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Spatial Analysis of Urban Development in Birnin-Kebbi Metropolis, Kebbi State, Nigeria

Dantani A
Department of Forestry and Wildlife Management, Faculty of Agriculture, Bayero University Kano, Nigeria
Correspondence: adantani.fwm@buk.edu.ng

Abstract: This research was conducted to in order to determine the Spatial analysis of urban development in Birnin-Kebbi Metropolis, Kebbi State, Nigeria. Land use land cover was developed using MODIS (Moderate Resolution Imaging Spectroradiometer) of 250 meters between 1990 and 2020 in ArcGIS environment. The MODIS Imagery was acquired using MODIS imagery for different years between 1990 and 2020. The processing was done using radiometric and atmospheric correction, geometric correction, and mosaic. The temporal Synchronization were done to ensure all images are in the same projection, resolution, and temporal frequency for accurate comparison and analysis. The study used supervised classification methods in ArcGIS to categorize land cover types. Consider creating training datasets based on spectral signatures for different land cover classes. The result shows land use classification in the study area for three decades between 1990- 2020, the land cover classifications were Bare soil, Built-up area, Cultivation, Flood plain, Grasses and Waterbody. In the year 1990, Urban area covers about 4.6km^2 (0.1%), in 2000 increased to 4.9km^2 (0.2%), in 2010 6.6km^2 (0.3%) and finally in 2020 urban area covers 20.5km^2 (1%) on the study area. Conclusively, the study area has undergone significant urbanization over the past three decades, with urban coverage increasing from a modest 0.1% in 1990 to a more substantial 1% in 2020. This transformation underscores the importance of strategic planning, sustainable development practices, and careful consideration of environmental impacts to ensure the well-being of both urban and natural landscapes.

Keywords: Urban, Spatial, MODIS, LULC, and Vegetation

INTRODUCTION

In recent times, urbanization has developed globally at an unprecedented rate. In the last 50 years, the global urban population has grown by nearly 20%. By 2008 over 50% of the global population lived in urban areas; in 2016, the extent of global urbanization reached 54.3% (World Bank Group, 2017). Urbanization is one of the most significant human activities to affect Earth. It is a process that concentrates populations in towns, cities, and metropolitan areas and alters land use with the urban landscape (Angel, 2012). Urbanization includes a complex geographical relationship between humans and the land surface as well as associated economic and social activities (Fragkias *et al.*, 2017). Urbanization drives global economic growth, affects global and regional resources, and changes the natural environment on many scales. It fundamentally changes the ecology of a region (Liu *et al.*, 2011). Urban expansion alters land use and land cover, affects ecosystem biodiversity, modifies watershed hydrology, and changes biogeochemical cycles through waste discharge (Lin *et al.*, 2015; Schneider *et al.*, 2015; Kalantari *et al.*, 2017). Land use/land cover change (LU/LCC) has become part of the global science agenda (Lambin *et al.*, 2001). It is driven by human activities (Teixeira *et al.*, 2014) and is associated with negative impacts on ecosystems observed at local, regional and global scales (Girma & Hassan, 2014). The interaction between nature and humans has transformed the face of the earth for their demands as no other living species ever done (Melaku, 2016). Usually, the development of LU/LCC is relied on the two broader groups of man-made agents, i.e., proximate drivers and underlying causes. The proximate drivers explain the direct action of humans on local land covers and include expansion of agriculture, unsustainable exploitation of forest resources and infrastructure development (Geist & Lambin, 2002). Indirect

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forces as economical, institutional, technological, cultural and demographic changes accelerate the effect of proximate drivers on natural resource use (Geist *et al.,* 2006).

