KIGALI
27-29 nov. 2024

9e Universités de perfectionnement des géomètres

La technologie au service d'une gestion foncière équitable et d'un aménagement inclusif des villes.

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INES

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***Title:*** *Spatio-temporal assessment of the urban growth and its impact on land surface temperature: A cellular automata and artificial neural network approach*

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# *Background of the research*

- In 1950, the global population in urban areas was 30% of the world's population, whereas in 2018, the urban population was estimated to be 55%(Rousta et al., 2018).
- According to the United Nations (UN) Department of Economic and Social Affairs (2018), the number of people living in cities is expected to grow by 2.5 billion from 2018 to 2050, with a high rate in the continents of Asia and Africa.
- In 2019 the total area covered by urban zones was not greater than 0.1% of the earth's surface (Fatemi & Narangifard, 2019).

# *Background of the research cont'*

- According to Yiran et al., (2020), the SSA urban growth rate is 3.6% per annum. East Africa is the least urbanized sub-region in the SSA region. Still, its urbanization rate is the fastest.

- According (MININFRA, 2015), In 2012, the urban population of Rwanda was 16.5%
  - The counrty has experienced an exponential urban growth of its capital and six secondary cities, with 4.5% annual urban growth.
- Kigali has grown spatially where in 1999, the total area of Kigali city was 112 $km^2$and in 2018, the area was 730 $km^2$ (Nduwayezu et al., 2021)

- In the process of urban growth in Kigali city, natural vegetation cover was largely replaced by impervious surfaces such as buildings, roads, parking lots, sidewalks and other built surfaces.
- According to Ndayisenga (2014), the land cover change has been proved to have an impact on the hydrographical characteristics like the evapotranspiration process, storage, and emission of the heat which affect the land surface temperature.

# *Problem statement*

- A comprehensive investigation of the relation between the changes in LST and the change in urban growth in Kigali is still missing to unveil environmental issues caused by human activities.
- Existing studies focused on determining how LST increases depending on the land use land cover type without emphasizing the urban growth process behind the land use land cover changes in Kigali.
- Little understanding of the urban growth process and its influence on LST limits the efficacy and sustainability of proposed measures to adapt to and mitigate the effect of increased LST.

# *Research objectives*

## *General objective*

The main objective of this research is to assess spatial-temporal urban growth of Kigali and its impact on land surface temperature from 2000 up to 2040 using Cellular Automator-Artificial Neural Network (CA-ANN).

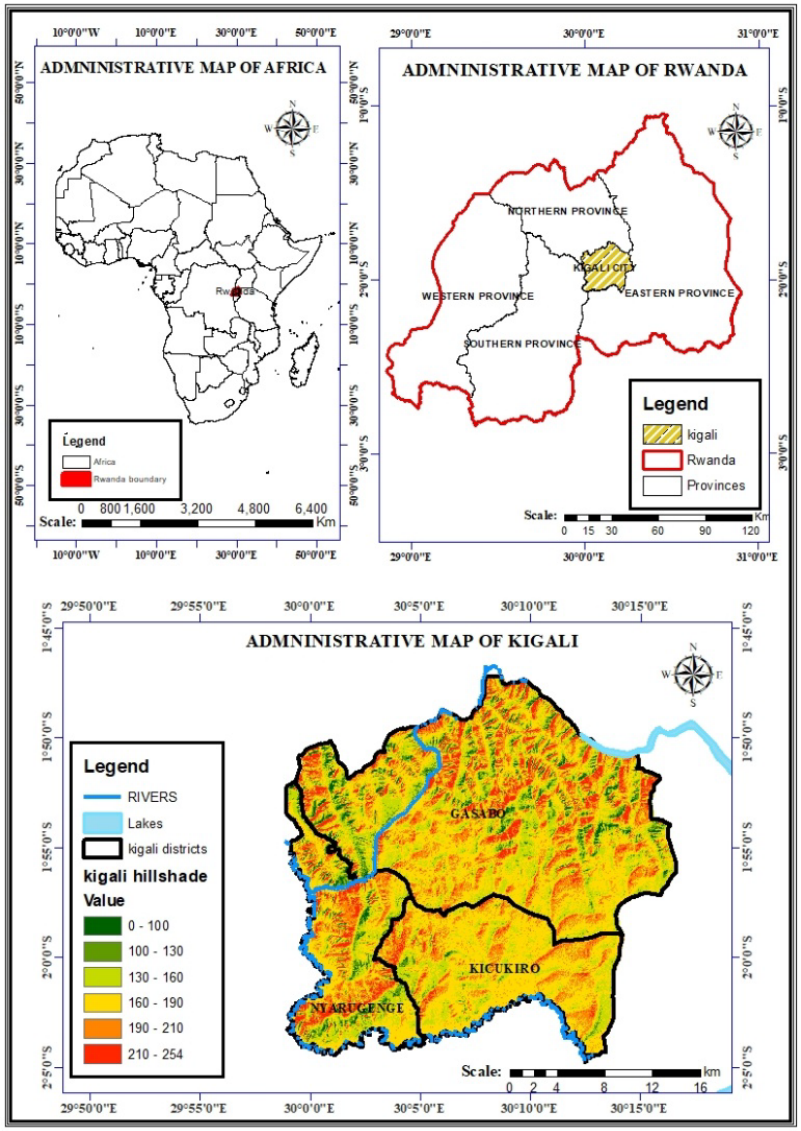
## *Specific objectives*

- To determine the spatial distribution and urban growth rate in Kigali from 2000 up to 2020.
- To determine the trend of land surface temperature from 2000 up to 2020.
- To model urban growth and LST of Kigali in 2040 using CA-ANN.
- To assess the impact of urban growth on LST between 2000 and 2040.

