

Impact of Urban Expansion on Land Use and Land Cover Change in Rwanda, Bugesera District

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Abstract:- Global land use has significantly changed during the past decades due to the urban expansion. Historically, the driving force for land and use changes is population growth and urban expansion. Rwanda as the most densely populated country in Africa with population was estimated to be about 11.37 million, of which 28.81% resided in urban areas and by 2030, this population is expected to reach about 17 million, with 41.55% living in cities. This study aimed to assess the dynamism of urban expansion, determining the land use and land cover change (LULCC), and showing the effect of urban expansion and LULCC of Bugesera over a period of 2002 to 2022. For determining the dynamism of urban expansion, statistical data collected from National Institute of Statistics of Rwanda (NISR) and district reports have been used and analyzed. The Land use and land cover change has been determined by use of secondary data obtained from Landsat images. By use of application of GIS (Geographical Information system) and remote sensing specifically with software ArcGIS Pro 3.0, the Landsat Images of different times were classified using supervised classification. It has been observed that over this entire period of 20 years, the urban area has expanded up to 5766.751% which is also the increase of built up areas; with population increase of 179.831%. The forest, water bodies and wetland have experienced an increase of 241.451%, 156.470% and 61.366 % respectively. These increases are justified by the policies that the government has established regarding to restoration of the nature. The vegetation and agriculture land experienced the decrease of 38.644% and 37.761% respectively. The local people should comply with the national land master plan during their activities as the human activities are among the contributors of environment degradation, they should avoid any activity which harm the natural environment. Researchers should also interest the players in environmental protection to be inspired by use of GIS and remote sensing tools during monitoring of urban expansion and LULCC. Local leaders should strengthen the implementation of planning policies by respecting Environmental rules and regulation related to the zonings. The Government should increase awareness to the population in the application of circular economy practices which result the resource efficient and reduction of wastes.

Keywords: GIS And Remote Sensing, Land use, Land Cover, Land use and Land Cover Change, Landsat Images, Population Growth, Urban Expansion.

I. INTRODUCTION

Global land use has significantly changed during the past decades due to the urban expansion (Ramankutty & Foley, 1999). Population growth and urbanization have historically been the main forces behind changes in land use (Kok, 2004). According to estimates, 55% of the world's population resided in urban regions as of 2018, and by 2050, nearly two-thirds of the world's population is anticipated to reside in cities, with urbanization rates in emerging nations accelerating at an alarming rate (Ayele & Tarekegn, 2020). Africa is the least urbanized of the inhabited continents, but it is also the one that is having the fastest rate of urbanization, primarily in Sub-Saharan nations (Ru et al., 2022). According to the World Bank (2020), 15.75% of the area's population resided in agglomerations of a million or more people. The rate of urbanization in Sub-Saharan Africa surpassed 4% over the course of 20 years (2000–2019), doubling in less than two decades (Ru et al., 2022). Even though the percentage of the people living in cities is growing, East Africa is still under-urbanized (Charlery de La Masselière et al., 2017). Although the urbanization rate in Sub-Saharan Africa as a whole grew from 28% in 1990 to almost 50% in 2010, this rate did surpass 21% in East Africa in 2010, with notable differences between countries: 10% in Burundi, 14% in Uganda, 26% in Tanzania, and 45% in Kenya are just a few examples (Charlery de La Masselière et al., 2017). Being the most populous nation in Africa, Rwanda has felt the effects of urbanization in recent years (Baffoe et al., 2020). It was expected that 11.37 million people lived in Rwanda in 2015, with 28.81% of them living in cities (Li et al., 2021). With 41.55% of people residing in cities, the population is projected to be around 17 million by 2030. With 52% of people residing in cities, the population is expected to reach 25 million by 2050. (Li et al., 2021). Any country's urban area is never stable; it evolves over time (Ade & Afolabi, 2013a). Land use and land cover are impacted by development and the expansion of infrastructure facilities (Ade & Afolabi, 2013). Since the 1994 end of the Tutsi genocide of 1994, Rwanda is experiencing a significant and quick structural transformation. (Nduwayezu et al., 2021). Urbanization process in Rwanda with the increase of population and the development of social economy continues to accelerate. Mainly for the following aspects: the urban

population is growing, land for construction and urbanization has improved rapidly, urban land significantly changes (Egide, et al., 2018).

Urbanization is typically accompanied by complex problems, such as the ongoing need for affordable housing, transportation infrastructure, essential services, and employment. Environmental deterioration and social segregation are still effects of urbanization, even in places where it is happening more slowly (Baffoe et al., 2020). The demand for urban building and urban expansion are directly influenced by the urban population, which also serves as a primary driver of land use (Zhang et al., 2022). As the population grows, strain on the environment (such as land availability, resources for environmental common property, land degradation, or energy use) will also grow (Edeme & Chibuzo, 2018).

One of the main effects of urban population growth is the rapid expansion of urban areas (X. Li et al., 2020). Urban areas must be significantly expanded as well as new urban regions must be developed in order to handle the city's growing population (X. Li & Gong, 2016). Understanding a city's urban boundaries is crucial for recognizing the dynamic nature of the urbanization process and for developing particular development policies to prevent, reduce, or address social and environmental issues that arise concurrently with urbanization (Jayasinghe et al., 2021). Due to the lower value of land at the periphery compared to urban land, the outward expansion of city borders will result in the conversion of agricultural land, forest, and wetland into urban uses (Amin, 2012). Urban land expansion results in changes to the land's landscape, including the loss of natural habitat (McDonald et al., 2020).