Urbanisation is the social process referring to the physical growth of urban areas with the increase in population either due to migration or amalgamation of peri-urban areas into cities. The urban population in India has increased from 10.8% in 1901 to 17.3% in 1951, 28.5% in 2001 and 31.5% in 2011. More than 50% of the world population residing in urban areas (United Nations, 2009) consume more than 65% of the world's energy and emit 75% of global greenhouse gas (GHG) emissions. Large scale land cover changes have led to the loss of habitats, ecosystem's productivity and also the ability to sequester carbon. Urban areas have a very high ecological footprint (Herold *et al.*, 2003; Liu & Lathrop, 2002) as urban expansions are associated with problems such as destruction of vegetation, changes in local and global climate and the environmental factors in and around the region (Ramachandra *et al.*, 2013). Unplanned urbanisation have led to a much-skewed growth in the region, evident from the dispersed growth in peri-urban areas with the higher consumption of land and without basic amenities and infrastructure. Unplanned urbanization has brought huge environmental impacts and developed various problems in modern growing cities in India. The urban pattern growth analysis aids in understanding the underlying effects of urbanisation such as sprawl, loss of rural land (Huang *et al.*, 2009) and sensitive habitats. The absence of prior visualization of sprawl regions leads to ineffective administration as these areas are not documented in the administrative policy documents and hence deprived of basic amenities. Sprawl refers to disordered and unplanned growth of urban areas often used to describe the awareness of an unsuitable development (Sudhira *et al.*, 2003; Sudhira *et al.*, 2004; Ramachandra *et al.*, 2013). Agents responsible for sprawl are intense urbanisation in core areas, population increase, and population migration. Environmental problems associated with urban sprawl necessitates better techniques to understand the spatial patterns of temporal urbanisation for sustainable management of natural resources in rapidly urbanizing regions (Lambin *et al*, 2000). Remote sensing techniques provide economical and reliable spatial data (with diverse spectral and temporal resolutions) required to derive useful information for city managers and planners through the quantification of land use changes, especially quantifying the urban form and to monitor the dynamic changes at regular intervals, (Ramachandra *et al.*, 2013). Availability of the temporal remote sensing data of the earth's surface helps in mapping and monitoring of landscape. The gradient approach is adopted to identify the local pockets of urbanisation and the spatial patterns of urbanisation are assessed through spatial metrics. Spatial metrics aid in quantifying the urban structure and patterns of urban growth. Landscape metrics have been applied extensively to describe the structures of urban land-use classes (Herold *et al.*, 2002; Herold *et al.*, 2003) and for explaining the interrelationship of intra and inter land uses and the drivers of (Ramachandra *et al.*, 2013). The main objective of this study is to carryout Saptial Analysis of Urban Development in Birnin-Kebbi Metropolis.

Vegetation plays a crucial role in modulating the land versus atmospheric exchange of energy, water, carbon, and momentum, and provides pivotal ecosystem services (Seddon *et al.*, 2016; Piao, *et al.*, 2020; Zhang *et al.*, 2022; Liu *et al.*, 2023). Changes in the vegetation cover can impact the global carbon and water cycles, affecting the climate patterns as a result (Richardson *et al.*, 2013 and Fatichi, *et al.*, 2016) Vegetation changes are driven by concurrent climatic anomalies, environmental changes (Fensholt, 2012; Zhu *et al.*, 2016; Zhang *et al.*, 2022) and by human activities, such as land use and land cover changes (Song *et al.*, 2018; Zalles *et al.*, 2021; Zhang *et al.*, 2022). Specifically, land cover changes are closely related to shifts in vegetation conditions, which are viewed as one of the main drivers behind terrestrial ecosystem productivity (Zhang, *et al.*, 2022). Therefore, a deep understanding of the vegetation changes and related interactions with their climate and anthropogenic drivers is critical to describe and predict the vegetation dynamics under the changing climate and develop effective policies and strategies to promote environmental conservation and sustainability (Liu *et al.*, 2023). The increasing suite of remotely-sensed vegetation indices renders it possible to monitor vegetation dynamics, such as the NDVI (normalized difference vegetation index) (Zhang *et al.*, 2021) the LAI (leaf area index) (Li *et al.*, 2022), the EVI (enhanced vegetation index) (Zhou et *al.*, 2014) the NPP (net primary productivity), the kNDVI (kernel normalized difference vegetation index) (Camps-Valls, *et al.*, 2021) and so forth. Based on the remotely-sensed measure of vegetation changes at different scales, a huge body of studies have since appeared aiming to enhance the human understanding of drivers behind vegetation changes and their responses to climate changes (Zhang *et al.*, 2018; Zhang *et al.*, 2022). First of all, the distribution of global vegetation is strongly controlled by precipitation or rainfall patterns (Zhang *et al.*, 2018; Liu *et al.*, 2023). Climate warming also has an important role in vegetation change or plant phenology (Richardson *et al.*, 2013; Seddon *et al.*, 2016; Higgins *et al.*, 2023). Meanwhile, increasing the temperature exacerbates drought as the increase in evapotranspiration (Liu *et al.*, 2023). Vegetation changes in ecologically vulnerable regions have aroused pervasive concerns (Feng *et al.*, 2016; Mankin *et al.*, 2016; Chen *et al.*, 2019; Zhang *et al.*, 2022;). Vegetation changes over the drylands are highly sensitive to both climate changes and human disturbances (Fu *et al.*, 2021; Shen *et al.*,

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2021). Global warming is generally expected to amplify the existing spatial patterns of moisture conditions, leading to the drylands becoming even more drier (Allan, *et al.,* 2020). Nonetheless, satellite observations have shown a significant positive trend in dryland vegetation cover in recent decades (Fensholt, 2012; Chen *et al.,* 2019). Except for the increasing precipitation beyond "dry get drier", human activities also have the potential to drive the growing dryland vegetation cover (Chen *et al.,* 2019; Shen *et al.,* 2021; Li, *et al.,* 2021)

