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The Impact of Land Use and Land Cover Changes on Community Livelihood: A Case of Bugesera District

Alphonse Bizimana[1], Dr. Aboubakar Gasirabo[1] (PhD), Joseph Singirankabo[1], Shirambere Audrey Umurerwa[2]

[1]Faculty of Environmental Studies, University of Lay Adventists of Kigali
[2]Kigali Independent University

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Abstract

The study assessed the impact of land use and land cover (LULC) changes on community livelihoods in Bugesera District, where rapid population growth, urban expansion, infrastructure development, and rising land demand have driven significant environmental and socio-economic change. Using a mixed-methods approach combining satellite imagery (2016, 2020, 2025) and household surveys, the findings show that cropland remains the dominant land use but is increasingly fragmented due to expanding built-up areas along settlement and transport corridors. Wetlands and water bodies remained relatively stable, while vegetation and tree cover fluctuated due to natural dynamics and agroforestry practices. Key drivers of LULC change include urbanization and infrastructure development (mean > 4.2), weak land use policy enforcement (mean = 4.80), population pressure, and economic factors, while agricultural expansion had a moderate influence (mean = 3.81). The study also reveals significant livelihood impacts, including declining soil fertility (mean = 4.39) and increased land degradation (mean = 4.29), leading to reduced agricultural productivity, food insecurity, and lower household income. Statistical results show strong correlations among drivers (r = 0.58–0.81) and significant negative relationships with livelihood outcomes (r = -0.52 to -0.81). Regression analysis confirms that LULC drivers significantly predict livelihood outcomes (R^2 = 0.55–0.62, p < 0.001), highlighting population growth, urbanization, and economic pressures as key negative predictors.

Keywords: *Community Livelihoods, Ecosystem Services, Land Use and Land Cover Change (LULC), Remote Sensing, Urbanization.*

1. Introduction

Land use and land cover (LULC) change is one of the most significant human-induced transformations of the Earth's surface, strongly affecting ecosystems, climate regulation, biodiversity, and livelihoods. Globally, between 1992 and 2020, artificial surfaces increased by 133% and cropland by 6%, while pasture and forest areas declined by 4.0% and 3.8% respectively, largely driven by population growth and socio-economic

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development (Li et al., 2021). These changes contributed to rising greenhouse gas emissions from 31 to 46 Gt CO_2 eq, with urban expansion identified as a key driver. Satellite evidence further confirms widespread global land transformation across forests, croplands, and urban areas between 2000 and 2020 (Potapov et al., 2022).

In Africa, rapid population growth and urbanization have intensified land conversion and environmental degradation. Countries such as Ethiopia, Nigeria, and South Africa have experienced major shifts, including expansion of cultivated land and built-up areas at the expense of forests, wetlands, and grasslands, leading to soil erosion, biodiversity loss, and declining ecosystem services (Demessie et al., 2025; Hussien et al., 2026). In Eastern Africa, cropland expanded by 18,154,000 ha (34.8%) between 1988 and 2017, while settlements increased by 43.5%, causing significant loss of woody vegetation (Bullock et al., 2021). These regional transformations increase vulnerability to climate change and threaten rural livelihoods.

In Rwanda, high population density and development pressure have led to dramatic land shifts. Forest cover declined from 10,894.89 km² in 1990 to 4,322.12 km² in 2015, while cropland nearly doubled. Built-up areas are also expanding, with projections indicating continued urban growth by 2050 (Li et al., 2021; Hakorimana et al., 2025). These changes are driven by population pressure, topography, and agricultural demand, affecting food security and environmental stability.

At the local level, Bugesera District illustrates these dynamics more intensely. Between 2004 and 2024, agricultural land decreased by 51%, while built-up areas increased by 5,800% and forest cover dropped from 840.59 km² to 221.85 km² (Dusengimana et al., 2025). These changes have led to a 70% decline in water quality, 32% biodiversity loss, and a 19% reduction in carbon sequestration (Kayitesi et al., 2026). NDVI and NDWI analyses confirm vegetation loss and hydrological disruption. Consequently, soil fertility decline, reduced crop yields, and livelihood vulnerability among smallholder farmers have intensified.

1.2 Objectives of the Research

1.2.1 General objective

The general objective of the study was to assess the impact of land use and land cover (LULC) changes on community livelihoods in Bugesera District, Rwanda.

1.2.2. Specific objectives

(i) To investigate the major drivers of land use and land cover changes in Bugesera District

(ii) To examine the community livelihoods in Bugesera District

(iii) To assess the relationship between land use and land cover change drivers and community livelihood outcomes in Bugesera District.

2. Research methods

2.1 Description of the study area

Bugesera District is located in Rwanda's Eastern Province, about 40 km southeast of Kigali City, between 2°15′–2°55′ South latitude and 30°00′–30°30′ East longitude (NISR, 2022). Covering approximately 1,288 km², the district is administratively organized into sectors, cells, and villages. It has experienced rapid population growth, with livelihoods largely dependent on subsistence agriculture, livestock rearing, fishing, and small-scale trade. The

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district is characterized by relatively low population density compared to areas closer to Kigali, but increasing migration and settlement expansion have intensified land pressure. It contains important lakes such as Cyohoha, Rweru, and Mugesera, which support fishing, irrigation, and domestic water supply, though these ecosystems are increasingly threatened by environmental degradation and land use changes.

Topographically, Bugesera consists mainly of flat to gently undulating plains that are highly vulnerable to seasonal flooding and waterlogging. The district experiences a semi-arid to tropical climate with bimodal rainfall patterns, irregular precipitation, and frequent dry spells, making agriculture highly sensitive to climate variability and drought. Agriculture remains the backbone of the local economy, with major crops including maize, beans, cassava, bananas, sorghum, and horticultural products (MINAGRI, 2020). However, productivity is limited by poor soil fertility, land degradation, and limited access to modern inputs. Livestock farming is also an important livelihood source.

In recent years, Bugesera has undergone significant land use and land cover changes driven by population growth, agricultural expansion, urbanization, and major infrastructure projects such as Bugesera International Airport. These changes have led to the conversion of agricultural land, forests, and wetlands into built-up areas, reducing ecosystem services such as soil fertility, water regulation, and biodiversity (Dusengimana et al., 2025). As a result, communities face increasing food insecurity, reduced productivity, and environmental vulnerability, making the district highly suitable for studying human–environment interactions.