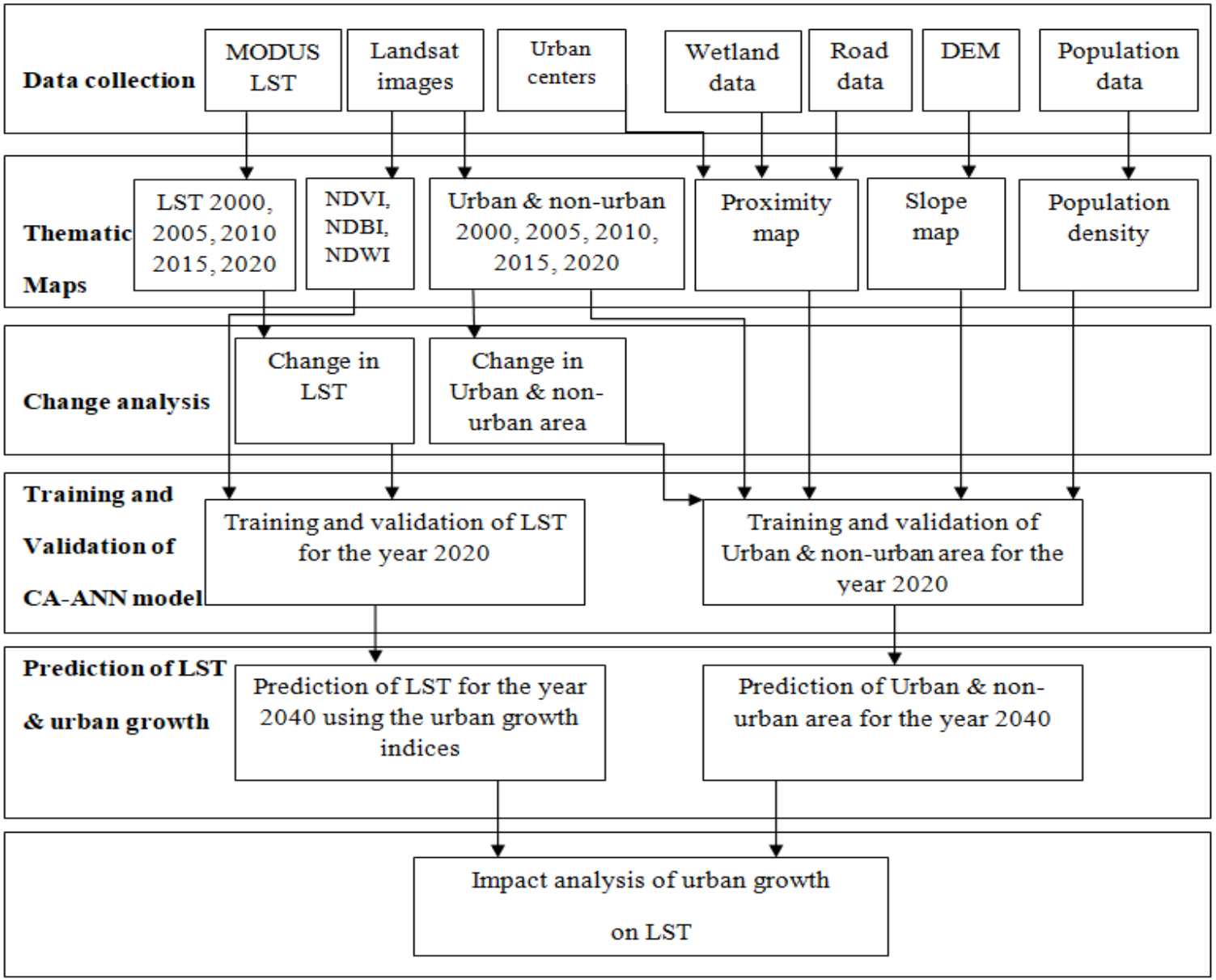
# 3. Methodology

## Study area description

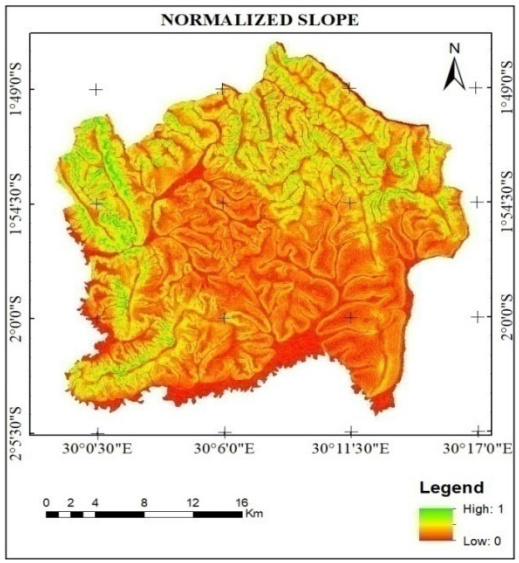
- **Location:** 1º 5’0”and 2º5’0” S of latitude and 30º 0’00” and 30º 15’0” E longitude.
- **Spatial coverage:** 730 km$^2$
- **Population:**1,745,555 in 2022, with 1,500 habitants /square km.

