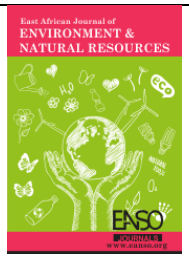

East African Journal of Environment and Natural Resources
eajenr.eanso.org
Volume 8, Issue 2, 2025
Print ISSN: 2707-4234 | Online ISSN: 2707-4242
Title DOI: https://doi.org/10.37284/2707-4242

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

The Impact of Urbanisation on Land use and Land Cover Change in Rwanda: A case of Muyumbu sector, Rwamagana District (2002-2024)

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Article DOI: https://doi.org/10.37284/eajenr.8.2.3340

Date Published: *17 July 2025*

Keywords: *Urbanisation, Land Use, Land Cover, Muyumbu, Rwanda.*

ABSTRACT

Urbanisation in Rwanda, particularly in satellite cities such as Rwamagana District and especially in sectors bordering Kigali city like Muyumbu sector, has experienced rapid and uncontrolled growth, leading to significant changes in habitat and negatively impacting land use and land cover. Remote sensing data were used to thoroughly assess the impact of urbanisation on land use and land cover changes in the Muyumbu sector, Rwamagana District, from 2002 to 2024. Landsat images were obtained, pre-processed, and their accuracy verified before being used to analyse LCLU trends. The results for the first objective showed that Muyumbu has experienced significant urban growth between 2002 and 2024, with an annual growth rate of 5.07% due to population growth and population shift from rural areas to urban areas. The findings for the second objective revealed that the availability of land for development in Muyumbu surged, heightened demand for housing and services, and accelerated urbanisation in the study area. The results for the third and fourth objectives illustrated that from 2002 to 2024, urban areas grew from 32.85 Ha in 2002 to 646.40 Ha in 2024, reflecting a 12.18% overall increase. In contrast, agricultural land saw a sharp decline of 19.27%, primarily due to the significant expansion of urban areas. Forested areas (natural vegetation) experienced an approximate reduction of 9.15%, mainly driven by population growth. This population increase, combined with the migration of people from Kigali city to Muyumbu sector, was the primary factor contributing to urban growth. The findings also highlighted a clear link between urbanisation and changes in land use and land cover in the Muyumbu sector. Based on the findings of this study, there is a strong need for increased government support for the introduction and development of inspection technology like the use of drones and satellites, to prevent illegal construction activities and unauthorised deforestation, and enforce laws and related sanctions to whoever doing contrary to the zoning regulations. Relocate people from agricultural land to public apartments. To stop shifting people from so-called high-risk zones and start design and implement climate-resilient buildings. Adaptation of a robust monitoring system that tracks land use changes, deforestation rates to preserve green spaces. Additionally, the study suggests the need for supplementary policy measures to promote environmentally responsible development.

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Article DOI: https://doi.org/10.37284/eajenr.8.2.3340

APA CITATION

Hagumimana, E. & Nsanzumukiza, M. V. (2025). The Impact of Urbanisation on Land use and Land Cover Change in Rwanda: A case of Muyumbu sector, Rwamagana District (2002-2024. *East African Journal of Environment and Natural Resources*, *8*(2), 280-295. https://doi.org/10.37284/eajenr.8.2.3340.

CHICAGO CITATION

Hagumimana, Emmanuel and Martin Vincent Nsanzumukiza. 2025. "The Impact of Urbanisation on Land use and Land Cover Change in Rwanda: A case of Muyumbu sector, Rwamagana District (2002-2024". *East African Journal of Environment and Natural Resources* 8 (2), 280-295. https://doi.org/10.37284/eajenr.8.2.3340

HARVARD CITATION

Hagumimana, E. & Nsanzumukiza, M. V. (2025) "The Impact of Urbanisation on Land use and Land Cover Change in Rwanda: A case of Muyumbu sector, Rwamagana District (2002-2024", *East African Journal of Environment and Natural Resources*, 8 (2), pp. 280-295. doi: 10.37284/eajenr.8.2.3340.