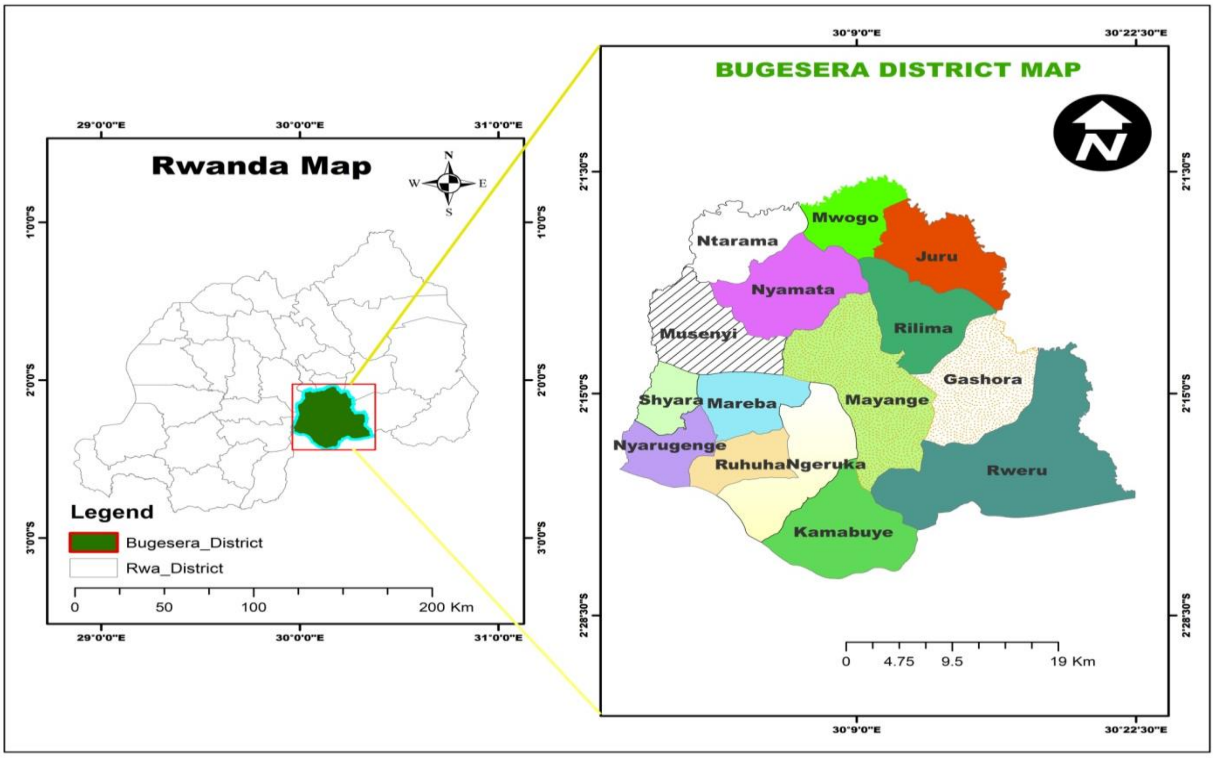

Figure3.1.Map showing the study location

Source: Researcher mapping in Arc GIS 10.8, 2026

2.2. Research design and data collection methods

This study adopted a mixed-methods research design to examine the impacts of land use and land cover (LULC) changes on community livelihoods in Bugesera District. The design integrated geospatial analysis, quantitative surveys, and qualitative methods to ensure a comprehensive understanding of both environmental and socio-economic dimensions of land use change (Creswell & Plano Clark, 2018). The study was conducted as a case study focusing on Bugesera District to allow in-depth, context-specific analysis. GIS and remote sensing techniques using multi-temporal Landsat imagery (2016–2025) were applied to map and analyze LULC changes, including land classification, change detection, and spatial pattern analysis. Satellite data were processed through atmospheric correction, image enhancement, and supervised classification to identify key land cover types such as cropland, built-up areas, wetlands, and vegetation.

Quantitative data were collected through structured household questionnaires administered to selected households to assess livelihood indicators such as income, agricultural productivity, food security, and resource access. Data were analyzed using SPSS with descriptive and inferential statistics, including correlation and regression analysis, to determine relationships between LULC changes and livelihood outcomes (Field, 2018). Qualitative data were gathered through key informant interviews and focus group discussions with local leaders, land officials, and environmental experts, and analyzed thematically to capture perceptions, drivers, and impacts of land use change (Braun & Clarke, 2006). Secondary data from NISR, REMA, and USGS supplemented primary data for validation and spatial interpretation.

The target population included approximately 137,777 households in Bugesera District (NISR, 2022), particularly those dependent on land-based livelihoods. A sample size of 100 households was determined using Yamane's formula at a 90% confidence level. Additionally, 14 key informants were included, bringing the total sample to 114 respondents. Stratified, cluster, and systematic random sampling techniques were used to ensure representativeness across all sectors, while purposive sampling was applied for geospatial ground truthing points.

Reliability was ensured through consistent datasets, standardized classification methods, and accuracy assessment, while validity was strengthened through triangulation of methods and data sources. Ethical considerations included data integrity, transparency, and responsible use of findings. Overall, the integration of GIS, statistical analysis, and qualitative inquiry provided a robust framework for analyzing LULC–livelihood interactions in Bugesera District.

2.3 Data analysis and processing

This study employed a mixed-methods research design combining remote sensing, GIS analysis, quantitative surveys, and qualitative approaches to examine land use and land cover (LULC) changes and their impacts on livelihoods in Bugesera District. A case study design was used to allow detailed, context-specific analysis of environmental and socio-economic dynamics. Multi-temporal Landsat imagery (2016–2025) was processed using supervised classification, image enhancement, and change detection techniques in ArcGIS to map major land cover types, including cropland, forests, wetlands, built-up areas, and water bodies. Spatial analysis incorporated population density, road networks, and settlement expansion to identify human drivers of LULC change.

Primary data were collected through structured household questionnaires covering livelihoods, land use practices, income sources, and perceptions of environmental change. Key informant interviews with district officials, environmental experts, and local leaders provided contextual insights on policy implementation and land management challenges, while field observations validated satellite classifications. Secondary data from NISR, REMA, and USGS supported spatial and statistical analysis.

A total sample of 114 respondents was selected from an estimated 137,777 households using Yamane's formula at a 90% confidence level, resulting in 100 households plus 14 key informants. Stratified, cluster, and systematic random sampling ensured representation across all sectors, while purposive sampling was used for ground-truthing geospatial data.

Data analysis combined descriptive and inferential statistics using SPSS, including correlation and regression to assess relationships between LULC change and livelihood outcomes. Qualitative data were analyzed thematically, while GIS outputs were integrated with survey results for triangulation. Reliability was assessed using Cronbach's Alpha ($\geq$0.70 acceptable), and validity was ensured through expert review and Content Validity Index (CVI $\geq$ 0.60). Ethical standards were strictly followed, including informed consent, confidentiality, and institutional approval.