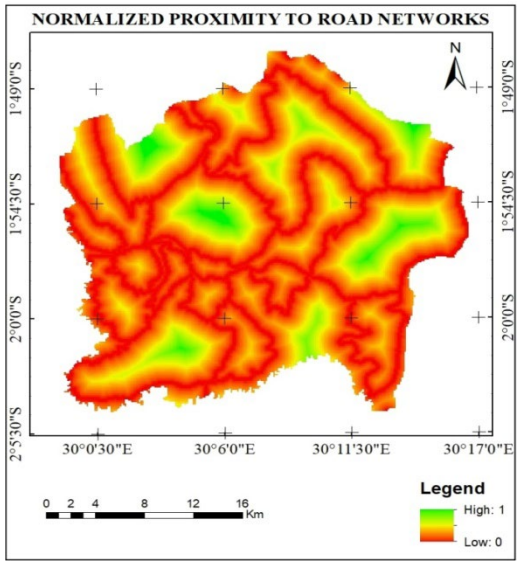


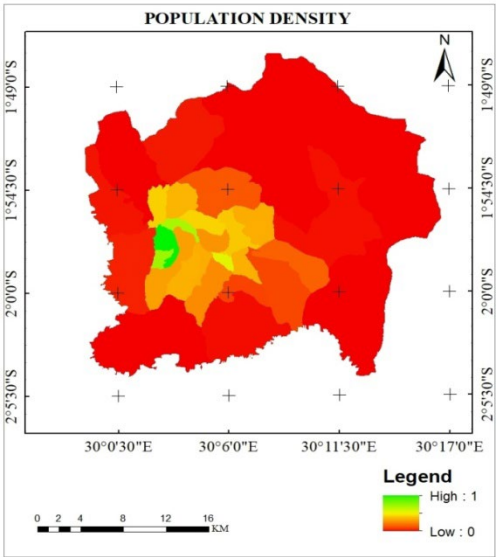
# *Methodology framework*

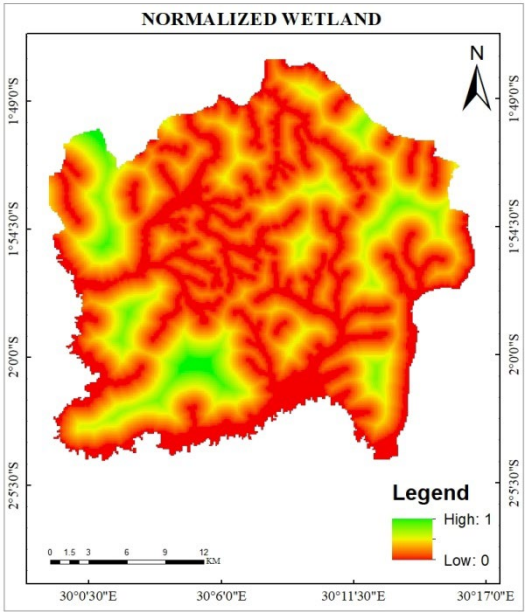


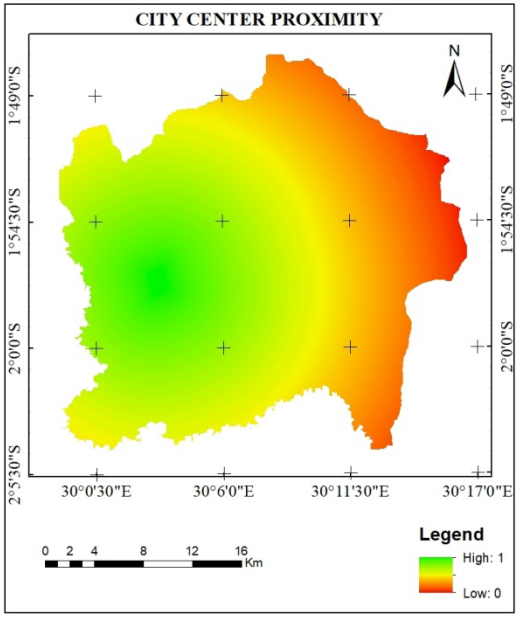
# 4. Results: thematic maps



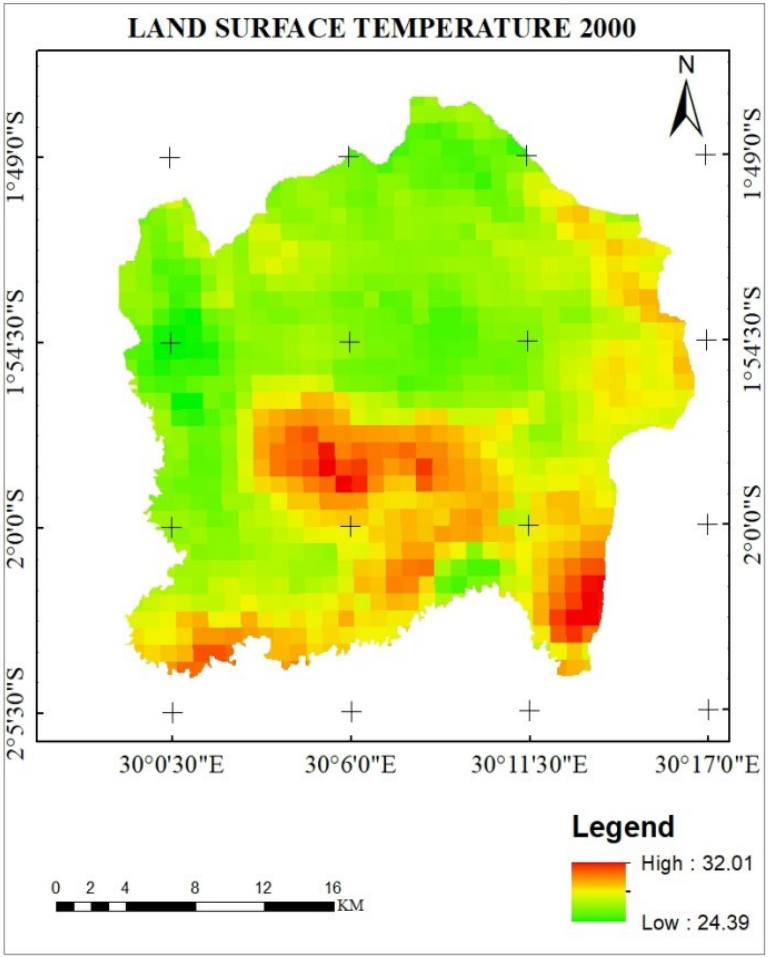



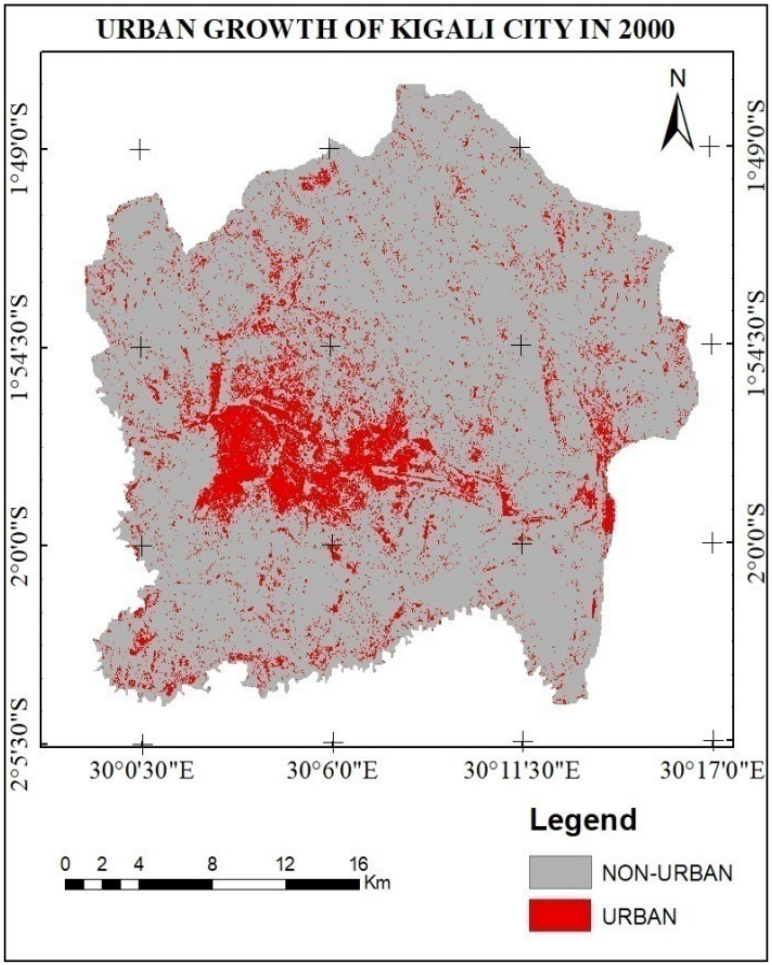



# *4. RESULTS: urban growth & LST for 2000*

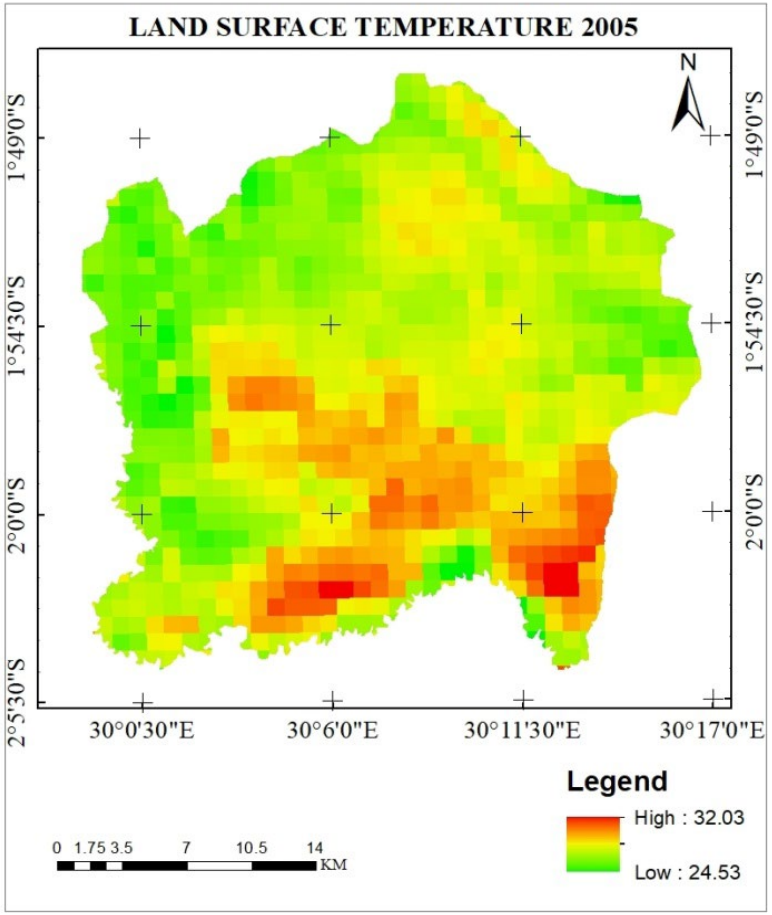
- In 2000 there is the predominance of non urban area
- The built-up is only in the center of Kigali
- The LST is high in the center and also in South and East along water bodies