IEEE CITATION

E. Hagumimana & M. V. Nsanzumukiza "The Impact of Urbanisation on Land use and Land Cover Change in Rwanda: A case of Muyumbu sector, Rwamagana District (2002-2024", *EAJENR*, vol. 8, no. 2, pp. 280-295, Jul. 2025.

MLA CITATION

Hagumimana, Emmanuel & Martin Vincent Nsanzumukiza. "The Impact of Urbanisation on Land use and Land Cover Change in Rwanda: A case of Muyumbu sector, Rwamagana District (2002-2024". *East African Journal of Environment and Natural Resources*, Vol. 8, no. 2, Jul 2025, pp. 280-295, doi:10.37284/eajenr.8.2.3340

INTRODUCTION

Land use is the administration of land to meet human requirements, which defines the function for which land is utilised by people. Instances of land uses established by humans consist of conservation zones, forestry for wood products, plantations, row crop farming, grazing lands, and urban developments (Turner and Meyer, 1994).

Land cover refers to the physical appearance and ecological state of the land surface, like closed forests, open forests, or grasslands (FAO/UNDP, 1996).

Urbanisation is the shift of individuals from rural regions to urban settings, reflects a steady rise in the proportion of the population residing in cities, and it also includes how various societies adapt to this transformation. Urbanisation entails the concentration of human populations in designated locations, resulting in the repurposing of land for housing, business, industry, and transportation needs. This phenomenon includes not only densely populated urban hubs but also the neighbouring suburban or peri-urban regions (Sanyaolo, 2018).

This study aims to confirm the accuracy of the null hypothesis; Urbanisation does not have a substantial effect on land use and land cover changes in Muyumbu, Rwamagana District and one of the alternative hypotheses; Urbanisation has a substantial effect on land use and land cover changes in Muyumbu, Rwamagana District.

The process of urbanisation changes the way landscapes look, leading to a prevalence of human-built habitats. This change includes reducing and breaking up natural habitats and creating obstacles that disrupt the movement of living organisms and ecological connections (Hensel, 2021). Urbanisation has led to the increased transformation of natural ecosystems into semi-natural and artificial ecosystems, which has changed the structure and functioning of ecosystems. As a result, there has been a loss of ecosystem services and a decrease in their value (Zimmerer, 2021).

It is predicted that by 2050, about 64% of Africa and Asia and 86% of the developed world will be urbanised (Economist, 2012). The primary reason for land use change worldwide is the historical and current ways in which people have utilised and controlled land. Human actions to obtain necessary resources directly and indirectly lead to land use change. The increasing population is the main catalyst for changes in land use, as the growing population relies heavily on native lands and vegetation for food and housing (Munyaneza Jean Pierre, 2023).

Urbanisation leads to land degradation, resource depletion, and environmental pollution, resulting in the reduction of land cover. In Rwanda,

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Article DOI: https://doi.org/10.37284/eajenr.8.2.3340

specifically in the Muyumbu sector of Rwamagana District, there has been a significant influx of immigrants, leading to extensive land use and heightened susceptibility to both loss of land cover and the impacts of climate change (Theoneste Bimenyimana, 2021).

The impact of urbanisation on land use and land cover change in Muyumbu sector, Rwamagana District was studied within a conceptual framework that combined various theories such as Modernisation theory, Central place theory and Human-nature interaction theory with empirical evidence to clarify the complex interactions between urban development, land use, and land cover change. In Rwanda, specifically in the Muyumbu sector of Rwamagana District, there has been a significant influx of immigrants, leading to extensive land use and heightened susceptibility to both loss of land cover and the impacts of climate change (Theoneste Bimenyimana, 2021).

Modernisation theory examines the progression of social evolution and societal development. It involves two analytical levels in classical modernisation theory: micro-level assessments that concentrate on the individual components of social modernisation, and macro-level studies that examine the observable paths and evident processes of modernisation in countries and their communities, economies, and political systems (Goorha, 2010). Modernisation theory argues that urbanisation plays a crucial role in the shift from traditional, agricultural societies to industrialised, contemporary ones. It considers urbanisation to be a catalyst for social, economic, and cultural transformation, resulting in development and advancement.