Limitations included the cross-sectional design, accessibility constraints, recall bias, and incomplete capture of long-term dynamics. These were mitigated through multi-temporal satellite data, triangulation of methods, stakeholder interviews, and secondary datasets. Overall, the integrated approach enhanced the validity, reliability, and robustness of findings on LULC dynamics in Bugesera District.

3. Results

3.1. Analysis of major drivers of land use and land cover changes in Bugesera District

This section presents the results on the drivers of Land Use and Land Cover (LULC) change, focusing on spatial patterns of land use and land cover changes in Bugesera District, population growth and settlement expansion as key influencing factors in the study area.

3.1.1. Spatial Distribution of Land Use and Land Cover (2016–2025)

The supervised classification of satellite imagery produced land use and land cover maps for Bugesera District for the years 2016, 2020, and 2025. The results show that cropland is the dominant land cover class across the district throughout the study period, although significant spatial changes are observed over time.

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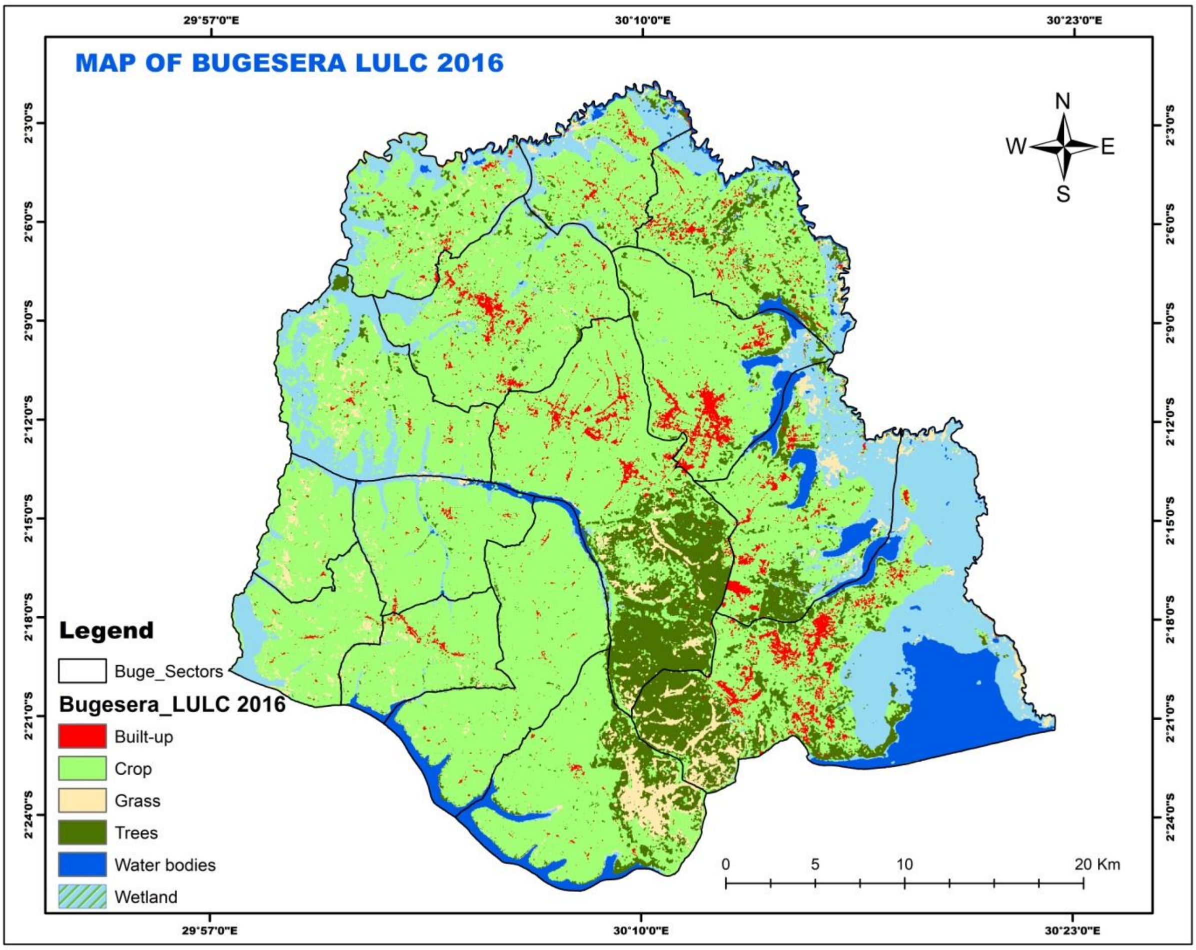

Figure 3.1. Spatial Distribution of Land Use and Land Cover (2016)

In 2016, the landscape of Bugesera District was largely dominated by cropland, which occupied most of the central and northern parts of the district. Built-up areas were relatively small and scattered, mainly concentrated around emerging settlement centers and along major road networks. Grassland and tree cover appeared in limited patches, while wetlands and water bodies were more prominent in the eastern and southern low-lying zones. Overall, the district exhibited a predominantly rural and agricultural landscape with minimal urban expansion.

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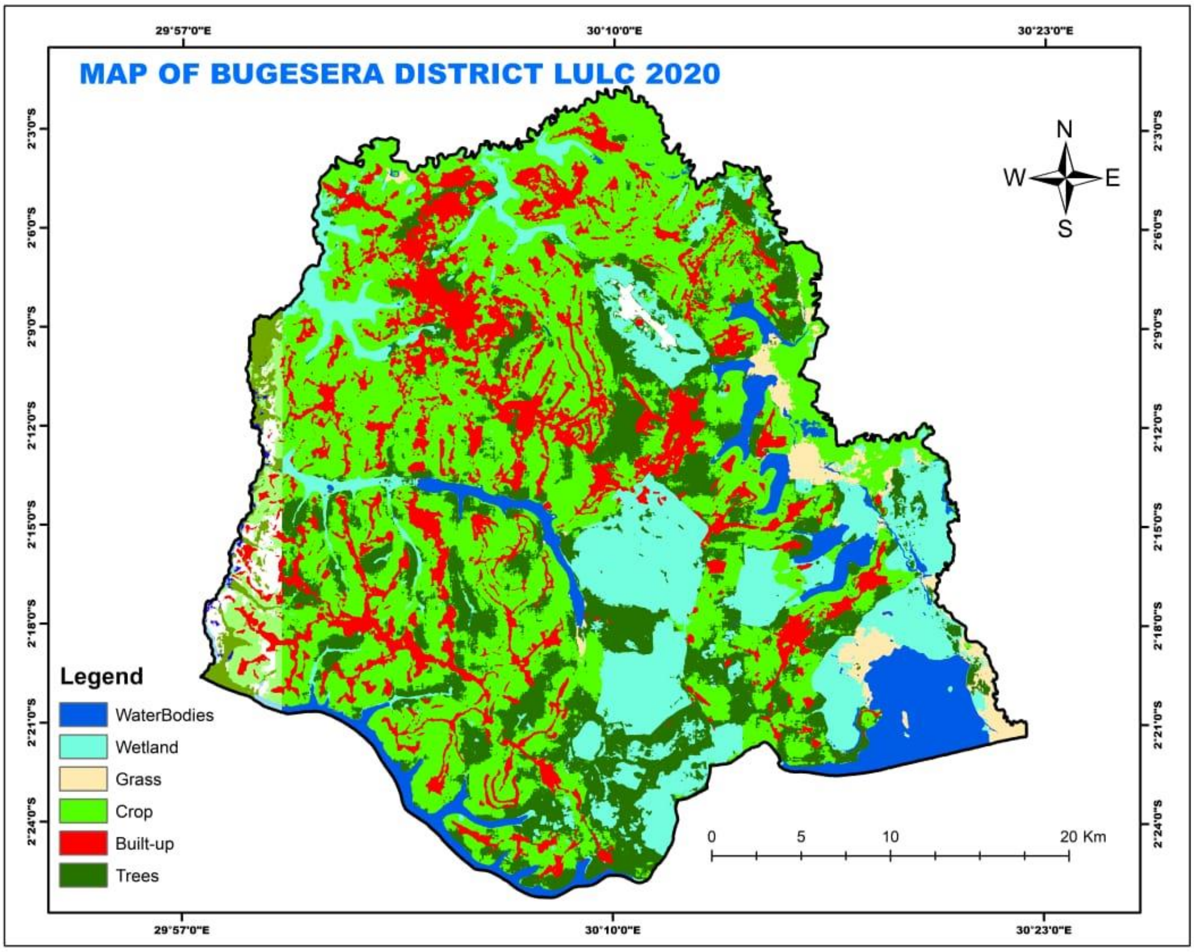