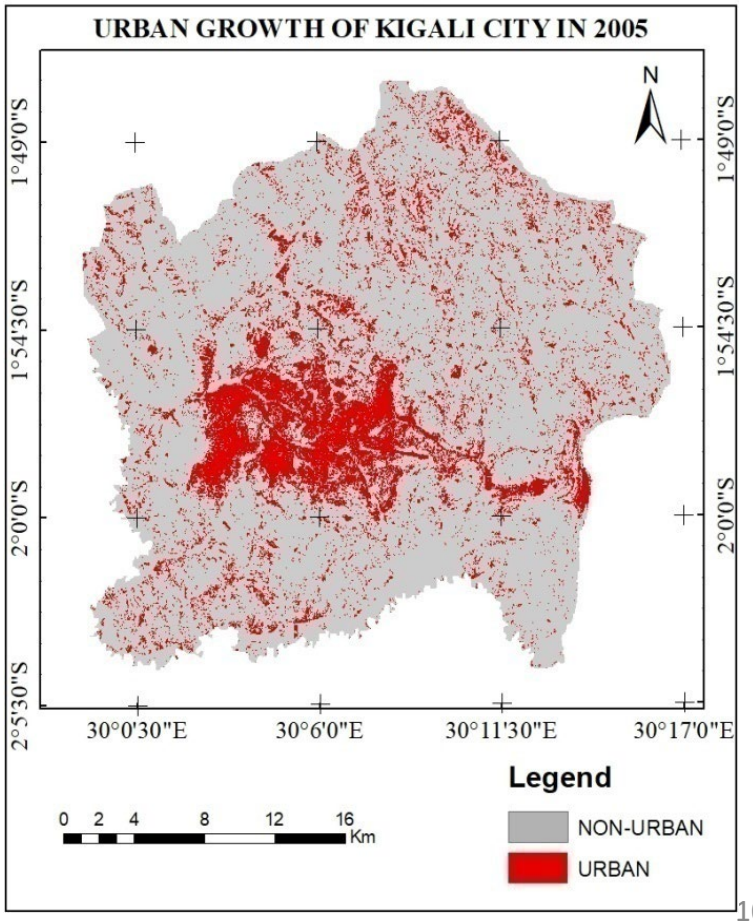


# *4. Results: urban growth & LST for 2005*

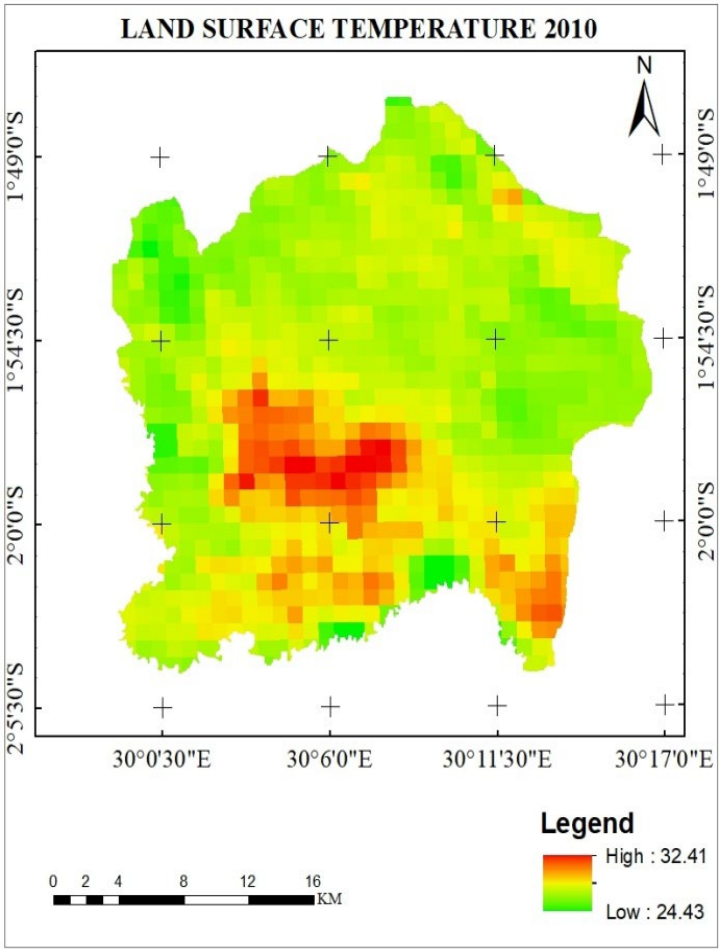
- There is an increase of built-up area mainly in the center compared to the 2000, LST has been increased mainly in the South, North, and Eastern par of Kigali