Central Place Theory is a geographic concept established by German geographer Walter Christaller in 1933 to analyse the spatial arrangement and distribution of cities and towns (central places) within a region. The theory emphasises how settlements act as "central places" that supply goods and services to their neighbouring areas, creating a hierarchical structure based on population size, distance, and economic influence (Mukherjee, 2022).

The Human-Nature Interaction Theory examines the evolving connection between people and their natural surroundings, emphasising how humans affect and are affected by nature. This theory draws from various fields, including geography, ecology, sociology, anthropology, and environmental science (Clark & Cary Wu, 2021).

This conceptual framework details how urban expansion modifies habitat structure and land patterns. Furthermore, it highlighted urbanisation as the main catalyst for land degradation and land cover change, influenced by factors such as population growth. Through operationalising key variables, urbanisation is an independent variable and land use and land cover change as dependent variables. The framework directs research endeavours to measure the extent and spatial distribution of urban effects on land use and land cover change, thus providing crucial information for evidence-based policies aimed at sustainable urban planning and land conservation in the Muyumbu sector, Rwamagana District.

The study aimed to assess the impacts of urbanisation on land use and land cover change in Rwamagana. The specific objectives of the study namely being to assess the level of urban growth in Muyumbu sector, assess the factors influencing the urbanisation in Muyumbu Sector, analyse the land use and land cover change in the Muyumbu sector and to examine the impact of urbanisation on land use and land cover change in the Muyumbu Sector. This research seeks to evaluate how urbanisation affects changes in land use and land cover in Rwanda, specifically concentrating on the Muyumbu sector, where the impacts of urbanisation on land use and land cover change are especially noteworthy. The research seeks to contribute to the promotion of sustainable urban development and the responsible management of land resources in the Muyumbu sector, Rwamagana District.

Objectives

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General Objective

The general objective of this research is to evaluate how urbanisation affects land use and land cover change in Rwanda, the case of Muyumbu sector in Rwamagana District, an urban area from 2002 to 2024.

Specific Objectives

The specific objectives of this study are the following:

- To assess the level of urban growth in the Muyumbu sector (2002-2024)
- To assess the factors influencing the urbanisation in Muyumbu Sector (2002-2024)
- To analyse the land use and land cover change over twenty-two years (2002-2024)
- To examine the impact of urbanisation on land use and land cover change in Muyumbu Sector (2002-2024)

REVIEW OF THE LITERATURE

Population Growth

The growth of a population, which refers to the increase in the number of individuals in a specific area over time, plays a crucial role in shaping urban development and its impact on the environment (Demena, 2005). Fast population growth puts pressure on land resources, leading to the expansion of cities and changes in natural landscapes. This expansion often results in the loss and fragmentation of habitats, posing a threat to how land is used and its vegetation. Additionally, the increased consumption of resources linked to population growth can further degrade land use and compromise the provision of land cover services. It is essential to understand the effects of population growth on urban development, land use, and vegetation to guide sustainable development strategies and conservation efforts in regions experiencing rapid growth. The swift rise in population has resulted in urban expansion, which has negatively affected the environment (Demena, 2005).

The difficulties brought on by climate change and the decline of global biodiversity are increasingly acknowledged as a critical concern for the future of both humanity and the natural world. To address these issues effectively, it is vital to gain a more profound understanding of the interactions between humans and nature. Over the past decade, various nature-focused strategies, such as Ecosystem-based Adaptation (EbA), Green Infrastructure (GI), and Nature's Contributions to People (NCP), have enhanced scientific discussions and have been recognised in policy and decision-making arenas (Lukas Egarter Vigl, 2022).

The population issue in Africa is undoubtedly significant and difficult. The consequences of elevated birth and death rates, growing population size and density, swift population growth, and rising dependency burdens lead to heightened demands on African governments regarding productive activities. This situation exacerbates challenges related to unemployment, underemployment, ongoing poverty, urban slums, crime, and political instability, but primarily contributes to environmental degradation (Stephan Klasen, 2007).

