8];[9];[10]

$$T_B = \frac{K_2}{\ln \left(\frac{K_1}{L_{\lambda}} + 1 \right)} \text{ to be converted from kelvin to degree celsius by adding } (-273.15) \quad \text{equation 2}$$

Where by:

T_B = top of atmosphere brightness temperature (K)

L_A = Top Atmospheric spectral radiance [watts/(m²*S rad*μm)].

K_2 = Band specific thermal conversion constant from the metadata file

K_1 = Band specific thermal conversion constant from the metadata file

3.3. Derivation of NDVI

Vegetation factors or indices help in determination the distribution of vegetation on the surface based on the reflectance characteristics patterns of vegetaion. The NDVI is a numerical indicator used to analyze the remote sensing measurements from a remote platform in consideration and investigate the existance of live and non living green vegetation [11].

NDVI is an index used to evaluate the condition of vegetation and crops by using remote sensing analysis techniques. Healthier vegetation reflects most near infrared light.

$$NDVI = \frac{NIR - RED}{NIR + RED} = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4} \quad \text{equation 3}$$

NIR= Near Infrared

1.1.1 calculation of proportion of vegetation(Pv) [12]

$$P_V = \left(\frac{NDVI_{max} - NDVI_{min}}{NDVI_{max} + NDVI_{min}} \right)^2 \quad \text{equation 4.}$$

Where by:

NDVI_{max}: Normalized Difference Vegetation Index maximum for vegetation

NDVI_{min}: Normalized Difference Vegetation Index minimum

3.4. Step III: Retriviell of Land Surface Emissivity

Land Surface Emissivity (LSE) is an essential parameter to describe the radiative absorption power of the surface in the longwave radiation spectrum. Land Surface Emissivity depends on the target surface top layer composition, such as presence of soil type,vegetation, and density[13]. LSE is an essential criteria in determining the land surface temperature(LST). LSE is determined by using the equation 5 [14].

$$LSE = 0.004 * P_V + 0.986 \quad \text{equation 5}$$

3.5. Step IV: Derivation of Land Surface Temperature (LST)

At this stage we are ready to convert the At satellite brightness temperature to Land Surface Temperature using equation 6[15];[14]

$$T = \frac{T_B}{\left(1 + \left(\lambda * \frac{T_B}{C_2}\right) * \ln(LSE)\right)} \quad \text{equation 6}$$

λ = Wavelength of emitted radiance

$C_2 = h * c / s = 14388 \mu_m K$

H = Planck's constant=6.626*10⁻¹⁴ J/K

C = velocity of light=2.998*10⁸m/s

3.6. determination of NDBI

NDBI indices allow us to delineate built-up area; is an useful measure of intensity of imperviousness [16]. It shows the urban area distribution by chacking on the reflectance in the short wave infrared band in comparison to the near infrared band [17]. NDBI is calculated using equation 7.

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} = \frac{Band\ 6 - Band\ 5}{Band\ 6 + Band\ 5} \quad \text{equation 7}$$

Where by:

SWIR: Short Wave Infrared

NIR: Near Infrared

4. Results and disccusion

Maximum temperature detected is 30°C and the minimum temperature is 16°C. NDVI is minimum in the urban area and increasing toward the periphery except where the land cover is bare soil. Therefore the correlation between numerical values of LST, NDBI, and NDVI illustrated on figure and maps 4,5,6 & 7 and overlapping of land cover to LST map illustrated on figure 3 & 8 show that there is an increase in land surface temperature with an increase of NDBI and there is a decreases when NDVI increases. Then by overlapping LST to land cover of Kigali city show that where vegetation is not concentrated imprecate the increase of land surface temperature.