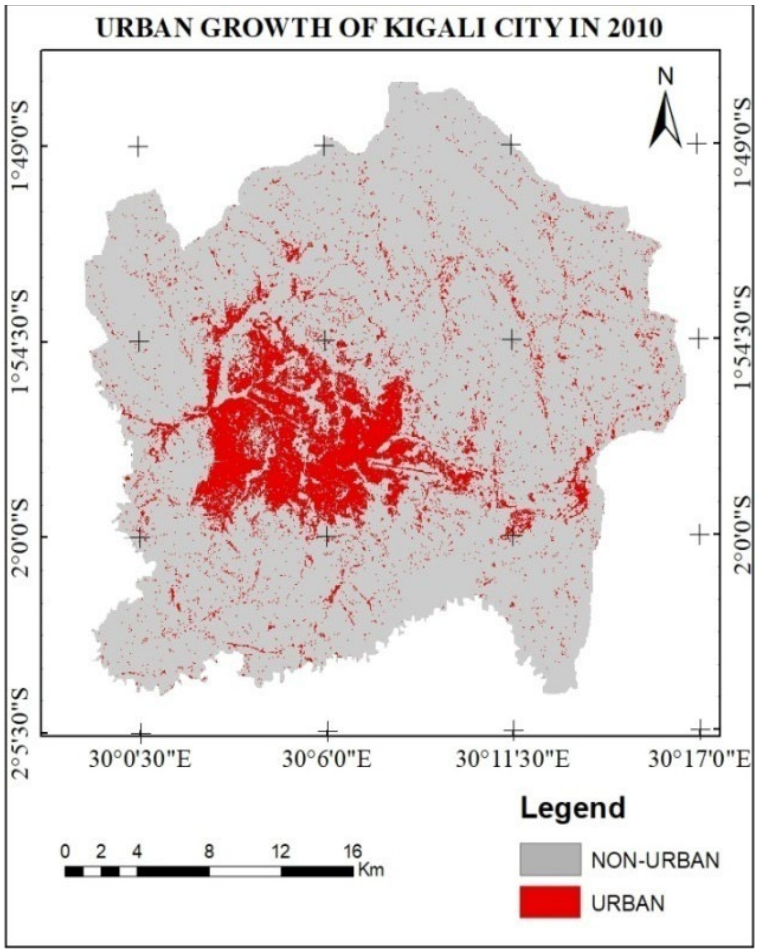


# *4. Results: urban growth & LST for 2010*

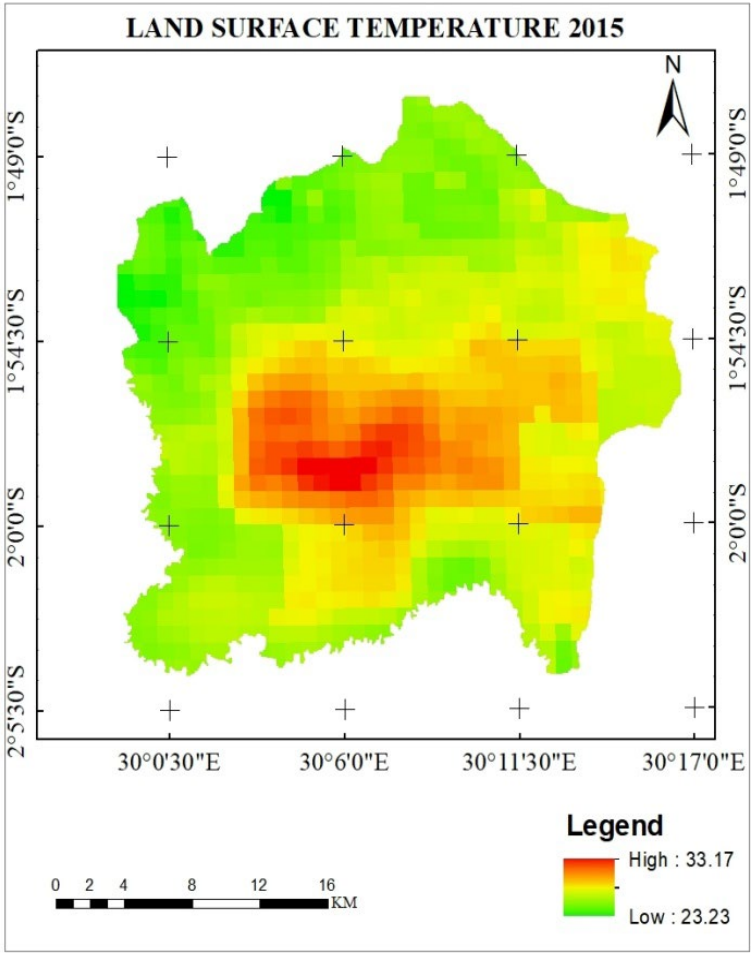
- the LST is very high in the center, high in South and East of Kigali
- The non built-up area still occupies the main area in Kigali
- The built-up is dense in the center of the city.

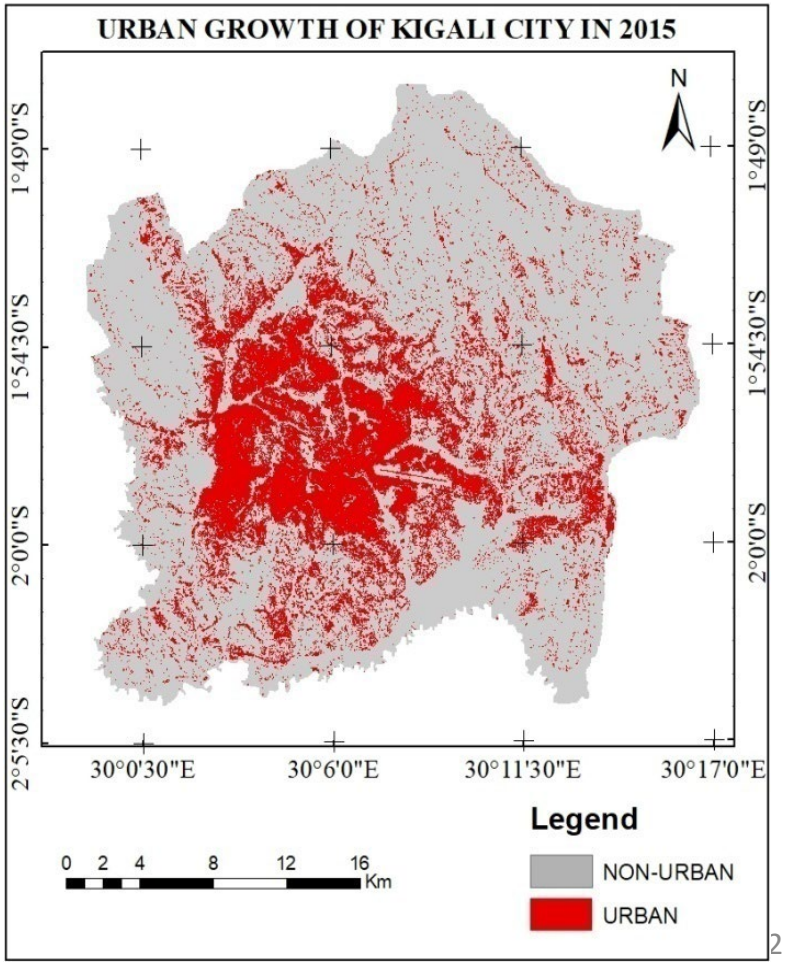


# *4. Results: urban growth & LST for 2015*

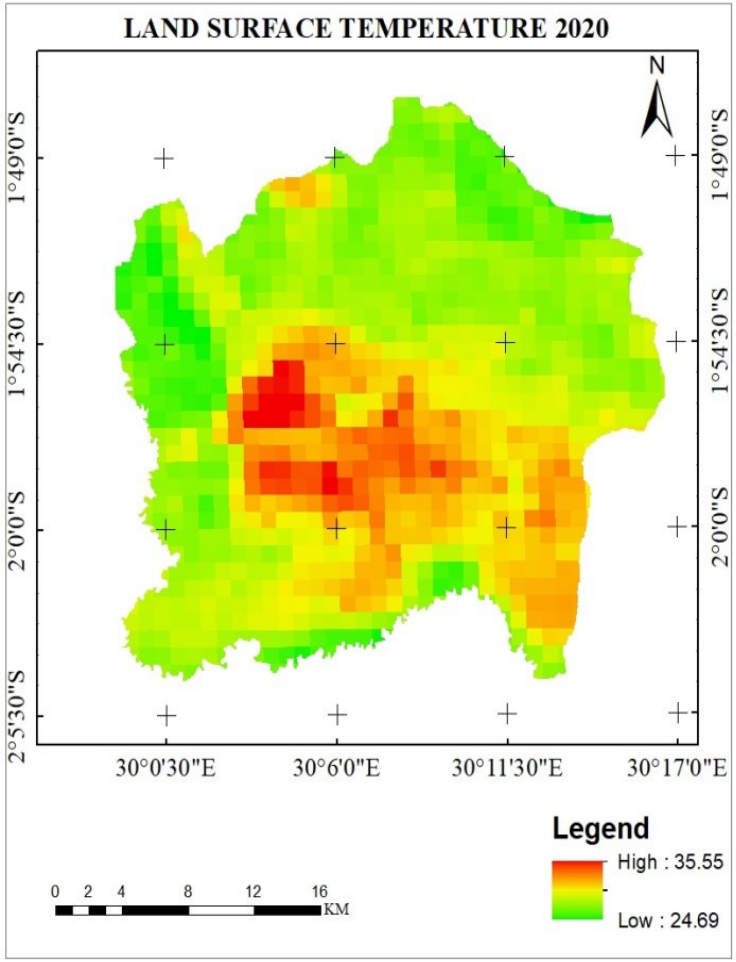
- Compared to 2010 the built-up has relatively increased towards the Eastern and southern parts of Kigali
- The LST is mainly high in the center of Kigali and relatively increasing towards the East