Formula to calculate annual growth rate

$$AGR = \frac{V_{final} - V_{initial}}{V_{initial} \times n} \times 100$$

……1

AGR is the annual growth rate

V_final = Final value

V_initial = Initial value

n = Number of years

The result will be in **decimal form**, so multiply by **100** to get the percentage.

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Development of Infrastructures (Urban Expansion)

Infrastructure development refers to the process of planning, designing, constructing, and maintaining the essential physical structures and systems that support the functioning of society (Group, 2023). Infrastructure refers to the public goods and services that serve as complementary inputs in the production process alongside traditional factors of production like capital, labour, and entrepreneurship. The success of various production efforts is significantly influenced by the availability and efficiency of infrastructure facilities and services.

Changes in land cover resulting from urban expansion involve converting natural or agricultural land into urban uses, including residential, commercial, and industrial areas. This transformation typically includes turning green spaces, forests, or farmland into developed areas with buildings, roads, and infrastructure. Monitoring changes in land cover is crucial for understanding how urbanisation affects the environment, biodiversity, and ecosystem services. It enables policymakers, planners, and researchers to evaluate the scale of urban expansion, identify rapidly developing areas, and anticipate potential environmental impacts such as loss of habitats, fragmentation, and the proliferation of impermeable surfaces, leading to problems like urban heat islands and water runoff. Therefore, effective infrastructure development is fundamental for achieving sustainable economic growth and improving societal welfare through enhanced access to essential services (Langemeyer, 2015).

Urbanisation and Land Use

Urbanisation refers to the concentration of populations in urban areas, resulting in the expansion of cities and towns. Urbanisation is a significant phenomenon affecting land use and land cover (LULC) across the globe, particularly in developing countries like Rwanda (Celestin, 2022). Rwanda has experienced rapid urbanisation since the early 2000s, driven by population growth, economic development initiatives, and government policies aimed at promoting urban centres as engines of growth. According to Rwanda's National census 2003, the urban population increased from approximately 16% in 2002 to around 30% by 2020. This trend is expected to continue as the Government implements its Vision 2050 strategy, which emphasises urban development (NISR, Fifth Population and House Census, 2022). The rapid growth of urban areas leads to various changes in land use patterns, which can have profound environmental, social, and economic implications. While urbanisation can stimulate economic development and provide opportunities, it also presents challenges such as environmental degradation, resource depletion, social disparities, and public health hazards (Celestin, 2022).

The impacts of urbanisation on land use are varied and are determined by aspects such as the rate and size of urban expansion, as well as the existence of green spaces and preserved areas in urban environments. Urbanisation brings about substantial changes to land use arrangements, resulting in a range of environmental, social, and economic consequences. Conversely, land use pertains to the diverse methods by which humans engage with land for various purposes. This includes a broad spectrum of activities, such as agricultural, residential, industrial, recreational, and commercial functions. It provides crucial ecosystem services that are vital for human well-being, including climate stabilisation, water purification, as well as food and medicine supply. However, human actions like habitat destruction, pollution, and climate change pose significant threats to land use, resulting in land scarcity and loss of fertility (Theoneste Bimenyimana, 2021).

Urbanisation and Land Cover

As previously stated, urbanisation refers to the movement of people from rural regions to urban centres, leading to the growth and development of cities and towns. This trend is closely associated with changes in land cover, which encompass the alteration of natural terrains into constructed environments (Sanyaolo, 2018).