METHODOLOGY

Study Area

Birnin Kebbi Metropolis is located in Birnin Kebbi Local Government and also the capital city of Kebbi State, the state that was carved out and created from part of Sokoto State in 1991, the headquarter of Birnin Kebbi local government area and also the seat of Gwandu Emirate is located in Northwestern Nigeria. It is geographically defined within latitude 12^0 24' 00" and 12^0 30' 30" N and longitude 4^0 10' 0" and 4^0 15' 30" E. (Yauri, *et al.,* 2018). It lies along Sokoto River at the intersection of roads from, Jega and Bunza bonded in the east by the Gwandu LGA, to the west by Arewa Dandi Local government and the Kalgo and Argungu local government areas to the south and north respectively. The climate of the area is local steppe which falls within Koppen-Geigers BSh tropical Continental climatic. The average annual temperature ranges between 28.40 C to 370 C, with the mean annual rainfall is about 807mm with some local variations. The study area is part Sokoto basin of an elongated sedimentary basin underlying which is characterized by gently rolling to undulating relief features, the soils are the vertisols. Which comprises of heavy, cracking clayed soils with more than 35% clay have shrinking and swelling properties, the elevation around varies from about 225 meters to 238 meters above sea level (Yauri, *et al*., 2018). The Birnin Kebbi landscape is mostly dominated by floodplains of Rima and Shella rivers which are located in the north and south-east of the town respectively. The study area falls within the northern Guinea savannah zone which is mostly described by heterogeneous mixture of vegetation, with few medium height trees the population of Birnin Kebbi was estimated to be about 125,594 peoples according to 2006 population census, the area comprises of multiple ethnic groups, major among who are Kabawas, Fulanis, Zabarmawas, Dakarkaris, with Islam as the major religion, due the nature of the area i.e. the two fertile Fadama lands; the Shella and Rima rivers fadama. Shella river fadama is situated approximately 3km south east of the town and averages about 1.5km width the people of the area are predominant fadama farmer with rice as the major agricultural product as well as other crops (Yauri, *et al*., 2018).

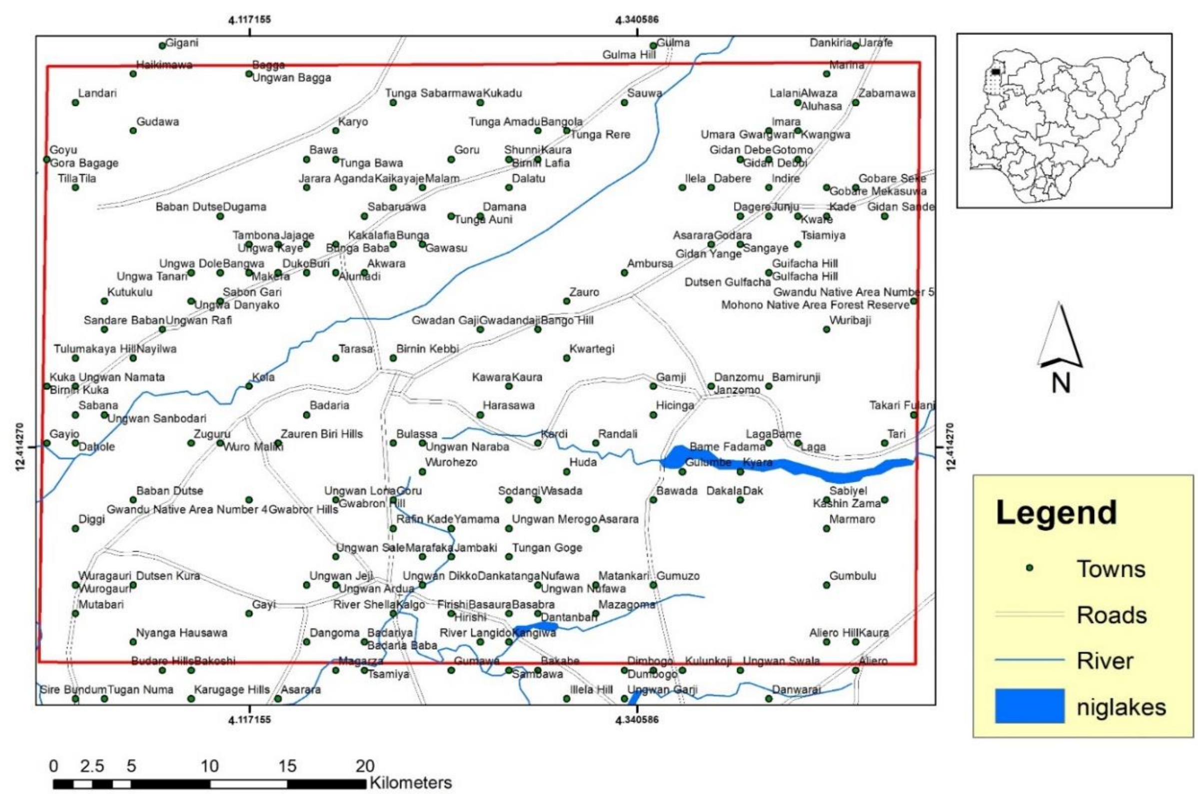

Fig. 1. *Map of the Study Area*

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Methodology and Image processing

Land use land cover was developed using MODIS (Moderate Resolution Imaging Spectroradiometer) of 250 meters between 1990 and 2020 in ArcGIS environment.