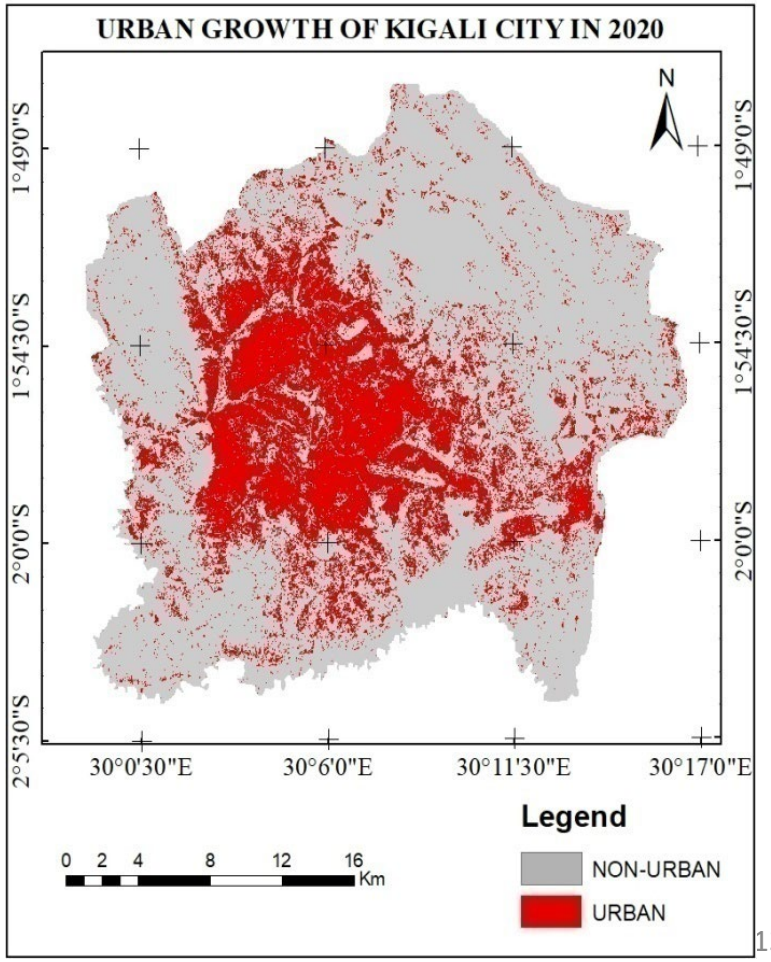


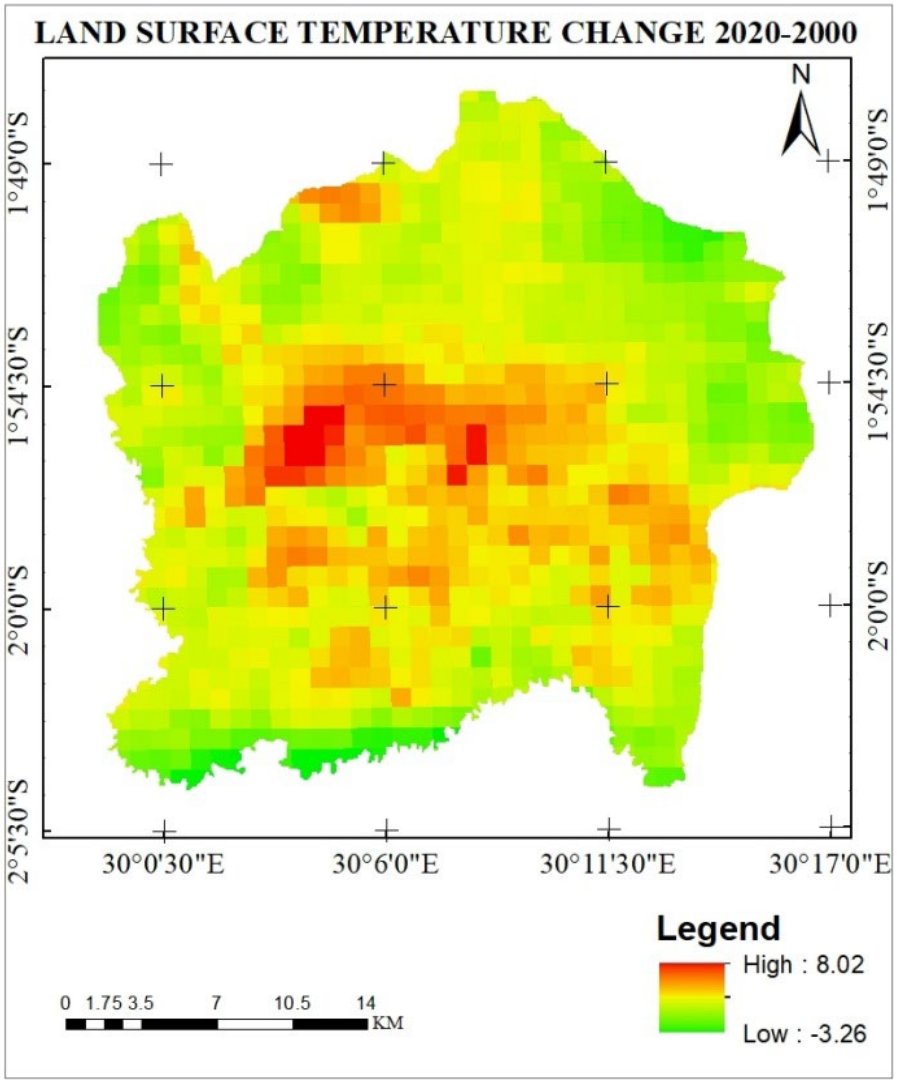
# *4. Results: urban growth & LST for 2020*

- Built-up areas have increased over other land uses.
- Nyabarongo river wetland in southern part of Kigali was maintained over 20 years.
- The LST has also increased spatially from the center towards the South East



