



Land Surface Temperature Analysis of Kigali City

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The 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 remote sensing technique. The study design is shown on the follow chart.

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, 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.

Land cover classification results show that, the area is dominated 48% vegetation, 38% bare soil, 13% built up and 1% water with the overall accuracy assessment of 95.7% and Overall Kappa Statistics 0.94. Maximum land surface temperature is 30⁰C and lowest is 16⁰C.

The correlation between numerical values of LST, NDBI, NDVI and overlapping of land cover to LST map show that there is a positive correlation between NBDI and LST and negative correlation

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between NDVI and LST. This indicate that, there is an increase in land surface temperature with an increase of NDBI and there is a decrease if 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.

The study of land surface temperature in Kigali city help to understand that land cover in place may play a big role on microclimate distribution. Therefore informs the urban planners, urban designers and policymakers for successful mitigation measures of temperature increase by improving the land cover and landscape.

Keywords: 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 [3-5]. 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 process of urbanization play a big role in the modification and transformation of natural land cover over the time in a city into buildings, roads, parking and impervious surfaces [7] and affects evapotranspiration process, storage and emission of the heat in the urban environment. Urban heat Island phenomena had been

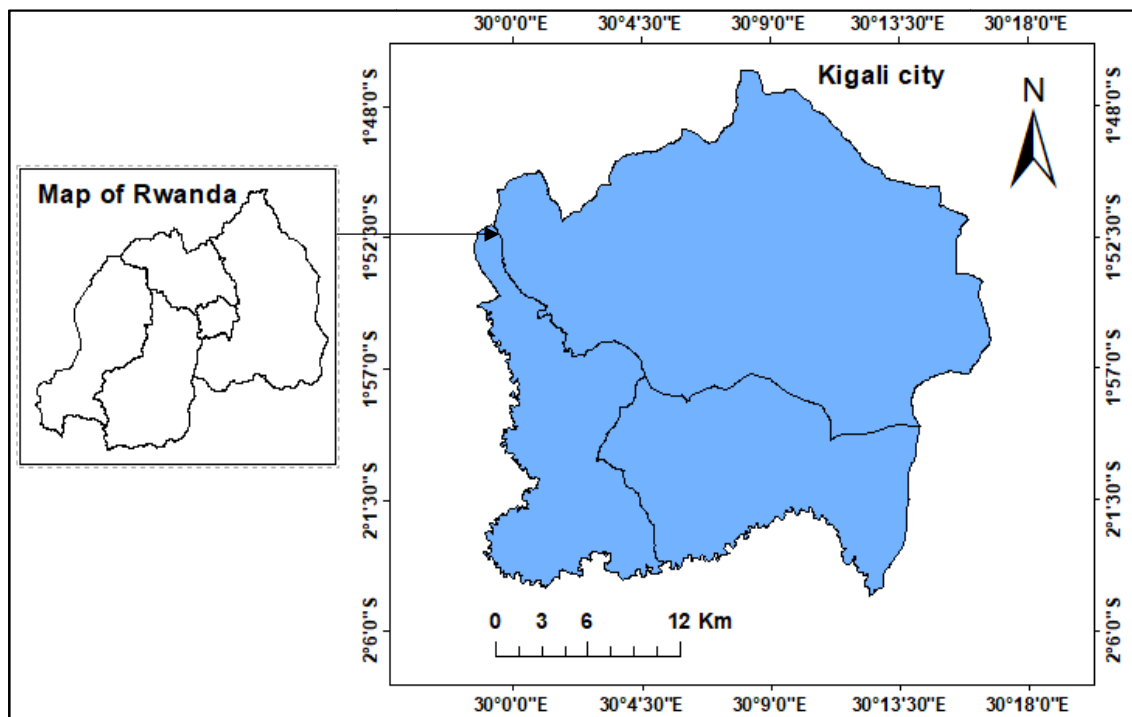


Fig. 1. Study area map

documented in different articles by using co-relationship between land surface temperature vs multiple vegetation indices and land use/cover factors [5,8-11].