Data Acquisition:

The MODIS Imagery was acquired using MODIS imagery for different years between 1990 and 2020. These satellite images are available at various spatial and temporal resolutions. Choose appropriate bands and image products suited for land use classification.

Preprocessing:

The processing was done using radiometric and atmospheric correction, geometric correction, and mosaic. The temporal Synchronization were done to ensure all images are in the same projection, resolution, and temporal frequency for accurate comparison and analysis.

Land Use Classification:

The study used supervised classification methods in ArcGIS to categorize land cover types. Consider creating training datasets based on spectral signatures for different land cover classes

RESULT AND DISCUSSION

Land Cover Classification

The result in table 1 below shows land use classification in the study area for three decades from 1990-2020 the classifications are Cultivation (Agricultural land) bare soil, Built-up area, Flood plain, Grasses and Water body. The area covered by cultivation has shown a slight increase from 1990 to 2020, reaching 63.2%, the area of bare soil has decreased over the decades, from 16.1% in 2000 to 13.7% in 2020, built-up areas have increased notably from 0.2% in 2000 to 1.0% in 2020, flood plain, grasses, and water body have shown relatively stable percentages over the years with minor fluctuations.

Table 1: Land cover classification/changes over three decades

Land Use	**1990(km^2)**	**%**	**2000(km^2)**	**%**	**2010(km^2)**	**%**	**2020(km^2)**	**%**
Bare Soil	340.0	10.1	339.3	16.1	326.5	15.5	289.5	13.7
Built-up Areas	4.6	0.1	4.9	0.2	6.6	0.3	20.5	1.0
Cultivation	2542.6	75.9	1299.7	61.6	1310.7	62.1	1334.3	63.2
Flood Plain	294.5	8.8	295.0	14.0	294.6	14.0	294.3	14.0
Grasses	166.9	5.0	168.7	8.0	168.9	8.0	168.7	8.0
Water body	2.6	0.1	2.6	0.1	2.6	0.1	2.6	0.1

Land cover changes in 1990

The result obtained indicates a landcover classification of the study area in 1990 showing various categories representing different types of land uses. The red-colored patches represent built-up or urban development or infrastructure in 1990 was relatively limited. The largest portion of the study area is devoted to cultivation (75.9%) which indicates a significant emphasis on agricultural activities in the region during 1990. It implies that a large portion of the land was used for farming or other agricultural purposes. The result also indicates about 10.1% of the area is being classified as bare soil indicative of areas where the natural vegetations were removed and the soil exposed to erosion (water and wind) this could be due to factors such as deforestation, agricultural activities as a result of population growth or natural processes. The presence of an 8.8% floodplain suggests that there are areas prone to periodic flooding. This could influence land use decisions and may contribute to the dominance of certain land cover types. The smallest percentage of the land was covered by grasses (5.0%). This might include natural grasslands or areas with vegetation dominated by grass species. The presence of water bodies, comprising 0.1% of the area, indicates the existence of rivers or other water features. This could have implications for both natural ecosystems and human activities and also hinder the development of the city in that direction.

