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(Research Article)

Assessment of land use and land cover change detection for Argungu Urban: A Remote Sensing and GIS Approach

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Abstract

Urbanization is a significant driver of land use and land cover (LULC) changes, impacting environmental and socio-economic systems. Accurate monitoring and analysis of urban LULC changes are crucial for sustainable urban planning and management. This study employed remote sensing and Geographic Information Systems (GIS) techniques to detect and analyze LULC changes in Argungu urban, Nigeria, between 2013 and 2023. Landsat 8 images were classified using supervised classification, revealing significant changes: 9.5% expansion of built-up areas, -32.9% decrease in vegetation cover, and 23.3% increase in bare soil areas. The study highlights rapid urbanization and infrastructure development, potentially leading to environmental degradation. However, limitations include data quality, classification accuracy, and temporal resolution. Future research should integrate high-resolution imagery, additional data sources, and predictive models to enhance understanding of LULC changes. This study informs sustainable urban planning, environmental management, and policy-making in Argungu urban.

Keywords: Land use/land cover change; Remote sensing; GIS; Urbanization; Environmental degradation; Sustainable urban planning.

1. Introduction

Urbanization is a global phenomenon, with cities experiencing rapid growth and transformation. Understanding urban land use/land cover changes is crucial for sustainable urban planning, resource management, and environmental monitoring [1, 2]. Urbanization is a rapid and complex process that has significant impacts on the environment, economy, and society [3]. Accurate monitoring and analysis of urban land use/land cover changes are crucial for sustainable urban planning and management [4]. Remote sensing and Geographic Information Systems (GIS) have emerged as powerful tools for detecting and analyzing urban land use/land cover changes (LULC) [5].

Remote sensing offers a cost-effective and efficient way to monitor urban areas over large spatial and temporal scales [6]. Multitemporal satellite images can be used to detect changes in urban LULC, such as urban growth, sprawl, and densification [7]. GIS, on the other hand, provides a platform for analyzing and integrating spatial data, allowing for the examination of the spatial and temporal patterns of urban land use/land cover changes [8].

Despite the progress made in urban LULC change detection, there are still challenges and limitations to be addressed [9]. For instance, the accuracy of change detection results can be affected by factors such as image quality, spatial resolution, and classification algorithms [10]. Consequently, it is critical to develop and improve GIS and remote sensing techniques for detecting changes in urban land use and cover.

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This study aims to develop a remote sensing and GIS approach with a focus on identifying and quantifying the types and rates of land use/land cover changes. The approach is applied to the Argungu urban area, and the results are validated using ground truth information. Our objective is to analyze urban land use/land cover changes over time using satellite imagery, to identify and quantify the types and rates of land use/land cover changes and investigate the driving factors and consequences of land use/land cover changes. The rest of the paper is organized as follows: Next section reviews the literature of the underlying concept. The methodology section describes the procedure for data collection and analysis. The results section presents the outcomes of the analysis. The discussion section gives a broader details of findings. Summary of the findings and future directions are outlined in the conclusion section.

2. Review of Related Literature

Land use and land cover (LULC) change detection is crucial for understanding the dynamics of landscape changes, managing natural resources, and mitigating the effects of climate change. Previous studies have demonstrated the effectiveness of remote sensing and GIS for urban LULC change detection [5]. Studies have utilized satellite imagery to detect LULC changes, such as deforestation [11], urbanization [1], and agricultural expansion [10].

Remote sensing techniques, like change detection algorithms [12] and image classification [13], have been employed to analyze LULC changes. GIS has been used to integrate remote sensing data with spatial data, enabling the analysis of LULC changes to various factors, such as topography [14], soil type [15], and climate [16]. GIS-based spatial analysis has also facilitated the identification of patterns and trends in LULC changes [17]. For example, Li, Sun [18] used Landsat images and GIS to detect urban growth and sprawl in Beijing, China. [19] used Sentinel-2 images and GIS to analyze urban land use/land cover changes in Xiongan, China. Bello [20] also applied remote sensing and GIS techniques to examine LULC change in Maiduguri, Nigeria.