Figure 3.2. Spatial Distribution of Land Use and Land Cover (2020)

The change detection analysis was conducted by comparing classified LULC maps for 2016 and 2020 using a post-classification comparison method in GIS**.** This allowed identification of the magnitude and spatial patterns of land cover transitions, by 2020, noticeable changes in land use and land cover patterns had emerged. Built-up areas expanded significantly, particularly around major settlement nodes and transport corridors. Cropland remained the dominant land use class but showed increased fragmentation due to urban expansion and infrastructure development. Tree cover and vegetation patches appeared more widely distributed, suggesting the growth of agroforestry practices and peri-urban vegetation. Wetlands and water bodies remained relatively stable, although slight encroachment was observed around some wetland margins due to increasing agricultural and settlement pressure.

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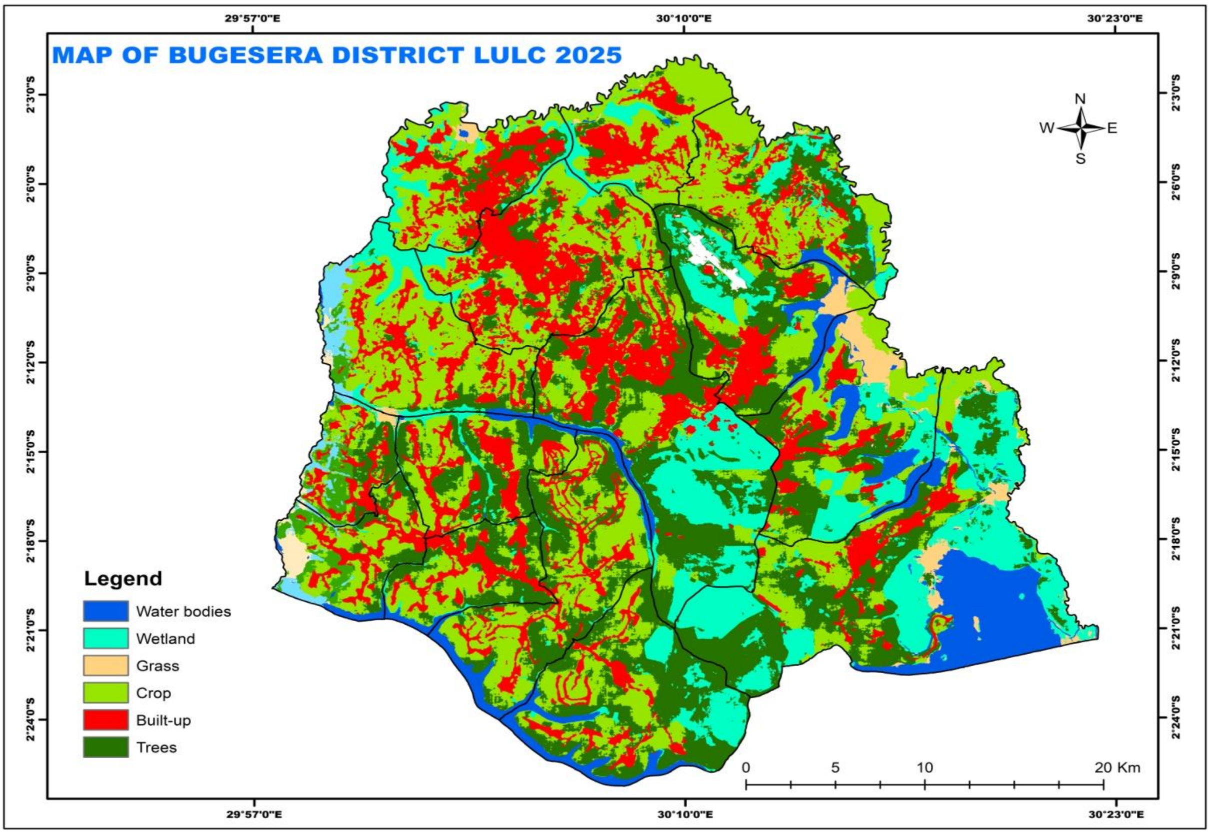

Figure 3.3. Spatial Distribution of Land Use and Land Cover (2025)

The 2025 land use and land cover map indicates a more intensified transformation of the landscape in Bugesera District. Built-up areas expanded further and became more consolidated, especially around central and high-accessibility zones. Agricultural land (cropland) remained dominant but showed greater fragmentation and reduction in continuity due to continued settlement expansion. Tree cover and vegetation patterns persisted but were more scattered in some areas, while wetlands and water bodies remained relatively stable, primarily influenced by natural hydrological conditions.