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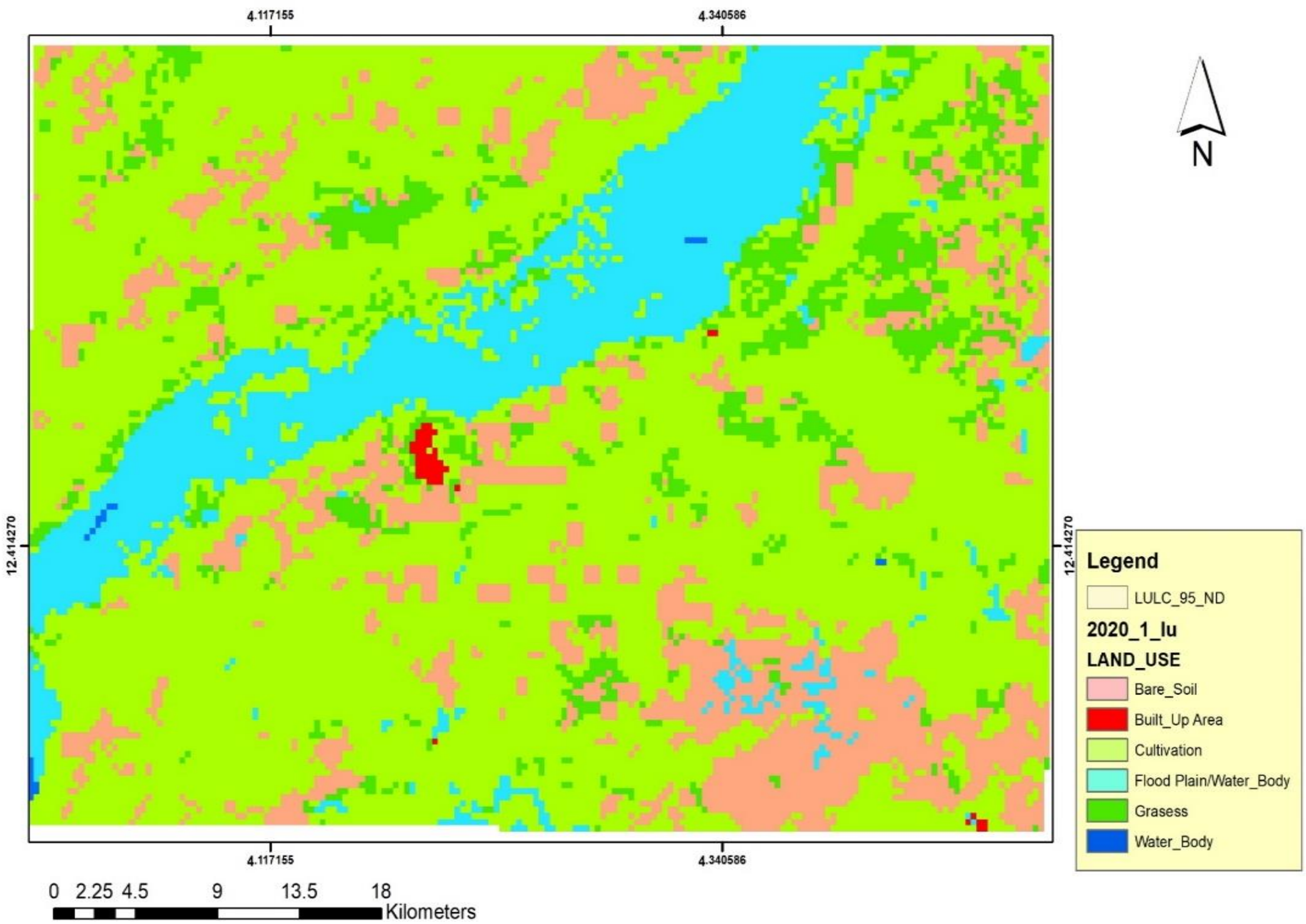

Fig. 2. *LULCC_1990*

4.1.2 Land cover changes in 2000

Thematic land cover image obtained in 2000 (Fig 3) showed cultivation land dominates the landscape, constituting the largest land cover class at 61.6%. This suggests a significant emphasis on agricultural activities in the region during the year 2000. Bare soils cover 16.1% of the area. This land cover type could result from factors such as deforestation, land clearing, or natural processes that leave the soil exposed. The presence of a floodplain at 14.0% indicates areas prone to periodic flooding. This may have implications for land use planning and development in flood-prone zones. Grasses cover 8.0% of the area, which may include natural grasslands or areas with vegetation dominated by grass species. The water body maintains the same size, indicating stability in water features such as rivers, lakes, or ponds. This could be influenced by factors like natural water sources or water management practices. The built-up area slightly increased to 4.9% compared to the previous decade. This suggests urban expansion, particularly towards the southern part of the city. The expansion of the built-up area could be indicative of increased infrastructure development and human settlement, urban expansion towards the southern part of the city suggests a specific directional trend in the growth of built-up areas and this information is very crucial crucial for urban planning and understanding the dynamism of urban development.