Therefore, to retrieve Land surface temperature in Kigali City, land cover detection and accuracy assessment 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 [12].

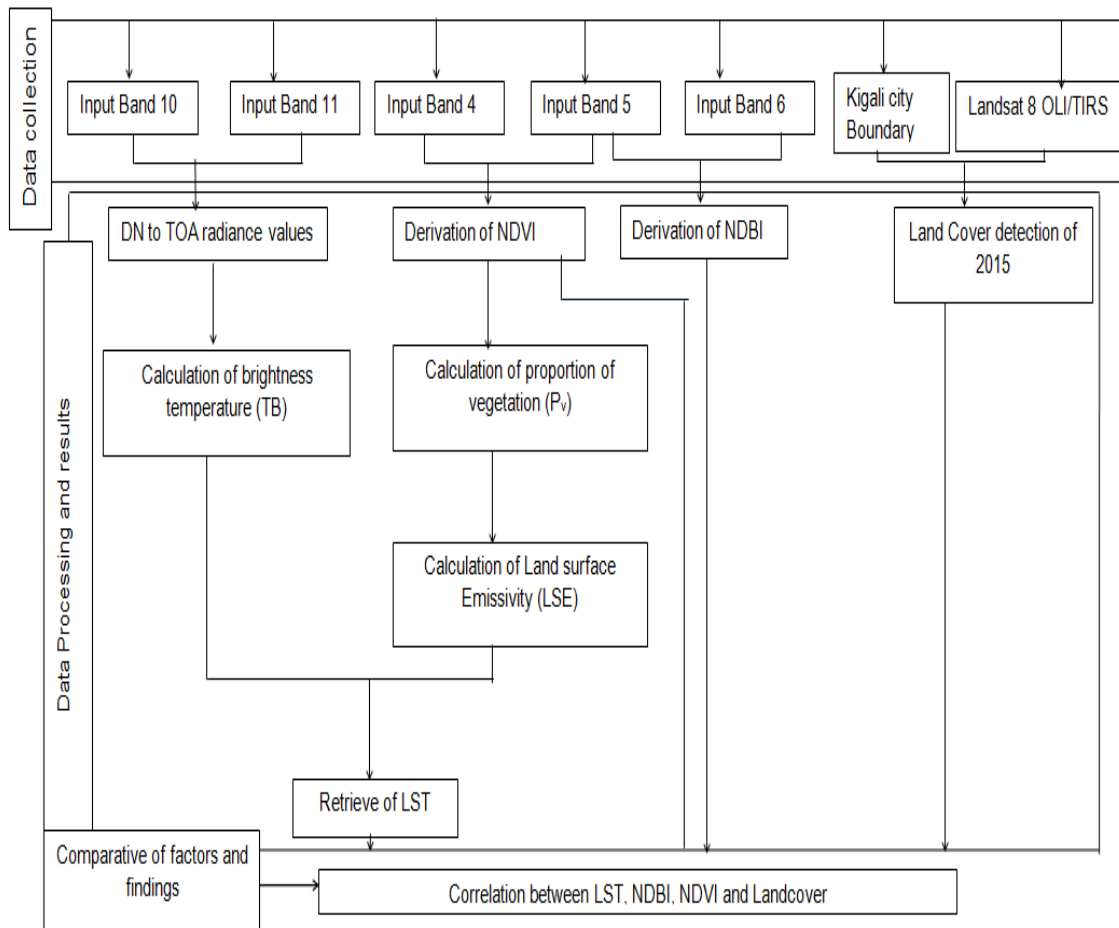
1.1 Study Area Description

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.

2. METHODOLOGY

To carry out this research, Landsat 8 OLI/TIRS data are widely used, shape file of Rwanda administrative boundaries, Landsat visible and

Flowchart Methodology/ Study design:



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 Arcgis 10.3 software for pre-processing and processing. Finally for analysis zonal statistics tools from Arcgis was used.