In 2017, World bank has mentioned Bugesera among the fast-growing cities and revealed that it has expanded its urban footprint in past decade and it is the closest city to Bugesera International Airport and special economic zone under development (World Bank, 2017). Thereafter, the presidential Order N° 058/01 of 23/04/2021 published through official gazette of 6/04/2021 has established the national land use and development master plan in which Bugesera has been proposed among three Kigali's satellites of 800k-1M inhabitants because they are growing faster than the secondary cities for the future urbanization plan. The purpose is to minimize the primacy of Kigali and to support the growth poles (Government of Rwanda, 2021). This Presidential Order has designated Bugesera as a logistics and airport city where trade, transport and tourism shall be the

main drivers of Bugesera to the new International Airport. For being able to boost the above sectors, as satellite city, construction, infrastructure services at high technology are the economic specialization deployed to the district by this presidential order (Government of Rwanda, 2021). The majority of the people (79% according to DDS, 2018) works in agriculture, which is the cornerstone of the Bugesera district's economy (J et al., 2015). The rapid urbanization is related to the rate of population increase, and land that was once used for agriculture is now being used for residential construction. (Ayele & Tarekegn, 2020). In line with the above, as Bugesera urban areas are kept expanding, the land for agriculture also shall keep decreasing. Many researchers have studied the land use and land cover change for the capital of Rwanda (Kigali) and for other secondary cities. However, for Bugesera, no similar study has been published and the available researches are related to other sectors like agriculture, climate changes. This study aimed to assess the dynamism of urban expansion; to determine the land use and land cover change (LULCC) and show the effect of urban expansion on LULCC in Bugesera District over a period of 2002 to 2022.

II. MATERIAL AND METHODS

➤ *Description of Study Area:*

Bugesera district is one of seven districts that compose Eastern Province of Rwanda. It is located in the South West of the Province, ranged between 30° 05' Eastern longitude, and 2° 09' Southern Latitude, and covers the surface of 1,337 km². As per national census of 2012, It had population density of 282 persons per km² (NISR, 2012) and for the census of 2022, its population density is 450 persons per km²(NISR, 2023). The topography is characterized by a series of low plateaus with hills and dry lowlands. The climate is dry compared to other regions of the nation, with temps between 20° and 30°C. In the past, the region had drought, which caused exodus driven by starvation, two plant forms stand out: the densely shrub-covered savannahs that cover the hills and the grassy savannahs that cover the dry valleys and trays of the hills. Acacia trees, euphorbiac, and cacti, along with gramineous plants and spiny bushes, make up a significant portion of the vegetation.

The study area is the urban sectors of district which are Ntarama, Nyamata and Mayange that are forming the city of Bugesera. The study covered a period of twenty years from 2002 to 2022. The results have been shown for 2002, 2012 and 2022.