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The growing population has placed considerable strain on the land resources in the Muyumbu sector over a long period. A variety of challenges, including land degradation, loss of biodiversity, increased deforestation, water shortages, and obstacles to achieving food security, have emerged as a consequence of rapid population growth. The onset of these issues has certainly had an adverse effect on sustainable development. These challenges are intertwined with the vital land resources necessary for human existence. Changes in land use and land cover can be influenced by both human activities and the natural environment. Since the 1990s, Rwanda has seen considerable growth in both population and economic development, resulting in notable alterations to the country's land use and land cover. As urban areas expand in response to rapid economic progress and farmland increases to support the rising population, natural environments like forests, wetlands, and grasslands are being compromised. Rwanda's significant dependence on rain-fed agriculture makes agricultural output and food security vulnerable to changes in rainfall patterns (Li, Yang, & Li, 2021).

Land Use and Land Cover Change

Agricultural and forest lands play crucial roles in the Earth's ecosystems, supporting human life, biodiversity, and climate stability through distinct yet interconnected means (ALTMAN, 2023).

Land used primarily for growing crops and raising livestock is known as agricultural land. This type of land encompasses different uses like cropland for annual crops, pastureland for grazing animals, and sometimes areas for agroforestry practices involving integrated tree and agricultural systems. Agricultural land is crucial for food production, but can also result in substantial environmental impacts if not sustainably managed, while forestland includes land with trees taller than 5 meters that occupy over 10% of the area. Forests are essential for capturing carbon, preserving biodiversity, and offering ecosystem benefits like regulating water, stabilising soil, and serving as wildlife habitat (FAO/UNDP, 1996).

The changes in land use and land cover within the study area predominantly involved a reduction in forested regions and an expansion of agricultural land, along with a slight rise in grassland area and an annual growth in urban land. In Rwanda, land use and land cover transitions primarily occurred from forests and grasslands to agricultural land, with a ratio of 0.72:0.28. After 2010, the primary conversion of land use and land cover shifted from forests to grasslands and agricultural land, with a ratio of 0.83:0.17 (Li, Yang, & Li, 2021).

Today's land use systems are largely influenced by urbanisation, which is considered a significant driving force. The process typically entails the permanent transformation of agricultural land. Urban land use transformation can manifest in various spatial layouts, building densities, and rates of change (Thomas Weith, 2021).

The interdependence between agricultural land and forestland highlights the need for an integrated approach towards managing these resources sustainably. By adopting best practices in both sectors, such as agroforestry techniques and ensuring effective policy frameworks are in place, it is possible to achieve food security while also protecting vital forest ecosystems essential for combating climate change (Thomas Weith, 2021).

MATERIALS AND METHODS

Research Design and Approach

This study will use a mixed research design comprising quantitative, qualitative, and correlative research approaches by integrating remote sensing data analysis with socio-economic data collection on land use obtained using ground truth data and the Rwamagana land use master plan. Landsat imageries covering the study area will be acquired for the 2002, 2012 and 2024 periods, allowing for temporal and spatial analysis of land cover changes. The study will analyse changes in land use and land cover by taking into account aspects such as socio-economic developments and environmental deterioration indicators. These indicators will be evaluated utilising existing research, mainly the 5th

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National Census and reports from various ministries like MINAGRI and MININFRA.

This thorough method will yield important knowledge regarding the intricate connections among urbanisation, land utilisation, and alterations in land cover, guiding upcoming urban development and conservation initiatives.