Recent studies have emphasized the importance of high-resolution imagery [21] and machine learning algorithms [9] for accurate LULC change detection. Integrating remote sensing and GIS has improved the accuracy and efficiency of LULC change detection [10]. This research will build on the existing literature to explore the use of remote sensing and GIS technologies for LULC change detection in Argungu urban.

3. Materials and Method

3.1. Study Area

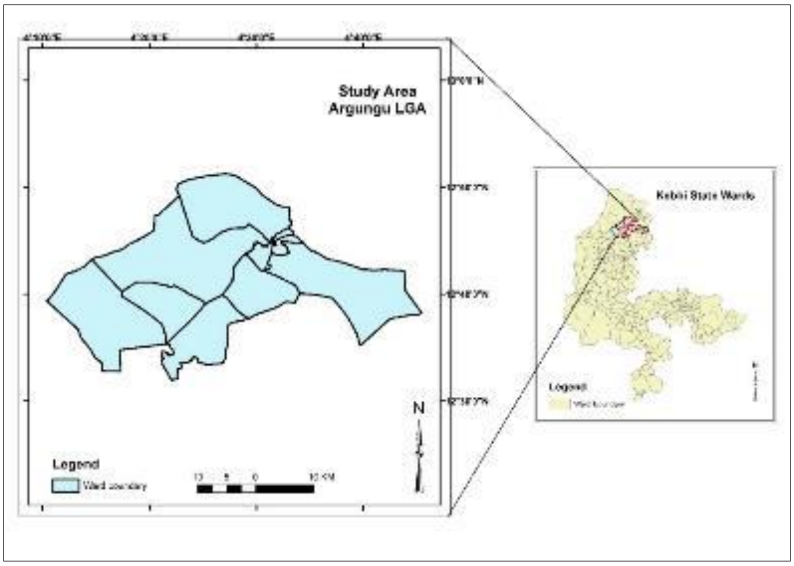

Figure 1 Location map of Argungu LGA

Argungu LGA, Kebbi State, established in 1976, comprises 11 wards with its headquarters in Argungu. It is located at latitudes 12°30'0"N - 12°50'0"N and longitudes 4°10'0"E - 4°50'0"E, covering 491.128 km^2 with an elevation of 241m. According to 2022 projected population estimates, Argungu LGA has a population of 342,100 [22]. Most of the inhabitants of the area live along the marshy Fadama land and are mostly farmers, fishermen and hunters. Major crops produced in the area include rice, vegetables and fruits in the Fadama area while sorghum, millet, and beans are the upland or rainfed crops.

The study area enjoys a tropical continental type of climate, which is largely controlled by two air masses namely; tropical maritime and tropical continental blowing from the Atlantic and Sahara deserts respectively. The air masses determined the two dominant seasons, wet and dry. Humidity is 27% while the wind blows at 15 km/h in the ESE direction. Argungu receives a mean annual rainfall of 800mm between May to September with a peak period in August, the remaining period of the year is dry. The average temperature is 26^0C and can rise to 40^0C in the peak of hot season (March-July). However, during harmattan, (December – February) temperature falls to 21^0C. Figure 1 shows the location map PHC in Argungu LGA ward boundaries.

3.2. Data

Multi-temporal Landsat 8 satellite imagery (row:191 and path:5) for multiple periods (2013 and 2023) for the study area's bounding box was sourced from the United States Geological Survey (USGS) data portal [23]. GIS data (e.g., land use/land cover maps, urban boundaries) will also be required [1]. Additionally, socio-economic data (e.g., population growth) is needed for analysis.

3.3. Method of Data Analysis

The Landsat image comes in separate bands that must be pre-processed (composed, rectified, georeferenced, and cropped). Next, we performed image classification (e.g., supervised, unsupervised) and change detection analysis (e.g., comparison, image differencing). ArcGIS 10.7 tools and R programming language were employed to conduct different image analyses, such as land use/land cover changes. The accuracy assessment was conducted to validate the results by ground-truth exercise.