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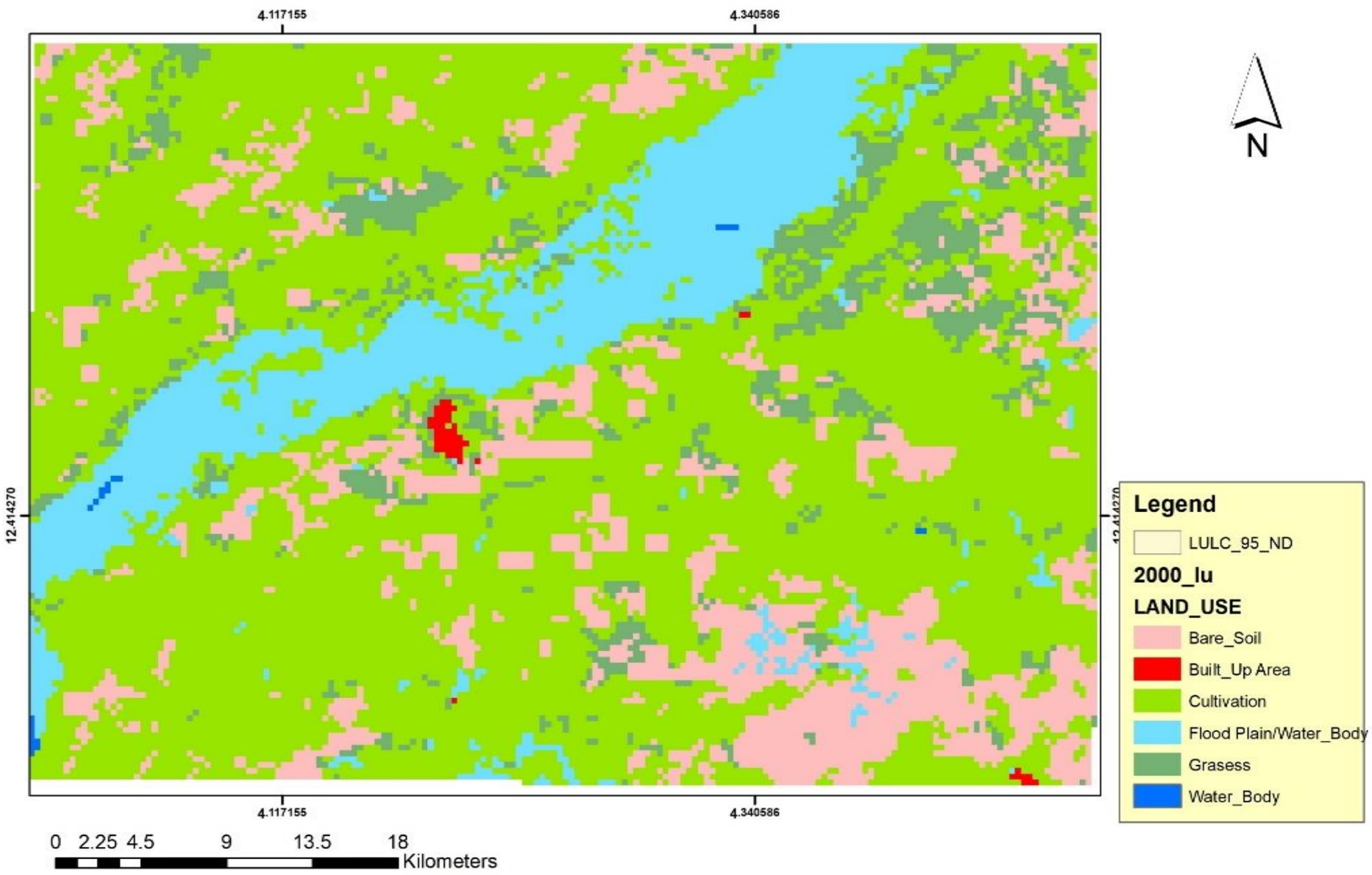

Fig. 3. *LULCC_2000*

Land cover changes in 2010

There is little increase in cultivation land, accounting for about 62.1% of the study area. This suggests a continuation of agricultural activities and potential expansion of cultivated areas. The increase in cultivation land reflects the ongoing importance of agriculture in the region which is the major occupation of the population. Bare soil has reduced to 15.5%, indicating a decrease from the previous decade. The reduction could be attributed to factors such as urbanization, land development, or changes in land use practices, decreased in the amount of bare soil may be a consequence of increased urbanization and land development activities. Urban expansion has increased to about 0.3%, representing 6.6 km^2. This indicates continued growth in built-up areas and urban development. The expansion of urban areas could be driven by population growth and infrastructural development, the expansion signifies ongoing growth and development in built-up areas, possibly driven by economic activities and population dynamics. Other land classifications remain almost the same with little or no pronounced changes from the previous decade. This suggests stability in the proportions of floodplain, grasses, and water body, emphasizing a degree of consistency in these features over the decade.