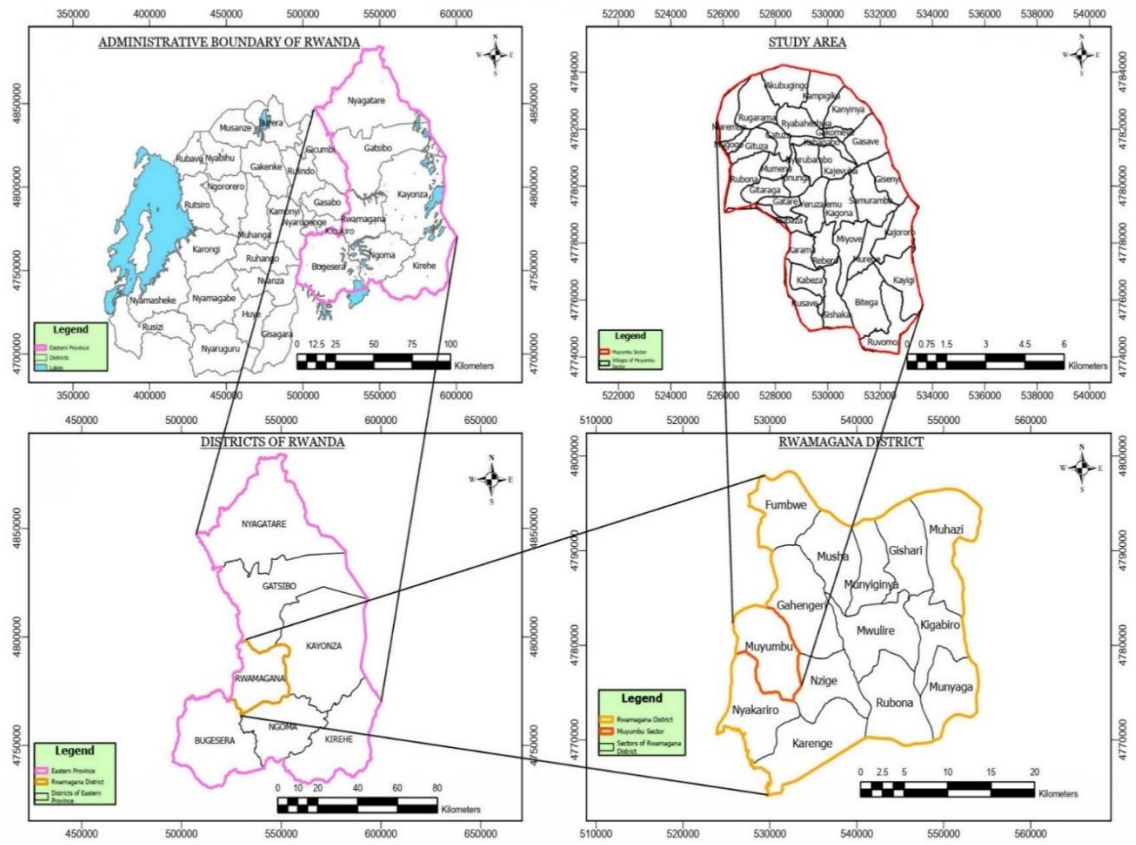
Description of the Study Area

Muyumbu sector is among the fourteen sectors that make up Rwamagana District. It shares its borders with Rusororo and Gahengeri sectors to the north, Nzige sector and part of Gahengeri sector to the east, part of Nyakaliro and Nzige sectors to the south, and Nyakaliro to the west. Muyumbu sector is composed of 5 cells, 35 villages. The population of Muyumbu sector was recorded at 56,881 residents in 2022, representing 11.73% of Rwamagana District's total population (NISR, Fifth Population and House Census, 2022). In terms of gender distribution, the Muyumbu sector has a majority female population, with 29,299 females making up 51.5% of the overall population (NISR, Fifth Population and House Census, 2022).

Muyumbu Sector is the second populated urban sector in Rwamagana District, with 65.3% of the population residing in the urban area after Kigabiro sector, which is the first populated urban sector with 72.6% of the population living in the urban area (NISR, Fifth Population and House Census, 2022).

The study area spans 50.37 square kilometres and has an approximate total population of 65,237 individuals. This results in a population density of 1,295 people per square kilometre.

Figure 1: Muyumbu Sector Location Map



Sources of Data and Data Collection Techniques

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Primary Data

Primary data were taken through observation, the observation method is a research technique frequently utilised in numerous domains, such as social sciences, psychology, education, and market research. It entails the systematic monitoring and documentation of behaviours, events, or phenomena as they happen in their natural environments.

Ground truth data were collected in the field to validate remote sensing results, assess land use, and land cover change. Demographic and socioeconomic information were gathered from government resources to analyse population trends, economic activities, infrastructure progress, and land use regulations in the urban regions of Muyumbu sector, Rwamagana district.