4. Results

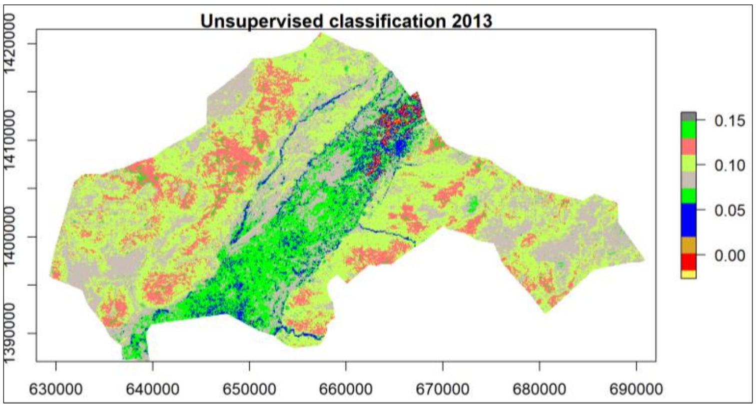

Figure 2 LULC unsupervised classification map for 2013

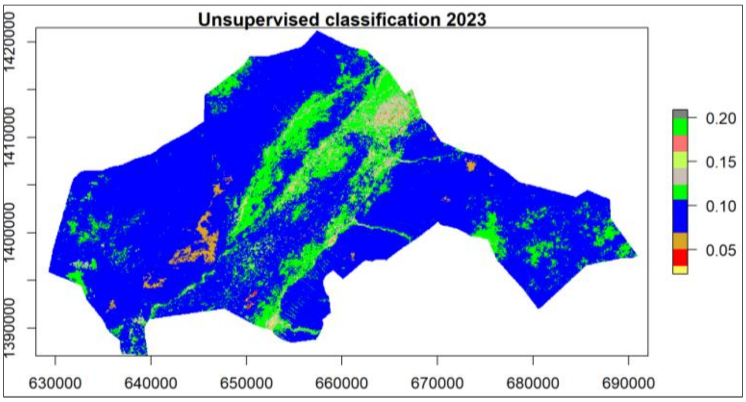

Figure 3 LULC unsupervised classification map for 2023

The overall accuracy of the LULC classification for 2013 and 2023 was 92.5% and 95.2%, respectively. The Kappa coefficient values were 0.89 and 0.93, indicating excellent agreement between the classified images and reference data. The LULC change detection analysis revealed significant changes in Argungu Urban between 2013 and 2023 (Figure 2 and Figure 3).

Table 1 presents the land use and land cover (LULC) change detection statistics for various land uses in the study area. Figure 4 illustrates a comparative chart of the percentage changes in LULC between 2013 and 2023.

Table 1 LULC Change Detection Matrix

LULC class	2013 (m^2)	2023 (m^2)	2013 (%)	2023 (%)	Change %
Built up area	3051	9221	12.59651	22.1648	9.568293
Irrigated land	833	207	3.439164	0.497572	-2.94159
Vegetation	8331	1823	34.39577	4.382001	-30.0138
Barren land	12006	30351	49.56856	72.95563	23.38707