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.

Table 1. 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
Cloud Cover-Land	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 Land Cover Detection

Landsat 8 OLI/TIRS, 2015 of Kigali city were used for assessing landcover detection, thus landcover map were generated by using supervised classification with maximum

likelihood classifier methods. The smilar pixels were grouped together 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 Table 2 bellow.

The training sample are pixels of land cover classes and for the study, the combination of R,G,B, L(8)-7,5,3, were used where by this combination provides a "natural-like" rendition, while also penetrating atmospheric particles and smoke. Vegetation is green, water is blue, bare soil is pink or white Urban areas or built up appear in varying shades of magenta. The results and accuracy assessment report are tabulated in Table 2 and Table 3 respectively with the overall classification accuracy of 95.70%.

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 reflect the increase of baresoil because the crops are already harvested, vegetation and greenness decrease.

The error matrix resulting from classifying training set pixels shows how the many pixels of know class are incorrectly classified as error of omission. Illustrating from the Table 3 shows how classification job was perfermed and how accurate is. It is usually done by comparing the classification product with reference data that is believed to reflect the true land cover accurately. The accuracy assessment report is discussed in Table 4.

Comparing the overall accuracy calculated by summing the number of pixels classified correctly and dividing by the total number of pixels and the value of kappa which more than 0.80 show that it's almost very much accurate in classification.

Table 2. land cover classes

Land cover	Supervised Classification/ Landsat 8- 2015			
	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