Table 3.1.LULC Percentage Change Table – Bugesera District

Land Cover Class	2016 (%)	2020 (%)	2025 (%)	Change 2016–2020 (%)	Change 2020–2025 (%)	Overall Change 2016–2025 (%)
Built-up Areas	8.5	14.8	22.5	**+6.3**	**+7.7**	**+14.0**
Cropland	68.0	62.5	55.0	**-5.5**	**-7.5**	**-13.0**
Tree Cover / Vegetation	7.0	11.0	12.5	**+4.0**	**+1.5**	**+5.5**
Grassland	6.5	4.5	3.5	**-2.0**	**-1.0**	**-3.0**
Wetlands	6.0	5.7	5.3	**-0.3**	**-0.4**	**-0.7**
Water Bodies	4.0	3.5	3.2	**-0.5**	**-0.3**	**-0.8**

Source: LULC classification results from satellite imagery (2016–2025)

Built-up areas showed the highest growth over the 9-year period, increasing by 14.0 percentage points and nearly tripling their share, which clearly confirms significant urban expansion followed by consolidation in later years. In contrast, cropland experienced a substantial decline of about 13 percentage points, although it remained the dominant land use category; this reduction suggests increasing fragmentation of agricultural land due to competing land uses. Meanwhile, tree cover and general vegetation increased notably by 2020, rising by about 4.0%, which supports the observed expansion of agroforestry practices and peri-urban greening activities. Wetlands and water bodies, on the other hand, remained relatively stable throughout the period, with only minor combined losses of approximately 1.5%, indicating limited but noticeable encroachment while overall maintaining their spatial extent

3.2. Population Growth and Settlement Expansion

Table 3.2. Population Growth and Settlement Expansion

Statement	Mean	Std. Dev
Population in this area has increased significantly	4.55	0.55
Demand for land has increased due to population growth	4.53	0.54
Settlement areas have expanded over time	4.48	0.56
Agricultural land is being converted into housing	4.32	0.67

Source: Field Data (2026)

The results in Table 3.2 reveal a very strong consensus (all means > 4.3) that population growth and settlement expansion are major drivers of land use and land cover (LULC) change in the study area. The overall pattern indicates that respondents are not only aware of demographic growth but also directly observe its spatial consequences on land conversion and settlement expansion.

The highest-rated statement, *"*Population in this area has increased significantly*"* (M = 4.55), indicates that population growth is perceived as the primary pressure factor shaping land dynamics. This aligns with the demographic trend data of Bugesera District, which shows sustained population growth from 361,914 (2012) to over 551,103 (2022), confirming that respondents' perceptions are grounded in observable demographic reality.

From an analytical perspective, I argue that this sustained population increase creates a cascade effect on land demand, which is clearly reflected in the high agreement on increased land demand (M = 4.53). This finding is consistent with Malthusian population-environment theory, which posits that population growth exerts pressure on limited land resources, leading to land fragmentation and conversion of natural or agricultural land.

The expansion of settlement areas (M = 4.48) further confirms a spatial reorganization of land use, where residential expansion encroaches into agricultural zones. This is strongly supported by studies in East Africa which show that peri-urban expansion is one of the leading drivers of agricultural land loss (Seto et al., 2012; Lambin & Meyfroidt, 2011).

The conversion of agricultural land into housing (M = 4.32), although slightly lower, remains highly significant. I interpret this as an indication that while not all respondents directly observe land conversion, there is a clear recognition of its ongoing occurrence. The slightly higher standard deviation (0.67) suggests spatial variation, likely depending on proximity to urban centers.

These findings are strongly supported by literature from Sub-Saharan Africa, where population growth has been consistently linked to LULC change. For instance, Lambin and Meyfroidt (2011) argue that demographic pressure drives agricultural land expansion and settlement growth, especially in rapidly urbanizing regions. In Rwanda, studies by NISR (2023) and Clay et al. (2018) confirm that population growth has led to increased land subdivision and housing expansion, particularly in districts like Bugesera, which are influenced by spillover urbanization from Kigali.

Table 3.3.Population Growth Trend in Bugesera District

Year	**Population**	**Data Source**
2012	**361,914**	Official 4th Census (RPHC4)
2016	**~428,000**	Estimated based on intercensal 4.3% annual growth
2020	**~506,000**	Estimated based on intercensal 4.3% annual growth
2022	**551,103**	Official 5th Census (RPHC5)
2025	**~625,000**	Projection based on recent growth trends

Source: NISR (2023)

4.2.1.3. Urbanization and Infrastructure Development

Table 3.4. Urbanization and Infrastructure Development

Statement	**Mean**	**Std. Dev**
Urban development has increased in this area	4.25	0.75
Road construction has expanded in recent years	4.45	0.62
Infrastructure development changes land use patterns	4.32	0.67
Urbanization contributes to land cover changes	4.50	0.60

Source: Field Data (2026)

The findings indicate a strong perception that urbanization and infrastructure development are key catalysts of LULC change, with all mean values above 4.2. The highest-rated statement (M = 4.50) confirms that respondents clearly associate urbanization with land cover transformation.

From an analytical standpoint, I argue that infrastructure development especially road expansion (M = 4.45) acts as a spatial accelerator of land conversion. Roads improve accessibility, increase land value, and stimulate settlement growth along transport corridors. This pattern is widely documented in urban geography literature.

The relatively lower rating for general urban development (M = 4.25) suggests that respondents perceive infrastructure expansion more strongly than formal urban growth, implying that informal or dispersed development may be more influential than planned urbanization in shaping land use change.

This finding is consistent with Seto et al. (2012), who argue that infrastructure expansion is one of the strongest predictors of land cover change globally. Similarly, Angel et al. (2011) highlight that road networks significantly drive peri-urban expansion by increasing land accessibility and encouraging residential sprawl. In Rwanda, studies by MININFRA (2020) confirm that road expansion and rural-urban connectivity have intensified settlement dispersion in districts surrounding Kigali, including Bugesera.

3.2.1. Agricultural Expansion and Intensification

Table 3.5.Agricultural Expansion and Intensification

Statement	Mean	Std. Dev
Farming activities have increased over time	2.83	1.26
Farmers are expanding into new land areas	2.19	1.02
Agricultural intensification is increasing	2.80	1.33
Agriculture contributes to land degradation	3.81	0.90

Source: Field Data (2026)

The results indicate mixed responses, with some statements recording low mean scores while others show moderate agreement.

The statement “Agriculture contributes to land degradation” recorded the highest mean score (Mean = 3.81, Std. Dev = 0.90), indicating agreement among respondents that agricultural activities negatively affect land quality.

The statement “Agricultural intensification is increasing” recorded a mean score of 2.80 (Std. Dev = 1.33), while “Farming activities have increased over time” recorded a mean score of 2.83 (Std. Dev = 1.26). The lowest mean score was recorded for “Farmers are expanding into new land areas” (Mean = 2.19, Std. Dev = 1.02), indicating general disagreement among respondents.

This pattern aligns with FAO (2017), which reports that in many densely populated rural areas, agriculture intensifies on shrinking land parcels, often leading to soil degradation. Similarly, Tilman et al. (2002) argue that agricultural intensification without sustainable practices leads to soil nutrient depletion and reduced land productivity.