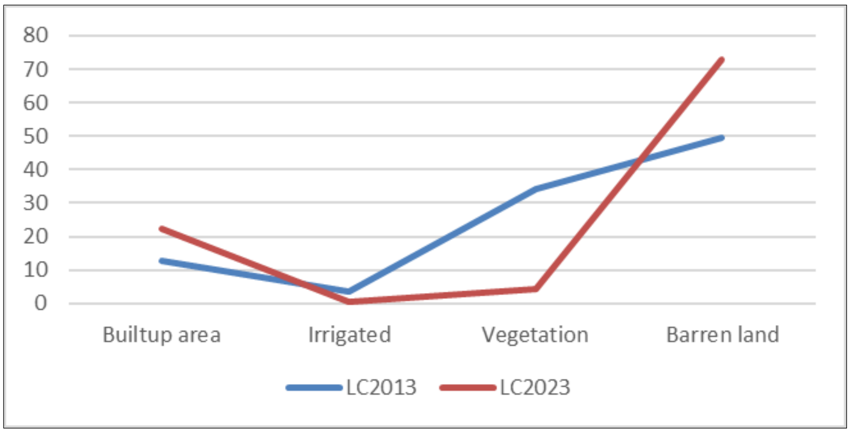

Figure 4 Comparative chart of LULC 2013 and LULC 2023

The change detection analysis revealed a significant expansion of built-up areas, with an increase of 9.5% (6,170 (m^2)) and a decrease in vegetation cover by -30.0% (-6508 (m^2)). Increase in bare soil areas by 23.3% (18345 (m^2)) and minimal change in irrigated land (-2.4% decrease). Figure 5 shows the LULC changes between 2013 and 2023.

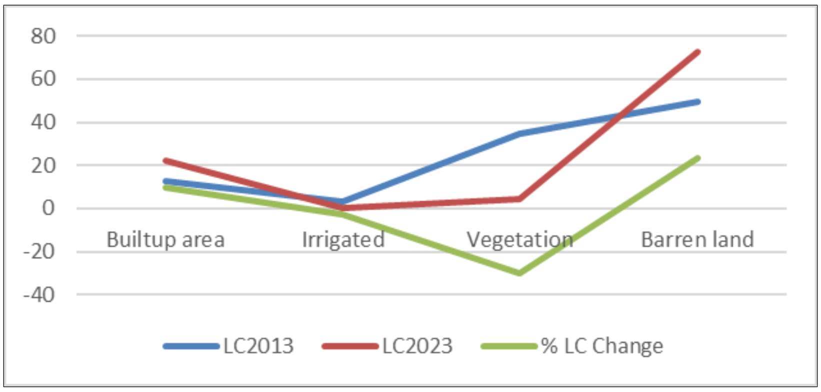

Figure 5 LULC differences chart for 2013 and 2023

5. Discussion

The results of this study reveal significant land use and land cover (LULC) changes in Argungu urban between 2013 and 2023. The expansion of built-up areas by 9.5% and decreases in vegetation cover by 30.0% indicate rapid urbanization and infrastructure development. These changes are consistent with Nigeria's urbanization trends [24]. However, the magnitude of changes observed in Argungu urban is higher than reported elsewhere [25]. The spatial analysis revealed urban sprawl and expansion towards the outskirts of Argungu Urban conversion of vegetation and reserved areas to built-up and bare soil areas. Increased development along major roads and infrastructure is also remarkable.

Loss of vegetation cover and increase in bare soil areas may lead to soil erosion, increased runoff, and reduced groundwater recharge [26]. Built-up area expansion may increase urban temperatures, affecting human health and comfort [27]. Consequently, the socio-economic impact of urbanization may lead to increased poverty, inequality, and strain on infrastructure and services.

On the other hand, several factors may have contributed to these LULC changes. Firstly, Argungu's population has grown exponentially over the years resulting in more pressure on the resources. Similarly, infrastructure, agriculture, and commerce investment may have driven urbanization. Urban planning and development policies may have influenced LULC changes in the study area.

6. Conclusion

This study employed remote sensing and GIS techniques to detect and analyze land use and land cover (LULC) changes in Argungu urban between 2013 and 2023. These changes indicate rapid urbanization and infrastructure development in Argungu, potentially leading to environmental degradation and socio-economic challenges.

The study contributes to an understanding of LULC changes in Argungu urban, some limitations should be acknowledged. The accuracy of Landsat 8 images may be affected by atmospheric conditions and sensor calibration. The supervised classification algorithm may not accurately capture complex LULC categories. The study only analyzed two periods (2013 and 2023), limiting the understanding of annual changes. To address these limitations and enhance our knowledge of LULC changes in Argungu urban, future research should integrate high-resolution satellite imagery (e.g., Sentinel-2) for improved classification accuracy. Conduct annual or seasonal analyses to capture dynamic changes in LULC patterns.

In conclusion, this study highlights the importance of remote sensing and GIS in monitoring LULC changes in Argungu urban. The findings provide valuable insights for sustainable urban planning and environmental management.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have reported no conflict of interest.

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