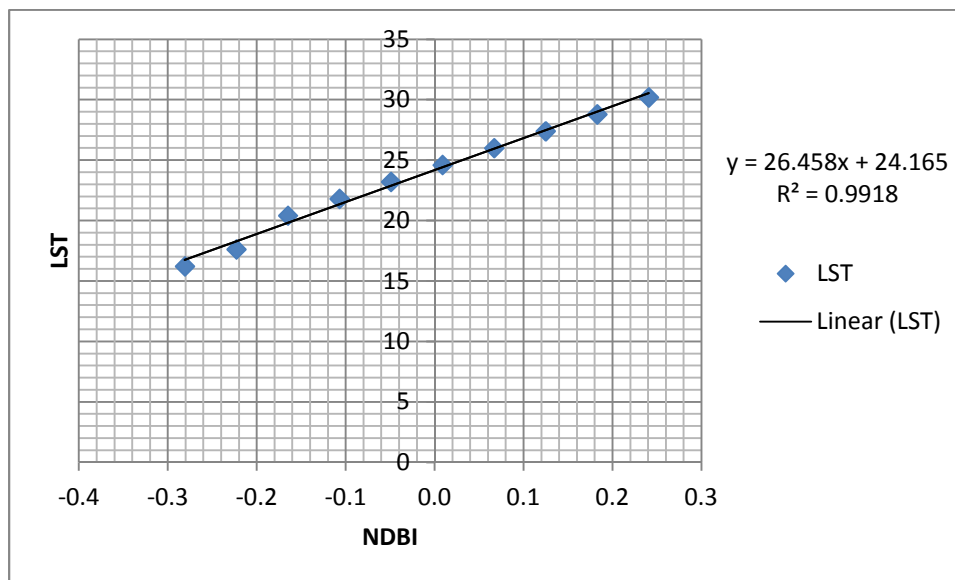


Figure 4: Graph of NDBI, 2015

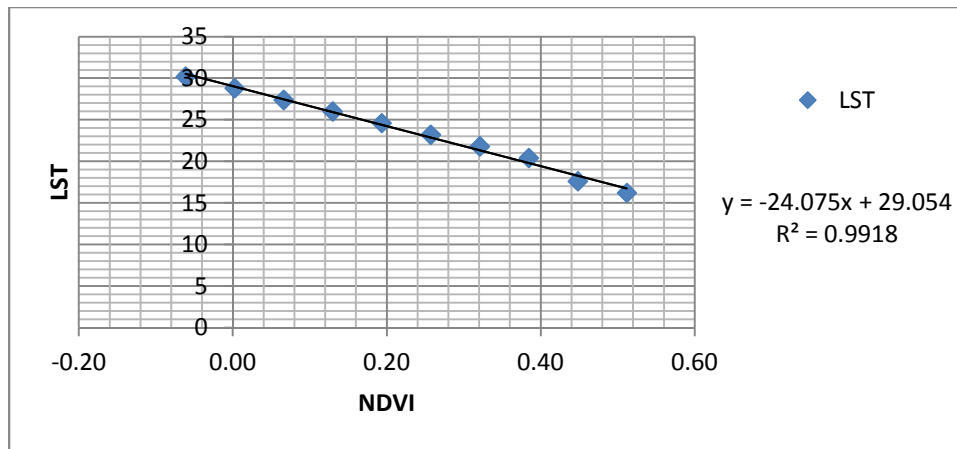


Figure 5: Graph of NDVI, 2015

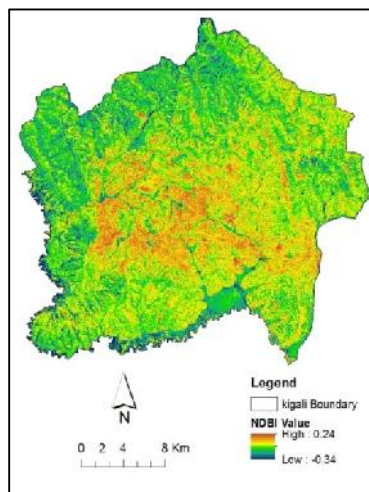


Figure 6: NDBI map, 2015

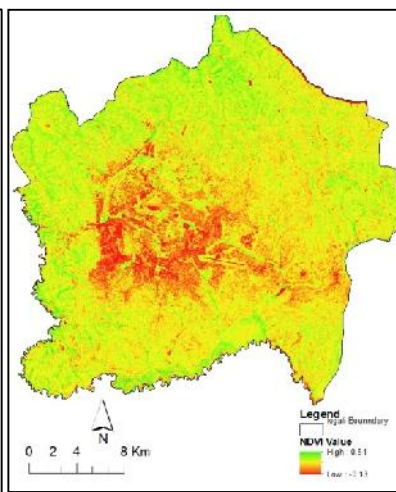


Figure 7: NDVI Map, 2015

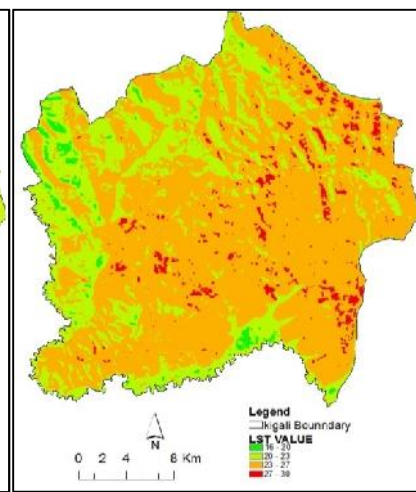


Figure 8: LST Map, 2015

5. conclusion

This paper analyses the temperature in Kigali city using calculation at satellite brightness from TOP radiance, calculating land surface emissivity from the proportion of vegetation and finally comparison of factors and findings. Hence, based on the results obtained in this paper, land surface temperature is maximum in the city center where NDBI is concentrated and NDVI is less concentrated. This shows that if there is a change in land cover it affects different factors and lead to the increase of land surface temperature. Thus, Land surface temperature distribution in Kigali city inform the urban planners, urban designers and policymakers for successful mitigation measures of temperature increase by improving the land cover and landscape including greenery where is necessary for sustainable future of city dwellers.

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