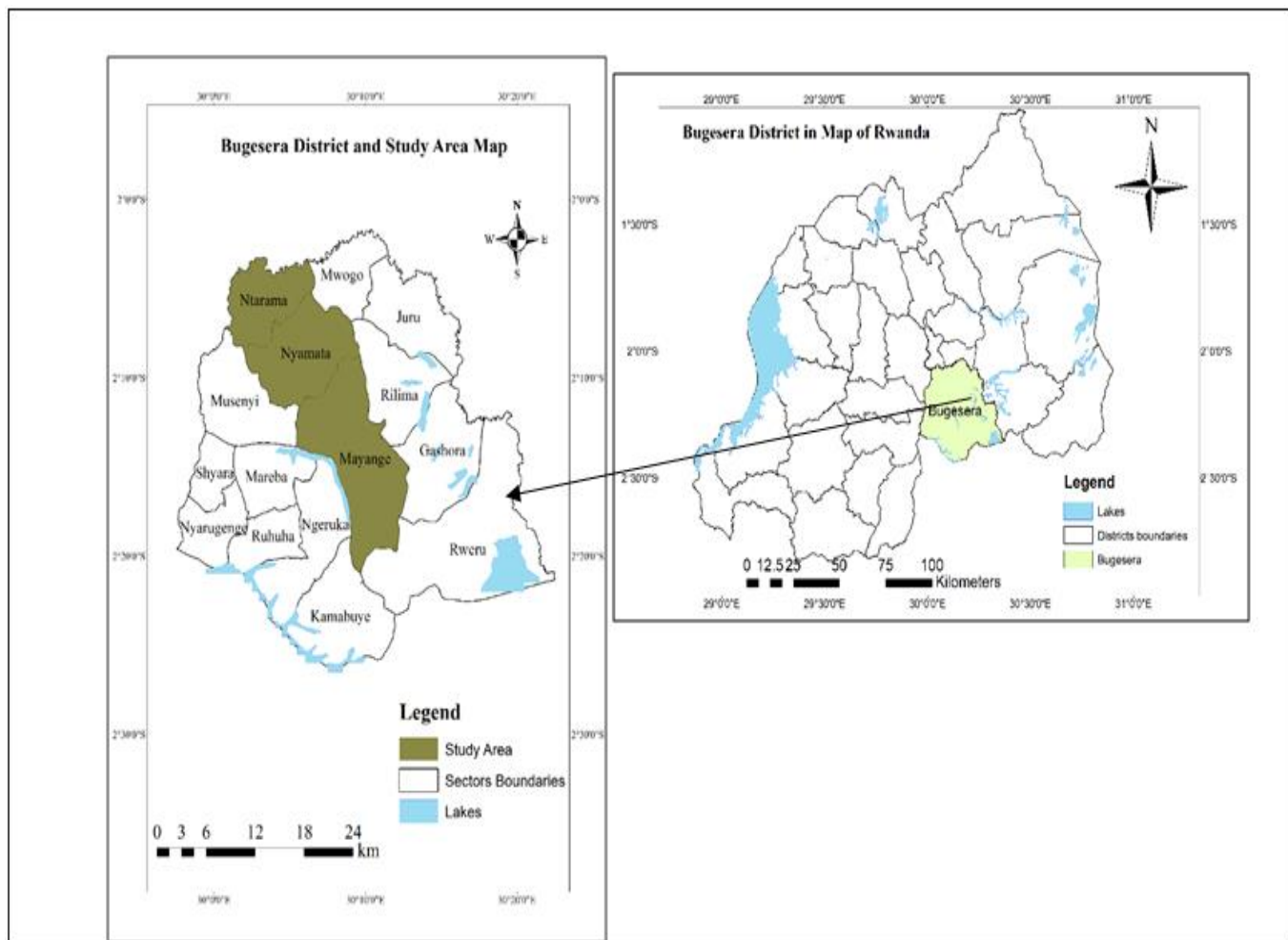


Fig 1 Map of Bugesera and Study Area

➤ *Data Sources and Analysis:*

In this research, the statistical data for urban expansion (Population growth) have been collected from Bugesera District office, and NISR website. The data used for creating the land use and land cover maps of the study area have been derived from an open source of United States Geological Survey (USGS) (<https://www.usgs.gov>).

The Landsat images were downloaded from this open source as data to be used in the study. Their details are given in the table 1 below.

Table 1 Satellite Date used During Study

| # | Image | Acquisition date | Spatial Resolution | Path/Row |
|---|--------------------|------------------------------|--------------------|----------|
| | Landsat7 ETM+ | 16 th July 2002 | 30m | 172/062 |
| | Landsat7 ETM+ | 11 th July 2012 | 30m | 172/062 |
| | Landsat-8 OLI/TIRS | 16 th August 2022 | 30m | 172/062 |

Source: Authors Compilation, 2023

Descriptive statistics were used to describe the urbanization in study area by using percentages. Computer software package MS Excel, was used to analysis of statistical data. The Landsat Images which were downloaded from USGC have been processed and analyzed by use of software ArcGIS pro 3.0.