# *The change in land surface temperature*



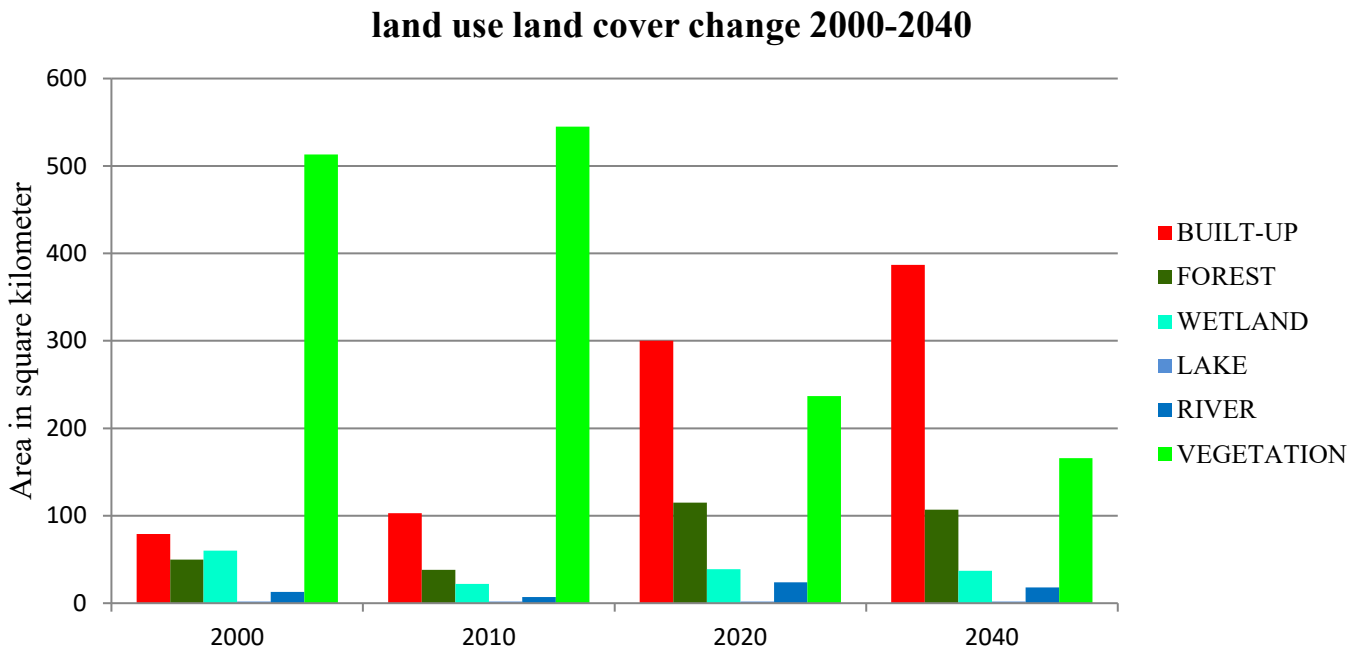

- From 2000 and 2020, the main changes are observed in the center with an increase of 8.18 degree Celsius,
- The decrease of LST especially in the North and South, East and West of Kigali, up to 3 degree Celsius.

## *The governmental policies*

- Water law of 2018 with emphasis on environmental protection,
- Kigali City Master Plan (KCMP) in 2013.
- Forest law of 2004 updated in 2018