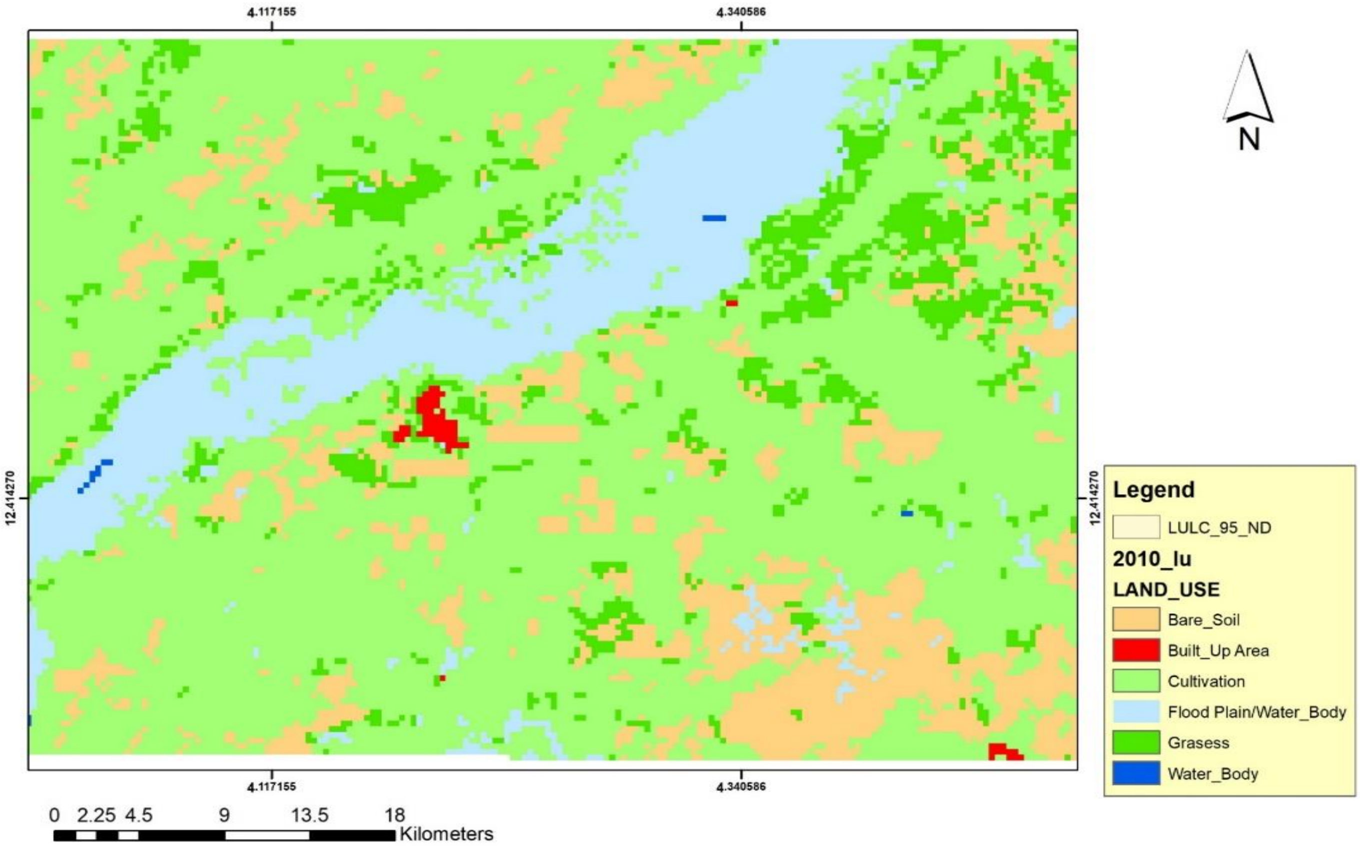

Fig. 4. *LULCC_2010*

Land cover changes in 2020

The information provided in figure 5 below highlights significant urban expansion in the map of 2020, particularly when compared to the previous decades. Let's break down the key points: The urban expansion has increased dramatically from 0.3% in 2010 to 1% in 2020, representing about 20.5 km2. This indicates a substantial growth in built-up areas within the study area over the past decade. The red patches on the map symbolize urban areas, showcasing the extent of built-up development. The use of red may indicate the intensity or significance of the urban expansion. The expansion is described as extending horizontally towards the southern part of the city. This directional information is crucial for understanding the pattern and orientation of urban growth. The information notes that the urban expansion avoids the northern part of the city, possibly due to its susceptibility to flooding. This reflects a consideration of environmental factors in the spatial planning of urban areas. The drastic urban expansion is mentioned to have a significant impact on farming activities in the study area. This is a common consequence of urbanization, where agricultural land is converted to built-up areas, affecting local communities dependent on farming. The statement mentions that the current trend of expansion coincides with the findings of Mukhtar and Yelwa in 2020. This suggests a consistency or validation of the current observations with previous research on urbanization trends in the area. The unprecedented urban expansion poses challenges to agricultural activities and could impact food security in the region. The avoidance of the flood-prone northern part indicates a consideration of environmental risks in urban planning.