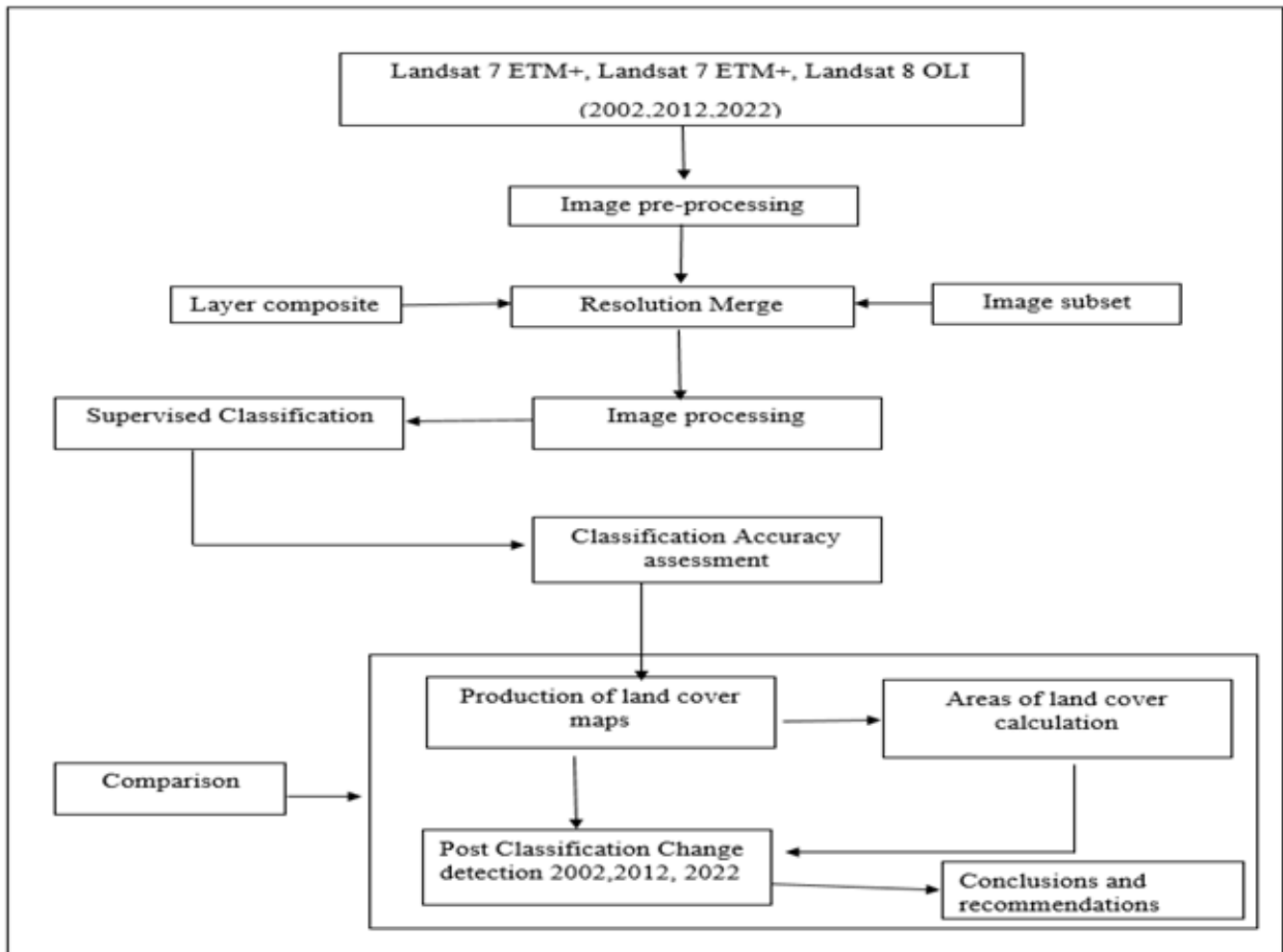


Fig 2 Image Classification Methodology (Source: Authors Compilation, 2023)

These techniques (on the figure 2 above) are most useful because many satellite image when examined on color, it gives inadequate information for image interpretation. False Color Composite of band combination of (band 5, 3 and 2 for Landsat 8 OLI) and true color composite was used to visualize the images study areas by using Arc-GIS. This study investigated conducted using the maximum likelihood supervised classification to create thematic maps from a multiband raster image. Satellite images have been converted to classified images via grouping the pixels of an image to specific training areas for categorizing all pixels in an image to obtain a given set of labels (Zubair, 2006). The classification has been made into six categories: Built-up areas, Crop land, Forest, Grassland, Wetlands and Waterbodies.

Land Use/Land Cover refers to data that is a result of classifying raw satellite data into land use and land cover (LULC) categories based on the return value of the satellite image. Land use defined in this way establishes a direct link between land cover and human activities in their environment. After the classification process, all signature sample point was grouped as class by record function

according to the determined land cover classification type in study area. Recording were involved the assignment of new values to one or more classes and was used to reduce the number of classes and combine classes. In this study, each of Land Use Land cover map was compared to the reference data to assess accuracy of the classification. The Reference Data was prepared by considering the ground control point, the field knowledge and Google earth image. During this classification in accuracy assessment, the Ground Control Points were used to identify the exact position of the place.

The change in percentage of statistics has been calculated by use of the following formula:

$$Percentage\ Change = \frac{p1 - p0}{p0} * 100$$

Where $p0$ is the initial value and $p1$ is the final value. For a positive value, it is an increase then negative value, it means a decrease (Bansilal, 2017)

III. RESULTS

➤ Population Growth:

As mentioned in the table 2, the NISR statistics and district reports shows that the population in the urban area of Bugesera has changed as follow: in 2002, the population was 47, 335; in 2012, there was 82,735 inhabitants and in 2022; 132,456 inhabitants.

Table 2 Population of Study Area

| No | Sector | 2002 | 2012 | NISR Projection 2022 |
|--------------|---------|---------------|---------------|----------------------|
| 1 | Mayange | 14,392 | 29,835 | 42,640 |
| 2 | Ntarama | 13,977 | 17,978 | 29,566 |
| 3 | Nyamata | 18,966 | 34,922 | 60,252 |
| TOTAL | | 47,335 | 82,735 | 132,456 |

Source: NISR and District reports, 2022

For the period of from 2002 to 2012, the population growth rate was 74.786%, from 2012 to 2022, the rate was 60.099% and for a period of from 2002 to 2022, the increase rate was 179.831% as stipulated in table 3.

Table 3 Increase Rate in Percentage

| Time period | Increase in percentage(%) |
|-------------|---------------------------|
| 2002-2012 | 74.786 |
| 2012-2022 | 60.099 |
| 2002-2022 | 179.831 |

Source: Authors Compilations, 2023

➤ Land Use and Land Cover:

The results of land use and land cover as per the classes and the change in land use and land cover in Bugesera city for 2002, 2012 and 2022 are shown in the table 4.

Table 4 LULC Findings

| Land use Type | 2002 | | 2012 | | 2022 | | Change 2002-2012 | Change 2012-2022 | Change 2002-2022(%) |
|----------------|-------------------------|----------------|-------------------------|------------|-------------------------|------------|------------------|------------------|---------------------|
| | Area (km ²) | Percentage (%) | Area (km ²) | % | Area (km ²) | % | % | % | % |
| Built-up areas | 0.624 | 0.205 | 3.471 | 1.136 | 36.619 | 11.994 | 456.023 | 955.128 | 5766.751 |
| Cropland | 192.695 | 63.214 | 246.042 | 80.523 | 119.931 | 39.280 | 27.685 | -51.256 | -37.761 |
| Forest | 23.525 | 7.718 | 9.608 | 3.145 | 80.328 | 26.309 | -59.158 | 736.030 | 241.451 |
| Grassland | 74.552 | 24.457 | 33.577 | 10.989 | 45.742 | 14.982 | -54.962 | 36.231 | -38.644 |
| Water | 1.073 | 0.352 | 0.835 | 0.273 | 2.752 | 0.901 | -22.221 | 229.741 | 156.470 |
| Wetland | 12.362 | 4.055 | 12.021 | 3.934 | 19.949 | 6.534 | -2.759 | 65.945 | 61.366 |
| Total | 305.553 | 100 | 305.553 | 100 | 305.553 | 100 | | | |

Source: Authors compilation, 2023

As shown in the results (table 4), Bugesera city has experienced the changes in land use and land cover for a period of 2002 to 2022. Each class has been analyzed. In 2002, The built up areas were occupying 0.248% equal to 0.624 km² of the study area. In 2012 the area increased to 1.136% equal to 3.471 km² and by 2022, it was increased up to 11.994% equal to 36.619 km². As the urban areas kept increasing, the total percentage change between 2002 and 2012 was 456.023%. Between 2012 and 2022, it was 955.128%. For this whole period of from 2002 to 2022, the change in percentage is 5766.751%.