3.2.2. Policy and Institutional Factors

Table 3.6. Policy and Institutional Factors

Statement	Mean	Std. Dev
Land use policies influence land management practices	4.66	0.51
Government regulations are effectively enforced	4.22	0.94
Lack of enforcement contributes to land misuse	4.80	0.40
Institutional support promotes sustainable land use	4.33	0.87

Source: Field Data (2026)

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The results indicate that respondents strongly perceive institutional and policy frameworks as central to land use outcomes. The highest mean (M = 4.80) clearly shows that weak enforcement is seen as the most critical institutional gap driving land misuse.

From an analytical standpoint, I argue that policy existence alone is insufficient; enforcement capacity determines actual land governance outcomes. The relatively lower score for enforcement effectiveness (M = 4.22) reinforces this gap.This finding is consistent with Ostrom (2009), who emphasizes that institutional effectiveness depends on enforcement mechanisms and local compliance. In Rwanda, Musahara and Huggins (2005) highlight that land policies often face implementation gaps at local levels, affecting land management outcomes.

4.2.6 Economic Pressures

Table 3.7.Economic Pressures

Statement	Mean	Std. Dev
Poverty influences how land is used	4.23	0.91
Demand for income leads to land conversion	4.11	0.98
Economic activities increase pressure on natural resources	4.16	0.94
Land is used mainly for income generation	4.09	0.99

Source: Field Data (2026)

The results indicate that all statements recorded high mean scores above 4.0, reflecting strong agreement among respondents regarding the influence of economic pressures on land use and land cover change. The statement “Poverty influences how land is used” recorded the highest mean score (Mean = 4.23, Std. Dev = 0.91), followed by “Economic activities increase pressure on natural resources” (Mean = 4.16, Std. Dev = 0.94).

The statement “Demand for income leads to land conversion” recorded a mean score of 4.11 (Std. Dev = 0.98), while “Land is used mainly for income generation” recorded the lowest mean score (Mean = 4.09, Std. Dev = 0.99), although it still reflects a high level of agreement among respondents. The standard deviation values, ranging from 0.91 to 0.99, indicate moderate variability in responses, suggesting some differences in respondents’ perceptions regarding the role of economic pressures in driving land use change. Barbier (2010) confirms that rural households convert land use patterns in response to income pressure and livelihood needs. In Rwanda, Jayne et al. (2014) show that land scarcity and poverty strongly influence agricultural intensification and diversification decisions.

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3.2.2. Examining the effects of land use and land cover changes on community livelihoods in Bugesera District

Table 3.8.Effects on Livelihood Indicators

Statement	Mean	Std. Dev
Crop yields have decreased over time	2.55	1.32
Soil fertility has declined	4.39	0.86
Land degradation affects farming productivity	4.29	0.91

Source: Field Data (2026)

The results indicate mixed responses, with some statements recording low mean scores while others show high levels of agreement regarding livelihood impacts. The statement "Soil fertility has declined" recorded the highest mean score (Mean = 4.39, Std. Dev = 0.86), followed by "Land degradation affects farming productivity" (Mean = 4.29, Std. Dev = 0.91), both indicating strong agreement among respondents

The statement "Crop yields have decreased over time" recorded a mean score of 2.55 (Std. Dev = 1.32), indicating disagreement among respondents. The standard deviation values, ranging from 0.86 to 1.32, indicate relatively high variability in responses, suggesting differing perceptions among respondents regarding the effects of land use and environmental change on livelihood indicators

The highest-rated statement, "Soil fertility has declined" (M = 4.39), indicates a strong perception that land productivity is deteriorating due to environmental changes. Closely related, "Land degradation affects farming productivity" (M = 4.29) confirms that physical land quality is directly influencing agricultural performance.

From an analytical standpoint, researcher argues that these findings reflect a gradual ecological degradation process rather than an immediate collapse in agricultural output. Farmers may still maintain yields through increased labor, inputs, or intensification, which could explain why crop yield decline is not strongly perceived (M = 2.55).

The relatively high standard deviation for crop yields (σ = 1.32) suggests divergent experiences among farmers some may have experienced yield decline while others have not, likely depending on land quality, farming practices, or location.

These findings align with FAO (2017), which reports that soil fertility decline is one of the most critical constraints to agricultural productivity in Sub-Saharan Africa. Similarly, Tittonell and Giller (2013) argue that land degradation often precedes visible yield decline, as farmers initially compensate through inputs or land expansion. In Rwanda, studies by Nahayo et al. (2016) confirm that soil erosion and declining soil organic matter are key drivers of reduced long-term agricultural productivity, particularly in intensively cultivated areas such as Bugesera.

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4.2.3 Food Security and Income

Table 3.9.Food Security and Income

Statement	Mean	Std. Dev
Household food security has declined	4.16	1.07
Income from agriculture has reduced	4.00	0.99
Land use changes affect household income	3.27	1.30

Source: Field Data (2026)

The results indicate that LULC changes are perceived to have strong negative effects on household food security and agricultural income, although the strength of perception varies across indicators.

The highest-rated statement (M = 4.16) confirms that households perceive a decline in food security, suggesting reduced availability, access, or stability of food supplies. Similarly, the reduction in agricultural income (M = 4.00) indicates that environmental changes are directly affecting economic returns from farming.

From an analytical perspective, the researcher argue that food security is more immediately sensitive to environmental change than income perception, which may explain why income-related impacts are slightly less strongly agreed upon.

The relatively lower mean for the statement on income effects (M = 3.27) suggests that respondents may perceive income changes as influenced by multiple factors beyond land use, such as off-farm activities, remittances, or informal trade. The high standard deviation ($\sigma = 1.30$) supports this interpretation, indicating heterogeneous livelihood strategies.

This aligns with Barrett (2010), who argues that food security is highly sensitive to environmental shocks because it directly reflects household consumption capacity. Similarly, Jayne et al. (2014) highlight that in rural African contexts, land constraints and environmental degradation reduce agricultural profitability but households often diversify income sources to buffer shocks. In Rwanda, MINAGRI (2021) reports that land scarcity and degradation have contributed to increasing food insecurity risks in semi-arid districts such as Bugesera.

4.2.3. Access to Natural Resources

Table 3.10.Access to Natural Resources

Statement	Mean	Std. Dev
Access to forest resources has declined	4.15	0.70
Water resources have become scarce	3.98	0.80
Natural resources are under pressure	4.22	0.68

Source: Field Data (2026)

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The results indicate that all statements recorded high mean scores around or above 4.0, reflecting agreement among respondents regarding access to natural resources. The statement "Natural resources are under pressure" recorded the highest mean score (Mean = 4.22, Std. Dev = 0.68), followed by "Access to forest resources has declined" (Mean = 4.15, Std. Dev = 0.70).