Secondary Data

The Secondary data were gathered by using a remote sensing technique, the land cover data were collected on Landsat ETM+30m, Landsat TM 30m and Landsat OLI 30, whose images were used to classify the land use and land cover changes for the study area of Muyumbu sector. Landsat ETM+30m, Landsat TM 30m, and Landsat OLI 30 satellites provide information on the Bottom of the Atmosphere. Their images are freely available on the United States Geological Survey (USGS) website and are good for land use and land cover classification (Segarra, Buchaillot & Araus, 2020). In this study, three Landsat images taken in 2002, 2012 and 2024 were retrieved and preserved for additional analysis to meet the objectives of the study. Landsat images were downloaded as individual files and then combined to create a single TIFF file by stacking the bands. The following extraction by mask from the images focuses on the area defined by the study area's bounding box. After the clipping process, the images underwent a pan-sharpening process aimed at enhancing their resolution, improving the spatial resolution from 30 meters to 15 meters. Pansharpening is good at enhancing image resolution because it combines the spatial detail from a high-resolution panchromatic (PAN) image with the spectral information from a lower-resolution multispectral (MS) image—resulting in a single image that is both high in spatial resolution and rich in colour/spectral detail, even though it can be affected by spectral characteristics.

Various techniques have been developed to categorise satellite imagery; however, supervised classification methods are regarded as having higher accuracy for quantitatively classifying remotely sensed information, and this supervised technique will be utilised in this study. Supervised classification methods, along with geographical information systems (GIS) and Remote Sensing techniques, serve as effective and robust tools for analysing changes in land use and land cover (LULC). Ground truth data were collected by using DGPS connected to a CORS network, which is the technique of taking coordinates representing feature samples like forest plantation, agriculture, urbanisation and bareland of the study area. Ground truth data were used to validate the accuracy of the results.

RESULTS AND DISCUSSION

Level of Urban Growth in Muyumbu Sector (2002-2024)

The urbanisation characteristics and changes in the landscape of Muyumbu sector in Rwamagana District over a 22-year period were assessed based on classified images using landscape metrics as indicated in Figure 2. Time-series analysis allows for the observation of changes over time, particularly in urbanisation. Between 2002 and 2024, significant transformations in Muyumbu urban area were evident. The built-up area changed from 32.85 Ha in 2002 to 228.43 Ha in 2012, with the difference of 195.58 Ha representing an increment of 3.8%. In 2024, the urban area changed from 228.43 Ha in 2012 to 646.4 Ha, representing changes of 417.97 Ha, corresponding to 8.3%. From 2002 to 2024, a big portion of Muyumbu sector became an urban area due to population increase, where the urban area increased from 32.85 Ha in 2002 to 646.4 Ha in 2024 with a difference of 613.55 Ha corresponding to a 12.18 % increment.