In 2002, The crop land was occupying 63.214% which equals to 192.695km². In 2012 it was 80.523% equal to 246.042km² and by 2022, it was 39.28% equal to

119.931km². For a period of 2002 to 2012, the cropland has known an increase of 27.685%, for 2012 to 2022, it experienced a decrease of 51.256% and for 2002 to 2022, there has been decrease of 37.761%.

In 2002, the area for forest was 7.718% equal to 23.525km², for 2012, it was 3.145% equal to 9.608km² and 26.309% equal to 80.328km² in 2022. The identified change is that for 2002 to 2012, there has been a decrease of 59.158%, for 2012 to 2022, an increase of 736.030% for 2012 to 2022 and an overall increase of 241.451% for a period of 2002 to 2022.

In 2002, the grassland occupied 24.457% equal 74.552km²; 10.989% equal 33.577km² in 2012 and 14.982%

equal 45.742km² in 2022. The observed change is a decrease of 54.962% for 2002 to 2012, an increase of 36.231% for 2012 to 2022 and a decrease of 38.644% for 2002 to 2022.

The waterbodies were identified to occupy 0.352% equal to 1.073km² in 2002 ,0.273% equal to 0.835km² in 2012 and 0.901% equal to 2.752km² The changes observed are a decrease of 22.221% for 2002 to 2012, an increase of 229.741% for 2012 to 2022 and an increase of 156.470% for 2002 to 2022.

The wetlands occupied 4.055% equal to 12.362km² in 2002, 3.934% equal to 12.021km² in 2012 and wetlands 6.534% equal to 19.949km² in 2022. The change observed are a decrease of 2.759% for a period of 2002 to 2012, an

increase of 65.945% for a period of 2012 to 2022 and an increase of 61.366% for a period of 2002 to 2022.

Between 2002 and 2022, within Bugesera urban areas has grown at a level of 5766.751%, from 0.624km² in 2002 to 36.619km² in 2022 which is indicating a substantial rapid urban expansion in Bugesera. And the population should be needing the dwelling facilities within the city, and necessary facilities for living like schools, roads, hospitals, markets and as long as the population keeps increasing, the built-up area also increases. The results of LULCC have shown that the increase of built up area has contributed in the change of LULC. Following areas of cropland, vegetation and forest have changed into built up areas respectively: 25.7760km², 8.2669 km² and 2.1167 km².