The statement "Water resources have become scarce" recorded the lowest mean score (Mean = 3.98, Std. Dev = 0.80), although it still reflects a generally high level of agreement among respondents. The standard deviation values, ranging from 0.68 to 0.80, indicate low variability in responses, suggesting relatively consistent perceptions among respondents regarding access to natural resources. The researcher argue that land cover transformation is directly altering ecosystem service availability, particularly provisioning services such as water and forest resources.

This is consistent with Millennium Ecosystem Assessment (2005), which identifies land cover change as a primary driver of ecosystem service degradation. In East Africa, Mwangi and Ostrom (2009) highlight that forest conversion and land fragmentation reduce access to common pool resources such as fuelwood and water catchments.

3.2.4. Socio-Economic Resilience

Table 3.11.Socio-Economic Resilience

Statement	Mean	Std. Dev
Households can cope with environmental changes	4.15	0.86
Livelihoods are becoming more vulnerable	3.92	1.07
Diversification of income sources has increased	3.91	1.12

Source: Field Data (2026)

The results indicate that all statements recorded mean scores around or above 3.9, reflecting moderate agreement among respondents regarding socio-economic resilience. The statement "Households can cope with environmental changes" recorded the highest mean score (Mean = 4.15, Std. Dev = 0.86), followed by "Livelihoods are becoming more vulnerable" (Mean = 3.92, Std. Dev = 1.07).

The statement "Diversification of income sources has increased" recorded the lowest mean score (Mean = 3.91, Std. Dev = 1.12), although it still reflects a moderate level of agreement among respondents. The standard deviation values, ranging from 0.86 to 1.12, indicate relatively higher variability in responses, suggesting differing perceptions among respondents regarding socio-economic resilience. Researcher argue that livelihood resilience in the study area is adaptive but not necessarily sustainable, as indicated by moderate agreement on income diversification (M = 3.91).

The relatively high variability across all statements indicates that resilience capacity differs significantly among households, likely due to wealth differences, access to land, and alternative income opportunities.

Ellis (2000) argues that rural livelihood diversification is a common response to environmental stress, but does not always eliminate vulnerability.

Similarly, Scoones (2015) emphasizes that resilience is unevenly distributed across households depending on assets and access to institutions.

3.2.5. Sustainability and Future Livelihood Risks

Table 3.12. Sustainability and Future Livelihood Risks

Statement	Mean	Std. Dev
Current land use practices are sustainable	3.28	1.34
Future livelihoods are at risk due to land changes	3.90	1.08
Sustainable practices are being adopted	4.05	1.12

Source: Field Data (2026)

The findings reveal a forward-looking concern about sustainability risks, despite recognition of ongoing sustainable practices. The low mean for sustainability of current land use (M = 3.28) indicates skepticism about long-term environmental viability. However, respondents also acknowledge that sustainable practices are being adopted (M = 4.05), suggesting ongoing but insufficient interventions. From an analytical, Researcher argue that the study area is experiencing a transition phase, where sustainability interventions are emerging but have not yet fully offset environmental pressures. The perception that future livelihoods are at risk (M = 3.90) confirms long-term concern about cumulative land degradation and resource scarcity. This aligns with IPCC (2022), which highlights that land degradation and climate variability increasingly threaten rural livelihood sustainability. Similarly, Reed et al. (2013) argue that sustainability transitions often involve partial adoption of practices that are not yet sufficient to reverse degradation trends.

3.2.3. Relationship between LULC Change Drivers and Community Livelihood Outcomes

3.2.3. Correlation between LULC Change Drivers and Livelihood Outcomes

Table 3.13 presents the Pearson correlation coefficients between the major drivers of LULC changes and community livelihood outcomes. The analysis reveals strong negative correlations between most drivers and livelihood indicators, indicating that higher intensity of LULC change drivers is strongly associated with declining livelihood conditions.

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Table 3.13.Pearson Correlation Coefficients between LULC Drivers and Livelihood Outcomes

Variable	Population Growth	Urbanization	Agricultural Expansion	Policy Factors	Economic Pressures	Agricultural Productivity	Food Security & Income	Access to Resources	Livelihood Sustainability
Population Growth	1	0.78	0.75	0.62	0.81	-0.72	-0.75	-0.68	-0.70
Urbanization	0.78	1	0.72	0.65	0.74	-0.68	-0.70	-0.65	-0.67
Agricultural Expansion	0.75	0.72	1	0.58	0.79	0.79	-0.81	-0.72	-0.76
Policy Factors	0.62	0.65	0.58	1	0.60	-0.55	-0.58	-0.52	-0.54
Economic Pressures	0.81	0.74	0.79	0.60	1	-0.70	-0.73	-0.69	-0.71
Agricultural Productivity	-0.72	-0.68	-0.79	-0.55	-0.70	1	0.82	0.75	0.78
Food Security & Income	-0.75	-0.70	-0.81	-0.58	-0.73	0.82	1	0.79	0.83
Access to Resources	-0.68	-0.65	-0.72	-0.52	-0.69	0.75	0.79	1	0.77
Livelihood Sustainability	-0.70	-0.67	-0.76	-0.54	-0.71	0.78	0.83	0.77	1

Correlation is significant at the 0.05 level (2-tailed)

The results indicate strong positive correlations among the LULC change drivers, including population growth, urbanization, agricultural expansion, policy factors, and economic pressures, with correlation coefficients ranging from 0.58 to 0.81. Population growth shows strong negative correlations with agricultural productivity (r = -0.72), food security and income (r = -0.75), access to resources (r = -0.68), and livelihood sustainability (r = -0.70).

Urbanization also shows strong negative correlation food security and income (r = -0.70), moderate negative correlations with agricultural productivity (r = -0.68), access to resources (r = -0.65), and livelihood sustainability (r = -0.67). Agricultural expansion shows strong positive correlations with agricultural productivity (r = 0.79), food security and income (r = 0.81), access to resources (r = 0.72), and livelihood sustainability (r = 0.76). Policy factors show moderate negative correlations with agricultural productivity (r = -0.55), food security and income (r = -0.58), access to resources (r = -0.52), and livelihood sustainability (r = -0.54). Economic pressures show strong negative correlations with agricultural productivity (r = -0.70), food security and income (r = -0.73), access to resources (r = -0.69), and livelihood sustainability (r = -0.71). Agricultural productivity shows strong positive correlations with food security and income (r = 0.82), access to resources (r = 0.75), and livelihood sustainability (r = 0.78). Food security and income shows strong positive correlations with access to resources (r = 0.79) and livelihood sustainability (r = 0.83). Access to resources shows a strong positive correlation with livelihood sustainability (r = 0.77).