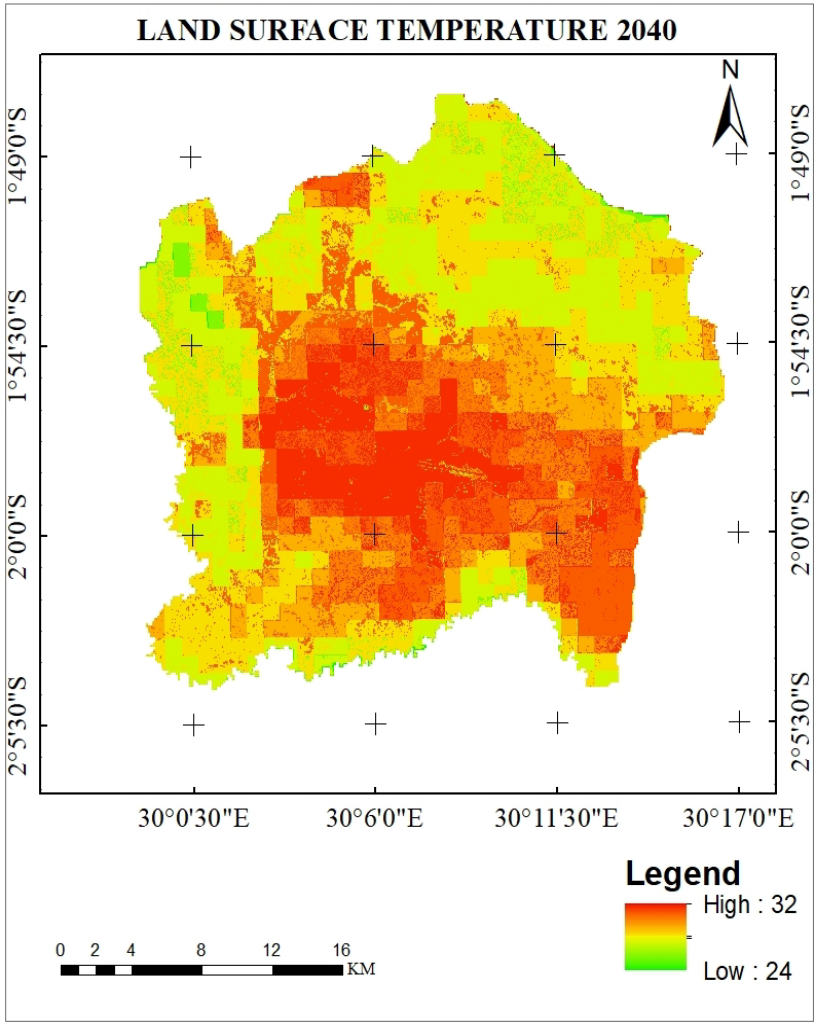
# *Land use and land cover change*

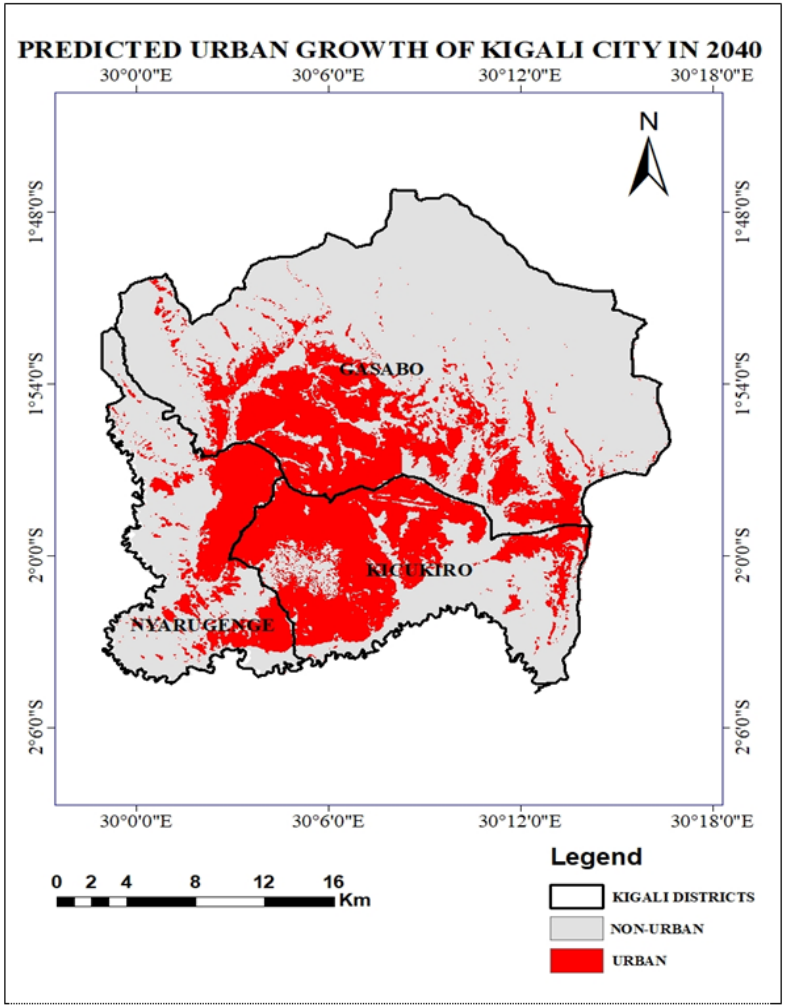
| CLASSES | LULC 2000 | | LULC 2010 | | LULC 2020 | | LULC 2040 | |
|---|---|---|---|---|---|---|---|---|
| | Area sqkm | Area % | Area sqkm | Area % | Area sqkm | Area % | Area sqkm | Area % |
| **BUILT-UP** | 79 | 11.02 | 103 | 14.37 | 300 | 41.84 | 387 | 53.97 |
| **FOREST** | 50 | 6.97 | 38 | 5.30 | 115 | 16.04 | 107 | 14.92 |
| **WETLAND** | 60 | 8.37 | 22 | 3.07 | 39 | 5.44 | 37 | 5.16 |
| **LAKE** | 2 | 0.28 | 2 | 0.28 | 2 | 0.28 | 2 | 0.28 |
| **RIVER** | 13 | 1.81 | 7 | 0.98 | 24 | 3.35 | 18 | 2.51 |
| **VEGETATION** | 513 | 71.55 | 545 | 76.01 | 237 | 33.05 | 166 | 23.15 |



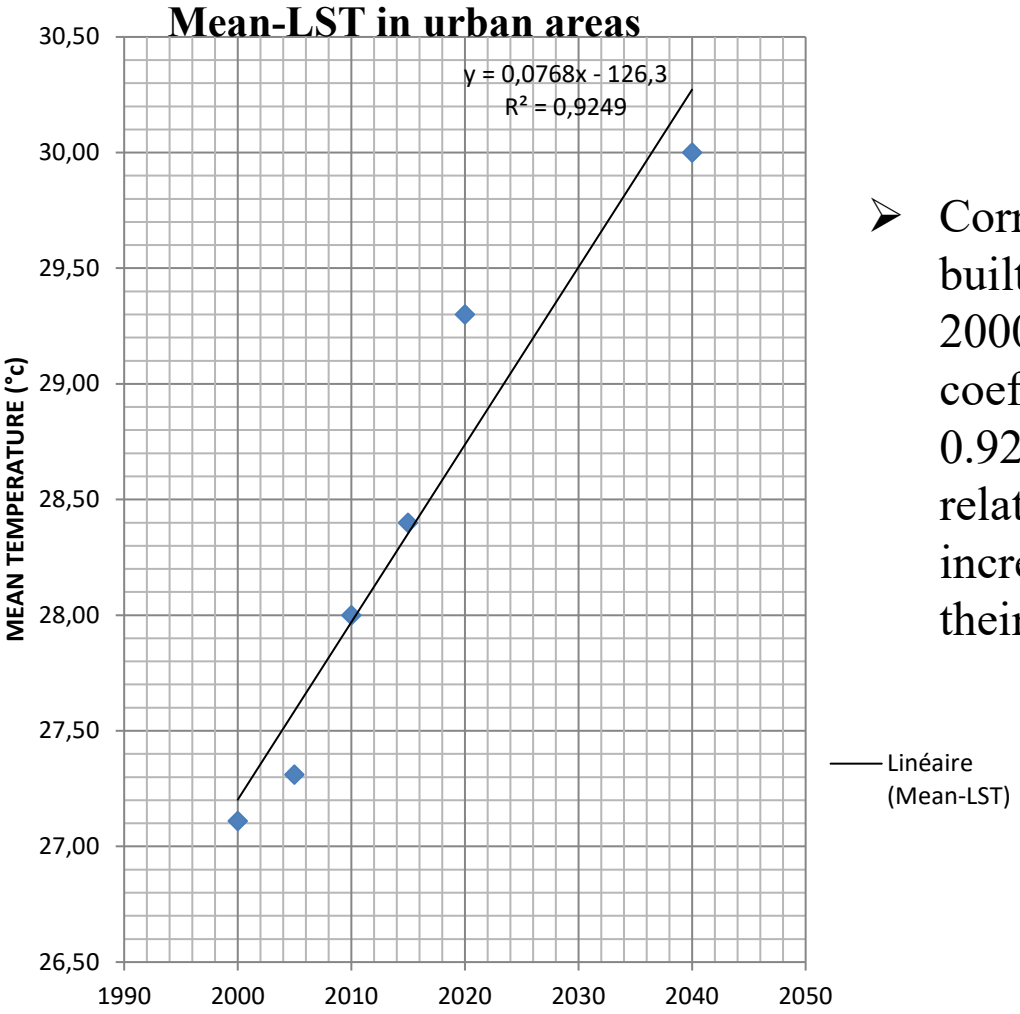
# *4. Results: urban growth & LST for 2040*

- In 2040 LST has spatially increased considerably from the city centers towards the South East
- LST trends has followed the trend of urban growth



# *Correlation analysis*




- Correlation between LST and built-up over the period of 2000 and 2020 shows strong coefficient determination $r^2$ of 0.924 indicating the strong relationship between the increase in built-areas and their associated LST values

# *Conclusion*

- urban coverage has increased in low-sloping areas of Kigali city over 20 years.
- LST has increased mainly in Kigali's city centre compared to its surrounding areas.
- A decrease in LST was also noted, especially on the outskirts of Kigali.
- The prediction done shows that the densification and expansion of urban areas will be higher, particularly from city core to its periphery.
- The increase in temperature of the city will follow this pattern.
- The increase in LST was closely and directly related to urban growth. However,
  - the rigorous implementation of tree planting, Greening Kigali projects and protection of natural environments will balance the temperature emanating from impervious surfaces of urban areas.
- Therefore, the land surface temperature throughout the city will be as high as 32°C, with low temperatures increasing by about one °C from 2020, while high temperatures will be reduced by around 3°C.

# *Recommendations*

- A similar study can also be applied to secondary cities in Rwanda to have a general picture of the effect of urban growth on LST in urban areas in the country.
- Future studies can use other machine learning models to validate the findings of this study.

- To include Kigali residents' health and economic data to better model urban growth's impact on land surface temperature in Kigali.

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