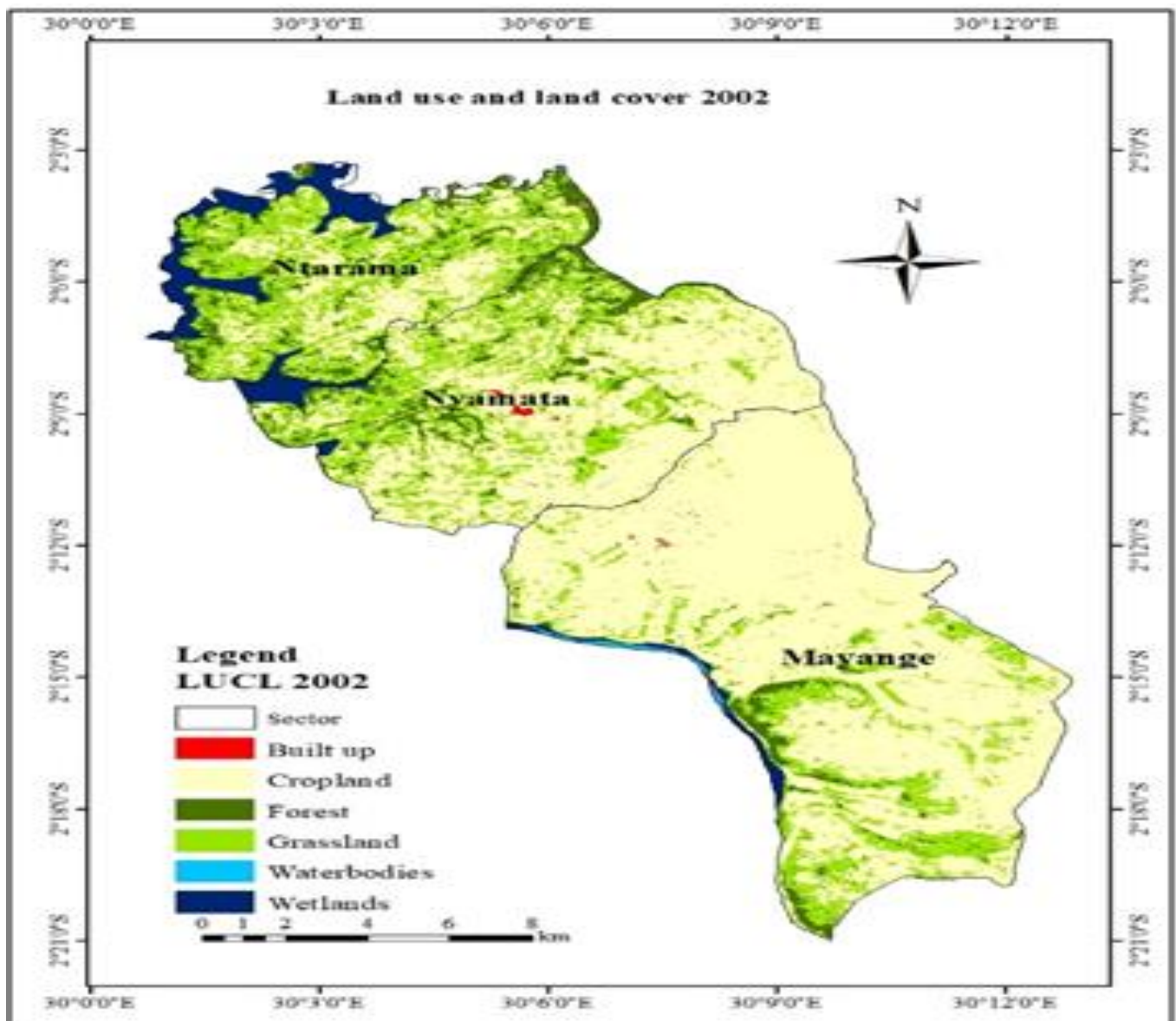


Fig 3. (a) Map of LULC 2002
(Source: Authors compilations, 2023)

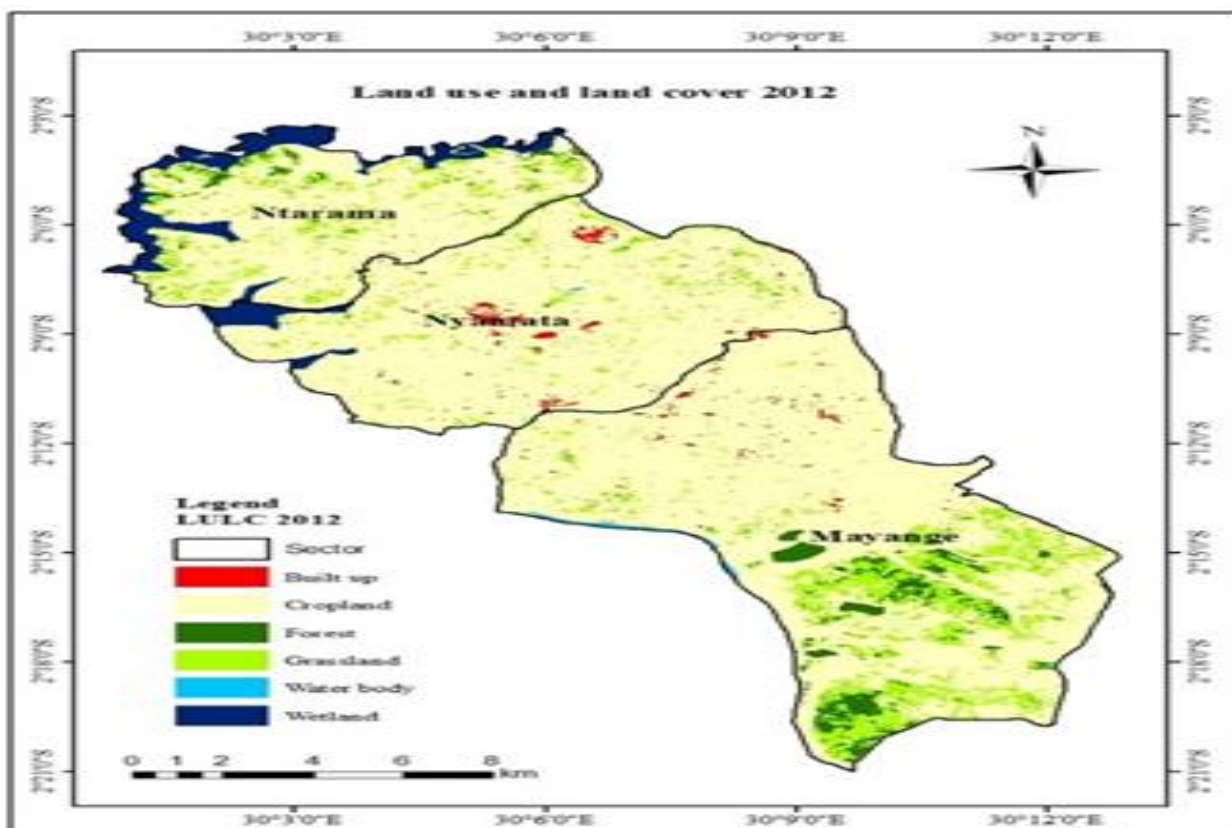


Fig 3. (b) Classified Map of LULC 2012
(Source: Authors compilations,2023)