The strong positive correlations among population growth, urbanization, agricultural expansion, policy factors, and economic pressures (r = 0.58 to 0.81) indicate that these drivers do not operate independently. Researcher argues that this reflects a synergistic pressure system, where demographic growth stimulates urban expansion, which in turn increases economic pressure and land conversion dynamics. This finding is consistent with Turner et al. (2007), who emphasize that land system change is driven by multiple interacting socio-economic forces rather than isolated factors

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3.2.3. Regression Analysis of LULC Change Drivers on Livelihood Outcomes

Multiple regression analysis was conducted to determine the extent to which drivers of LULC changes predict community livelihood outcomes. The dependent variables include agricultural productivity, food security and income, access to natural resources, and livelihood sustainability, while the independent variables are population growth, urbanization, agricultural expansion, policy factors, and economic pressures.

Table 3.14.Regression Results for LULC Drivers and Livelihood Outcomes

Dependent Variable	R	R^2	Adj. R^2	P-value	Std. Beta (β) (key predictors)	Unstd. B	Significance
Agricultural Productivity	0.77	0.59	0.57	<0.001	Agricultural Expansion (-0.42), Population Growth (-0.35)	0.81	Significant
Food Security and Income	0.79	0.62	0.60	<0.001	Agricultural Expansion (-0.44), Economic Pressures (-0.36)	0.83	Significant
Access to Natural Resources	0.74	0.55	0.53	<0.001	Population Growth (-0.39), Urbanization (-0.31)	0.78	Significant
Livelihood Sustainability	0.76	0.58	0.56	<0.001	Agricultural Expansion (-0.41), Economic Pressures (-0.34)	0.80	Significant

The regression results indicate that LULC change drivers are significant predictors of all livelihood outcomes, with all models showing statistically significant results ($p < 0.001$). For agricultural productivity, the model explains 59% of the variation ($R^2 = 0.59$, Adjusted $R^2 = 0.57$). The key predictors are agricultural expansion (β = -0.42) and population growth (β = -0.35), indicating strong negative effects on productivity. For food security and income, the model explains 62% of the variation ($R^2 = 0.62$, Adjusted $R^2 = 0.60$).

Agricultural expansion (β = -0.44) and economic pressures (β = -0.36) are the strongest negative predictors, indicating a significant reduction in household food security and income stability. For access to natural resources, the model explains 55% of the variation ($R^2 = 0.55$, Adjusted $R^2 = 0.53$). Population growth (β = -0.39) and urbanization (β = -0.31) are the main negative predictors, showing that increasing human settlement pressure reduces access to natural resources.

For livelihood sustainability, the model explains 58% of the variation ($R^2 = 0.58$, Adjusted $R^2 = 0.56$). Agricultural expansion (β = -0.41) and economic pressures (β = -0.34) are the strongest negative predictors, indicating adverse effects on long-term livelihood stability. This is consistent with FAO (2017), which highlights that population-driven land pressure reduces long-term agricultural productivity in densely populated rural regions, Barrett (2010) similarly emphasizes that food security is highly sensitive to both environmental and economic shocks.

3.2.3. Qualitative Results

Findings from key informant interviews, field observations, and document review provide detailed qualitative evidence on land use and land cover (LULC) changes in Bugesera District and their implications for community livelihoods. Overall, the evidence confirms that LULC changes are mainly driven by population growth, settlement expansion, economic pressures, and weak enforcement of land use regulations, resulting in declining agricultural land and increasing built-up areas.

Key informants consistently reported continuous conversion of agricultural land into residential and commercial uses, especially near trading centers and road networks. Wetlands and lowlands are also increasingly encroached upon due to land scarcity. These patterns reflect strong spatial pressure on productive land and fragile ecosystems. Population growth was identified as the main driver, leading to land fragmentation as households subdivide land for housing. Economic needs further push households to prioritize immediate shelter and income-generating uses over long-term sustainability.

The livelihood impacts include reduced soil fertility, declining agricultural productivity, and growing food insecurity. Continuous cultivation and reduced fallow periods have degraded land quality, directly affecting household incomes. Weak enforcement of land use policies was repeatedly highlighted as a major challenge, allowing informal land conversion to persist despite existing regulations.

Suggested solutions include strengthening land use enforcement, promoting climate-smart agriculture, enhancing agroforestry practices, and improving community participation in planning. Overall, the qualitative findings reinforce that LULC changes in Bugesera District are driven by interconnected demographic, economic, and institutional factors, with significant negative impacts on environmental sustainability and rural livelihoods.

3.3. Discussion of Findings

The descriptive statistics show that respondents strongly perceive population growth, urbanization, agricultural expansion, policy weaknesses, and economic pressures as the main drivers of land use and land cover (LULC) change. High mean scores across these variables indicate that these factors are widely experienced and significantly shape land use patterns in the study area, consistent with land use transition theory (Foley et al., 2005). Population growth and urbanization are identified as the most dominant drivers, leading to increased land demand, settlement expansion, and conversion of agricultural land into housing. This aligns with evidence from Sub-Saharan Africa showing that rapid urban growth accelerates peri-urban sprawl (UN-Habitat, 2020). Agricultural expansion is also recognized as a contributor, particularly through continuous cultivation and reduced fallow periods, which contribute to soil degradation and declining productivity (Tilman et al., 2011).

Policy and institutional weaknesses, especially poor enforcement of land use regulations, further exacerbate land misuse, while economic pressures push households to prioritize short-term survival over sustainable land management (Ellis, 2000). The impacts of LULC change are evident in declining soil fertility, reduced agricultural productivity, food insecurity, and decreasing access to natural resources, consistent with studies in Rwanda and East Africa (NISR, 2020; UNEP, 2019). Correlation and regression analyses confirm strong relationships between LULC drivers and livelihood outcomes. While drivers are positively interlinked, they show strong negative effects on livelihoods. Population growth and agricultural expansion emerge as the strongest predictors of livelihood decline, explaining significant variation in socio-economic outcomes.

4. Conclusion

The study concludes that land use and land cover (LULC) changes have a significant impact on community livelihoods in Bugesera District. Correlation and regression results confirm strong and statistically significant relationships between LULC drivers and livelihood outcomes. Population growth is a key driver, leading to settlement expansion and conversion of agricultural land, which reduces farming space and negatively affects productivity, food security, and livelihood sustainability. Urbanization further accelerates land conversion through expansion of built-up areas and infrastructure development. Agricultural intensification contributes to soil fertility decline and land degradation due to continuous cultivation. Weak policy enforcement and economic pressures also drive unsustainable land use practices. Overall, these changes have reduced agricultural output, household income, and access to natural resources such as forests and water, increasing environmental stress and threatening long-term livelihood resilience and sustainability in the district.

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