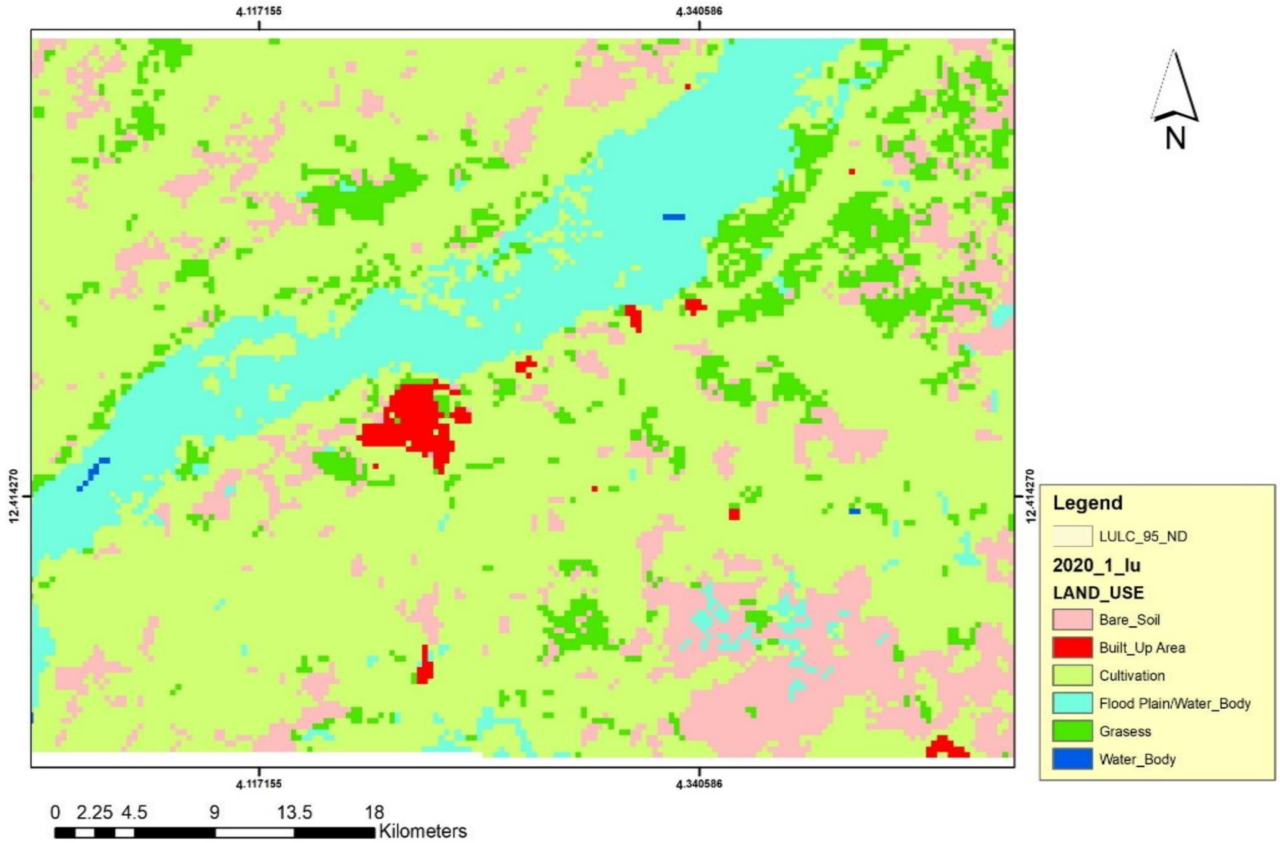

Fig. 5. *LULCC_2020*

CONCLUSION AND RECOMMENDATION

The rate of urban expansion appears to have accelerated, particularly from 2010 to 2020 when urban coverage increased noticeably, the increase from 6.6 km^2 (0.3%) in 2010 to 20.5 km^2 (1%) in 2020 indicates a substantial growth spurt. The expansion of urban areas has likely led to the transformation of other land cover types, with potential impacts on cultivation, bare soil, flood plain, grasses, and water bodies, this transformation have consequences for biodiversity, ecosystems, and the overall environmental balance. This transformation underscores the importance of strategic planning, sustainable development practices, and careful consideration of environmental impacts to ensure the well-being of both urban and natural landscapes**.**

i. Urban expansions be give preference on bare soils rather than agricultural land suggests a strategic approach to urban development. Preserving agricultural land is crucial for food security and sustainable land use.

ii. Irrigation be encouraged in flood-prone areas aiming to increase agricultural production as a supplement to the already lost agricultural lands lost by urbanization. Irrigation can offset the challenges posed by limited arable land

iii. Tree planting should be encouraged to reduce the vastness of bare soils which will enhance soil conservation, prevent erosion, and improve environmental quality (microclimate modification).

iv. There should be policies that will encourage collaboration between government agencies, urban planners, environmentalists, and agricultural experts, this will promote sustainable management of our environment.

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