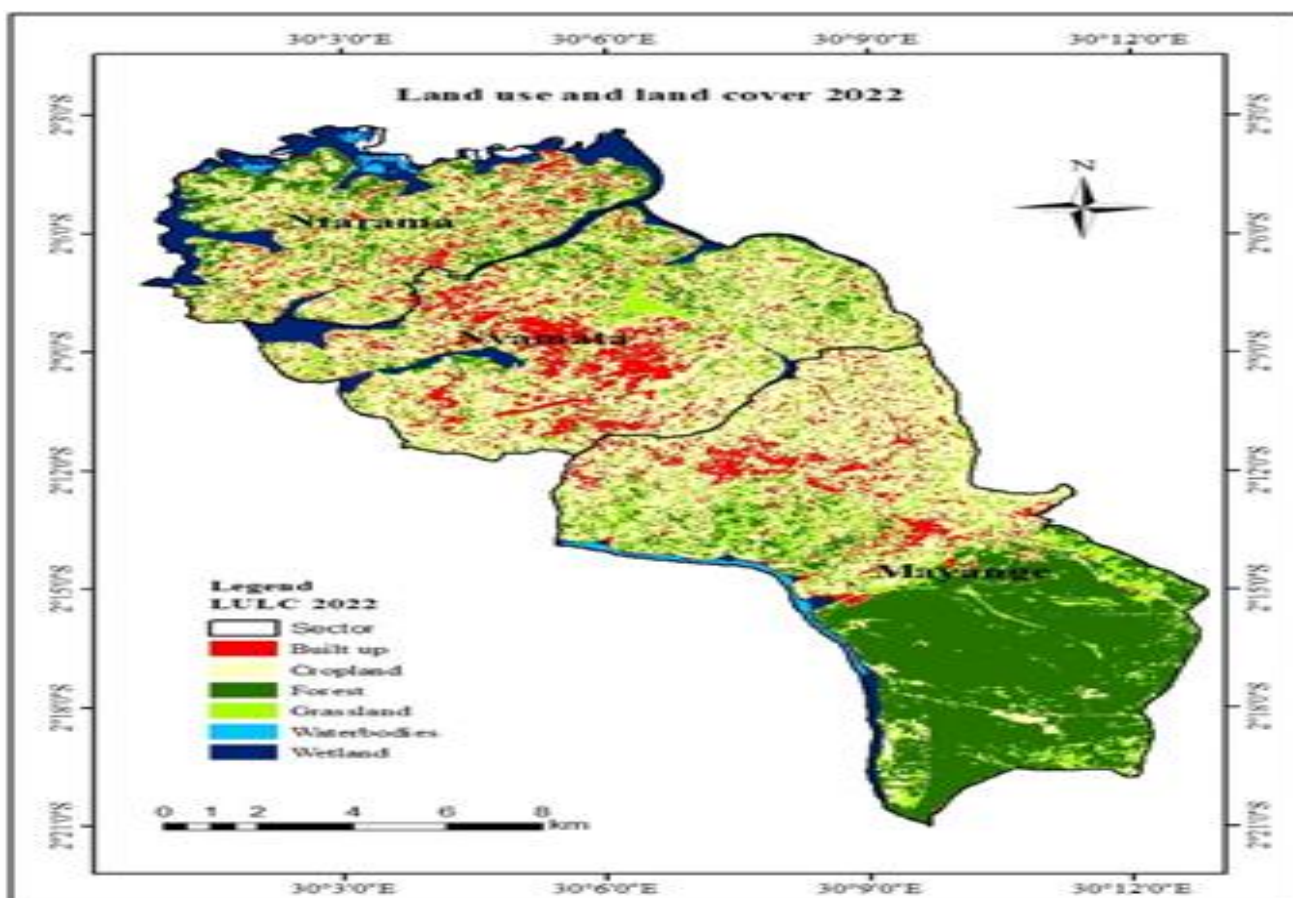


Fig 3 (c) Classified Map of LULC 2022
(Source: Authors compilations,2023)