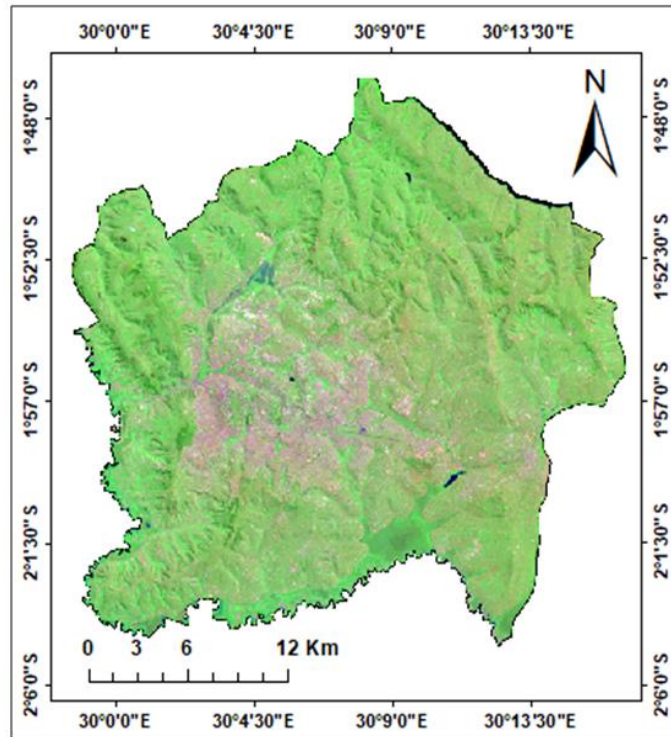


Fig. 2. Landsat 8 of Kigali city,2015

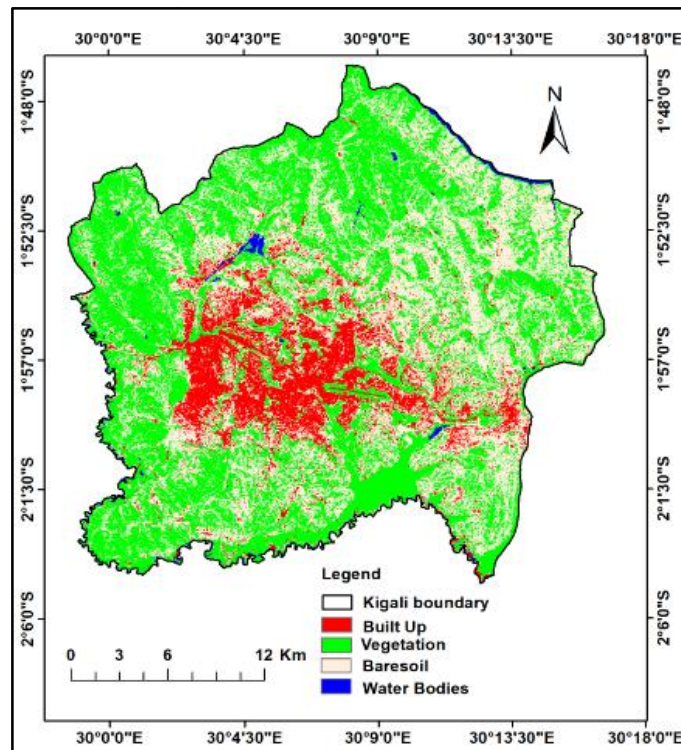


Fig. 3. Land cover map of kigali city,2015

Table 3. Confusion matrix

	Unclassified	Bare soil	Built up	Vegetation	Water Body	Total classified
Unclassified	85	0	0	0	0	85
Bare soil	1	51	1	6	0	59
Built up	0	0	19	1	0	20
Vegetation	0	1	0	88	0	89
Water Body	0	0	0	1	2	3
total	86	52	20	96	2	256

Table 4. Accuracy assessment report

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Bare soil	52	59	51	98.08%	86.44%
Built Up	20	20	19	95.00%	95.00%
Vegetation	96	89	88	91.67%	98.88%
Water body	2	3	2	100%	66.67%

Overall Classification Accuracy = 95.70%

Table 5. Kappa statistics

Class Name	Kappa
Bare soil	0.8298
Built Up	0.9458
Vegetation	0.9820
Water Bodies	0.6640

Overall Kappa Statistics = 0.9391

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.

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 [13-15].

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

to be converted from kelvin
to degree celsius by adding (-273.1) (1)

Where by:

T_B = top of atmosphere brightness temperature (K)

L_λ = 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

2.3 Data Processing

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

Step I: Detemination 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 metada file. The value of TOA Spectral Radiance was calculated by converting DN and TIRS into atmospheric Radiance by using equation 1 [13].

$$L_\lambda = M_L * Q_{Cal} + A_L \tag{1}$$

Where by:

$$L_\lambda = \frac{\text{Top Atmospheric spectral radiance Watts}}{m^2 * Srad * \mu m}$$

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 [16].

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.

$$NDVI = \frac{NIR - RED}{NIR + RED} = \frac{Band5 - Band4}{Band5 + Band4} \quad (2)$$

NIR= Near Infrared

Calculation of proportion of vegetation(Pv) [17]

$$P_v = \left(\frac{NDVI_{max} - NDVI_{Min}}{NDVI_{Max} + NDVI_{Min}} \right)^2 \quad (3)$$

Where by;

$NDVI_{Min}$: Normalized Difference Vegetation Index maximum for vegetation
 $NDVI_{Max}$: Normalized Difference Vegetation Index minimum

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[9]. LSE is an essential criteria in determining the land surface temperature(LST). LSE is determined by using the equation 5 [18].

$$LSE = 0.004 * P_v + 0.986 \quad (4)$$

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. [19,18].

$$T = \frac{TB}{(1 + (\lambda * \frac{TB}{C_2}) * l_n(LSE))} \quad (5)$$

λ = Wavelength of emitted radiance

$$C_2 = h * \frac{C}{S} = 14388 \mu K$$

H = Planck's constant= $6.626 * 10^{-14}$ J/K

C = velocity of light= $2.998 * 10^8$ m/s

Determination of NDBI

NDBI indices allow us to delineate built-up area; is an useful measure of intensity of imperviousness [20]. It shows the urban area distribution by chacking on the reflectance in the short wave infrared band in comparison to the near infrared band [21]. NDBI is calculated using equation 7.

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} = \frac{Band6 - Band5}{Band6 + Band5} \quad (6)$$

Where by:

SWIR: Short Wave Infrared
 NIR: Near Infrared

3. 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 Figs. 4,5,6 & 7 and overlapping of land cover to LST map illustrated on Figs. 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.

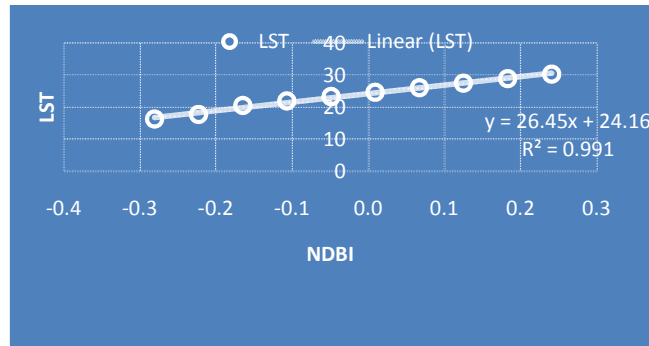


Fig. 4. Graph of NDBI, 2015

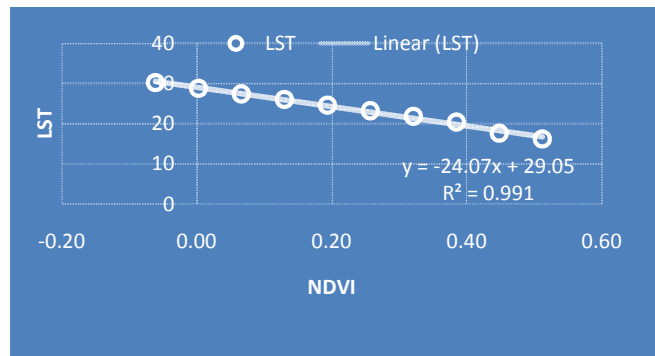


Fig. 5. Graph of NDVI, 2015

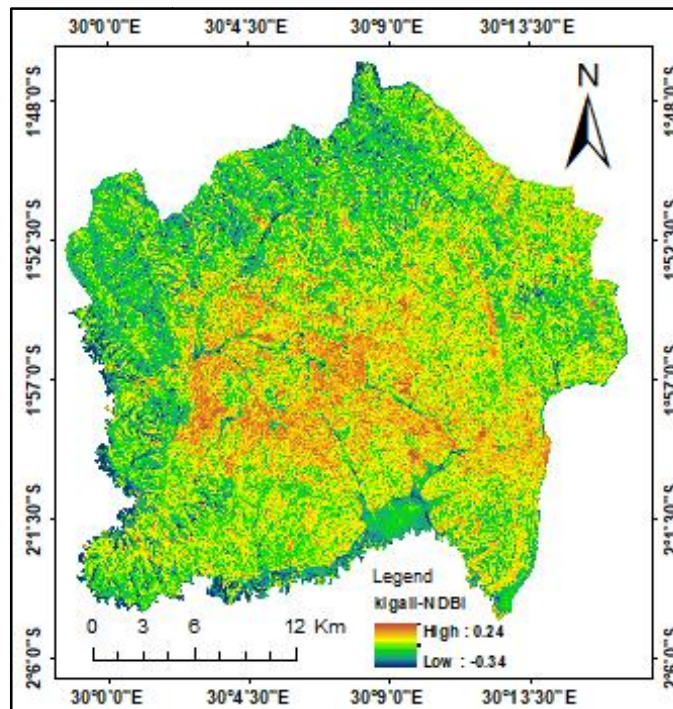


Fig. 6. NDBI map, 2015

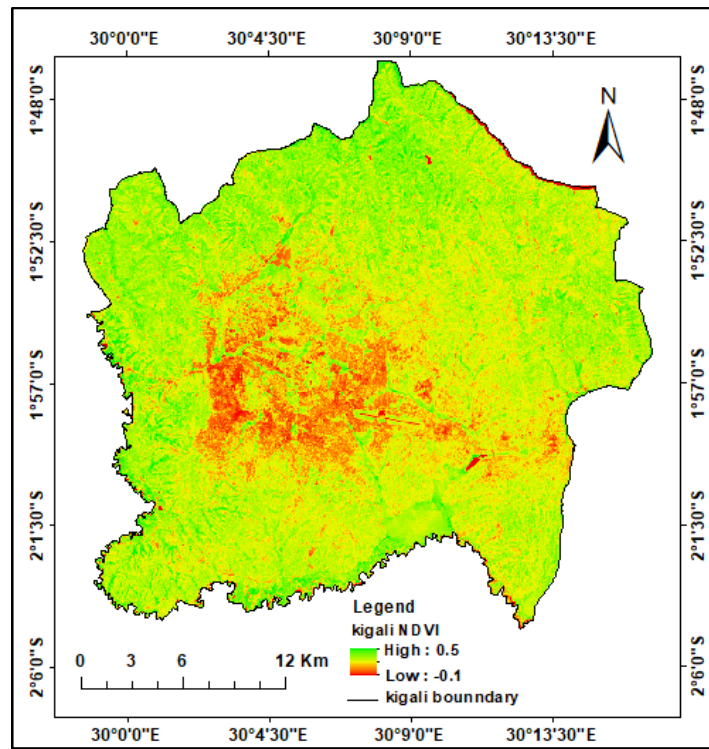


Fig. 7. NDVI map, 2015

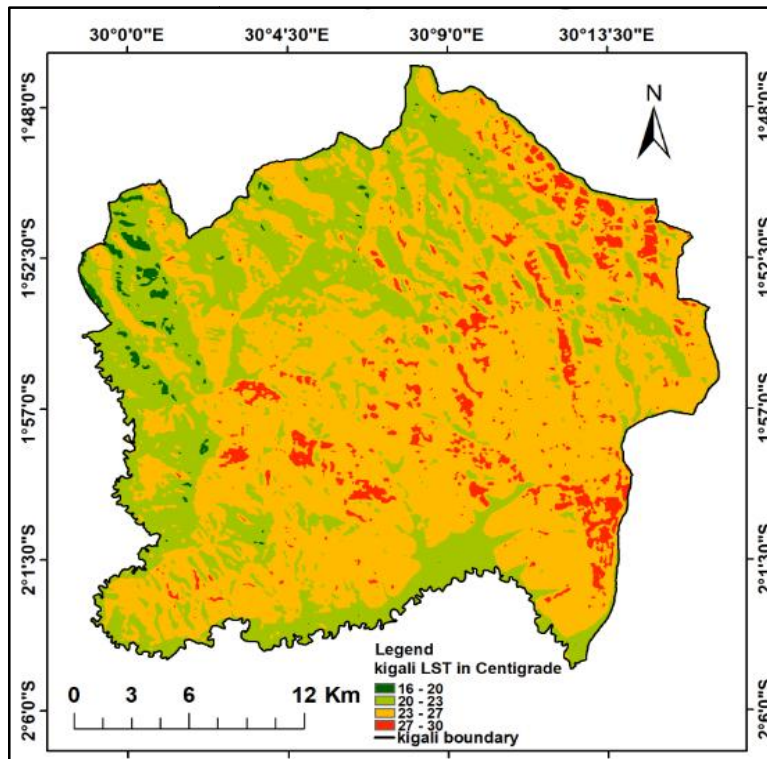


Fig. 8. LST map, 2015

4. 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, 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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