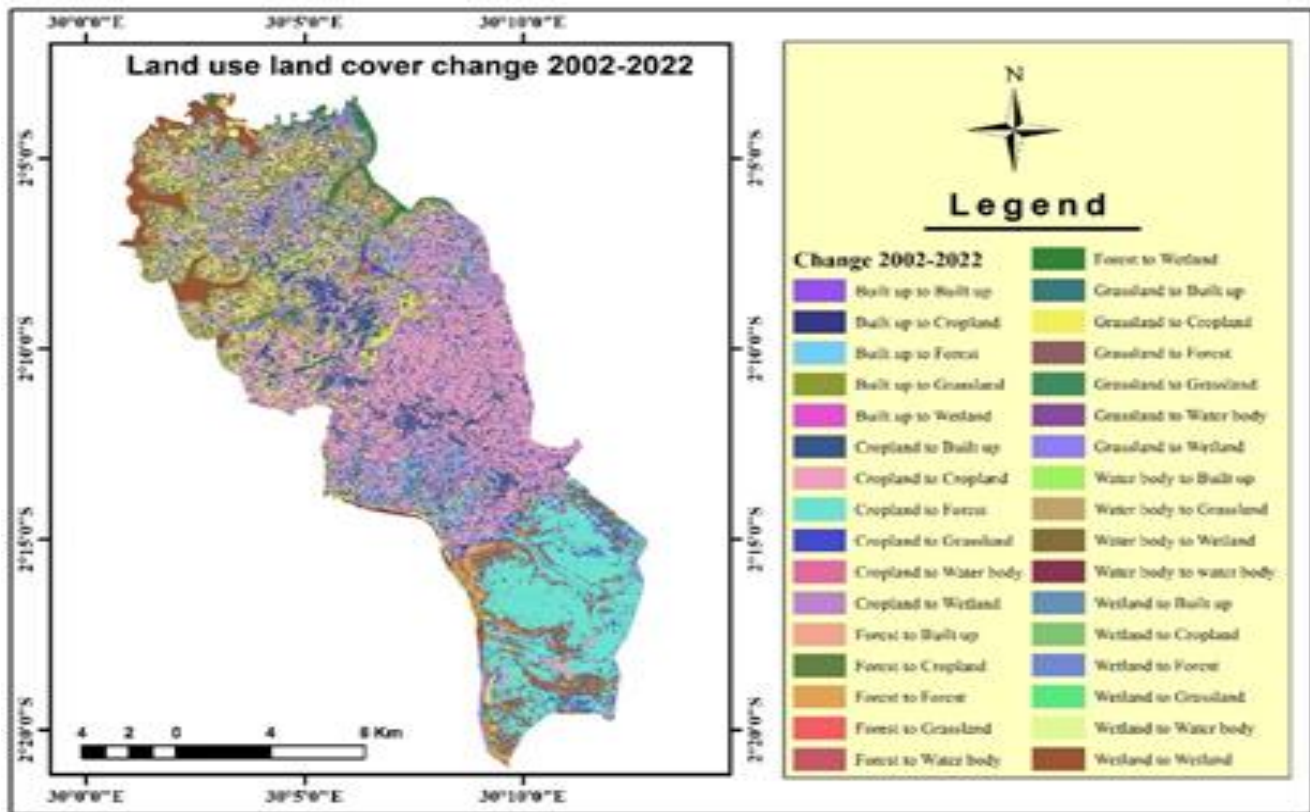


Fig 3 (d) Map of LULC Change Detection (Source: Authors compilations, 2023)

IV. DISCUSSION

The results have shown that Bugesera city has experienced dramatic urban expansion over the period twenty years from 2002 to 2022. The built-up area has expanded at a 5766.751% within this period of 20years. This is related to the population increasing which has occurred within that period. In 2002, the urban population was 47,335 and in 2022 it was 132,458. This has experienced an increase of 179.831% within this study period.

As per Ade and Afolabi, natural increase in population and migration to urban area are the main factors which influence rapid growth urban area (Ade & Afolabi, 2013b). The population may occurs due to people wish to move of urban area in order to pursue the more attractive employment options in urban centers (Razani & Jali, 2015).

As Bugesera has been classified among the satellite cities which are experiencing rapid growth and with are in periphery of Kigali, this also may cause a rapid growth of Bugesera city as it is very easy to live in Bugesera and work in Kigali and the government has facilitated the easy traffic movement among the roads.

By looking at table 4, it is clearly shown that boundaries of city have increased at 5766.751%., the city has expanded in all directions and the inner city has immersed with small centers which were away from the inner city and this causes the expansion of the boundaries of the city. The district officials explained that Bugesera has experienced some houses/dwelling which are built without

complying with planning regulations established by the government. However, the district building inspectorate prevent this by doing regular inspection and also make people being aware that there is a national land master plan that has to be followed by everyone.

The table 4 shows that for the period of 20years; The Built-up area has increased by 5766.751%, accompanying this significant increase of Built-up are, Agriculture land(Cropland) has experienced a decrease of 37.761%. Urbanization is among the factors causes agricultural land to be transformed into no agricultural land ((Hakim et al., 2021a). Road development and governmental policies also can contribute to this. The vegetation has experienced a decrease of 38.644%. Anthropogenic activities like construction, urban expansion, and agricultural production contribute to the decrease of vegetation. (Yi et al., 2022). From the table 4 the vegetation area which has been changed to built-up area is 8.26%, then to cropland is 28.27%. The forest cover has increased up to 241.451%. This is increase is due to the afforestation policies that the government has established specifically in that district of Bugesera which used to be an arid region with few vegetation and forest. In addition to this, Mayange is composed is composed by Gako forest which is a military camp and it is protected. The wetlands have also increased up to 61.366% due to the new national land master plan. The water bodies have also increased up to 156.470%.

V. CONCLUSION AND RECOMMENDATIONS

Generally, the purpose of this study was to evaluate the impact of urban expansion on land use and land cover change in Bugesera district with specific objectives of assessing the dynamism of urban expansion, determining the land use and land cover change (LULCC), and showing the relationship between urban expansion and LULCC in study area over a period of 2002 to 2022. The application of GIS and remote sensing materials is a good practice in analyzing the changes in environmental aspects. The city of Bugesera is experiencing a remarkable expansion. This is alerting the planners that strong measures have to be taken regarding the planning by looking at the population growth in the city. The observed change in land use and land cover is showing an extensive of the human activities in Bugesera city. The land which was used for agriculture is becoming a built area and also due to the population growth and increase of socio-development activities, this shall keep decreasing gradually. It will be the same for vegetation area. On the other side, the Rwanda governmental policies regarding the restoration of nature have played a big role in the district. This is demonstrated by the increase of forest, wetlands and water bodies in the district.

Referring to the results found in this research of evaluating the impact of urban expansion on LULCC a case study of Bugesera District, following recommendation were considered:

The local people are being advised to apply green practices in the place where they live like planting trees in their gardens and farms for being able to keep Bugesera more green. As it was found some cases of illegal housing, they are advised to comply with the national land master plan while constructing their houses and they should avoid any activity which harm the natural environment. The local authorities may increase the awareness to the population about the established policies regarding the environmental protection. The future researches on the same can dig deep on the factors which are causing this excessive urban expansion by mostly assessing the factors causing the population growth. They should also interest the players in environmental protection to be inspired by use of GIS and remote sending tools during monitoring of urban expansion and LULCC and they may also do the prediction of change for the years ahead. Local leaders should strengthen the implementation of planning policies by respecting environmental rules and regulation. The authorities should mobilize the population to construct high-rise buildings which can accommodate many dwellers on a small area instead of building single buildings which require a lot of areas for the purpose of reducing the rate of construction on large scale in short period. As the agricultural land are being decreasing, more technology in agriculture are required for having more production on small cropland for increasing the capacity of feeding the inhabitants of urban areas which are growing day to day. The Government can increase awareness to the population in the application of circular economy practices which result the resource efficiency.

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