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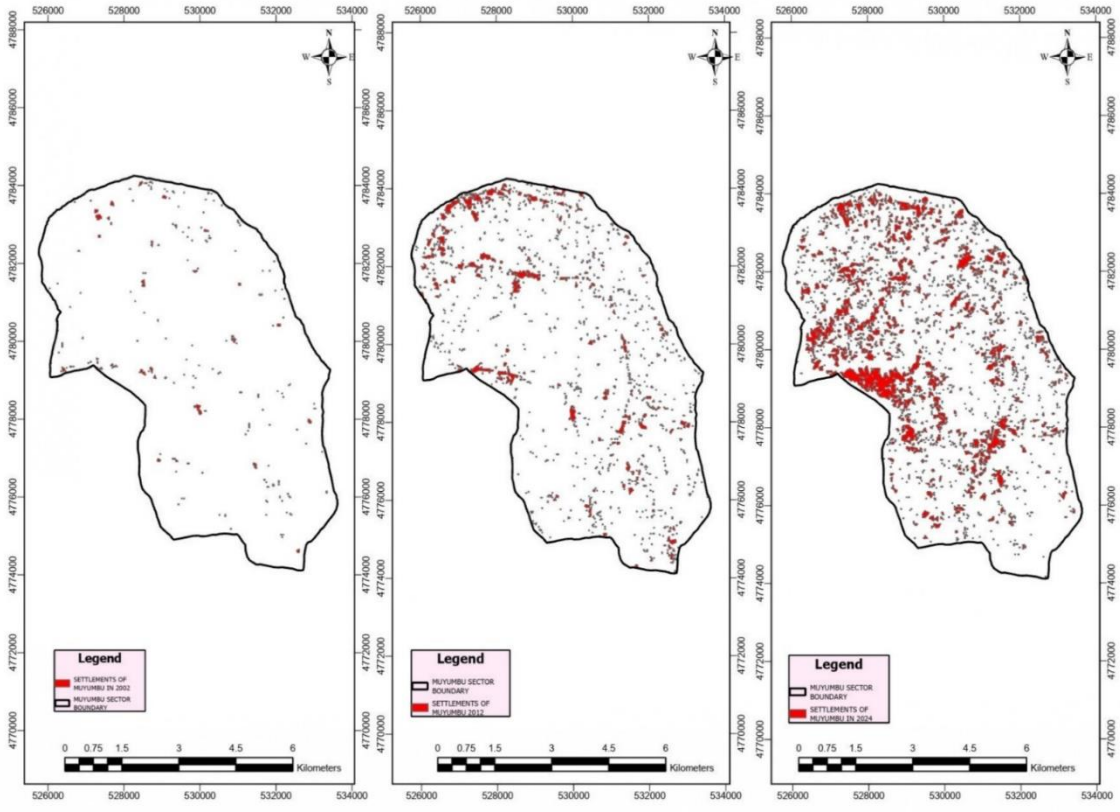
Between 2002 and 2024, Muyumbu Sector in Rwanda's Eastern Province experienced notable infrastructure development, driven by significant population growth and urban expansion, as indicated by Figure 3 (population trends of Muyumbu sector). The population increased from 24,242 in 2012 to 56,881 in 2022, with an urban resident increment of 32,639 population in 2022 (NISR, Fifth Population and House Census, 2022).

Among key infrastructure developments during this period include **Urban Housing Expansion**: Proximity to Kigali led to increased housing developments, transforming previously agricultural and forest lands into urban areas. Road infrastructure has enhanced access to markets and services, encouraging economic activities. **Educational Facilities**: The sector had only three primary school in 2002 (NISR, Fifth Population and Housing Census, 2022) but with the population increase the sector possess 16 schools among which 15 are primary schools, 4 primary schools having secondary level and there is one TVET school within Muyumbu sector (NISR, Fifth Population and Housing Census, 2022). **Healthcare Services**: Until 2002, Muyumbu sector had only one health center called Muyumbu Health Center, which was developed to provide medical services across the sector's 5,037 Hectares. Due to population density and urbanization, the sector possess one Heath center, one modern clinic and four health post helping Muyumbu sector to acquire health services (NISR, Fifth Population and Housing Census, 2022).

Figure 2: Urbanisation Changes in the Muyumbu Sector from 2002-2024



The **F**actors **I**nfluencing the **U**rbanisation in Muyumbu Sector (2002-2024)

The population of Muyumbu Sector has experienced significant growth between 2002 and 2024. In the 2002 the population census recorded 19,438 of total population of Muyumbu sector while in the 2012 census, the population was recorded at 24,242 and by the 2022 census, it had increased to 56,881 (NISR, Fifth Population and Housing Census, 2022), in 2024 Muyumbu population reached at 65,237 population (Rwamagana district database). This represents an

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addition of 40,995 people over the twelve-years period.

The population of Muyumbu more than doubled, increasing from 24,242 in 2012 to 56,881 by 2022. This surge reflects an average annual **growth rate of approximately 9.1%** over the decade. However, the overall growth rate of Muyumbu sector from 2002 to 2024 is **5.07%.**

Notably, the urban population expanded substantially, with 37,141 residents living in urban areas by 2022, compared to 19,740 in rural regions (NISR, Fifth Population and House Census, 2022).

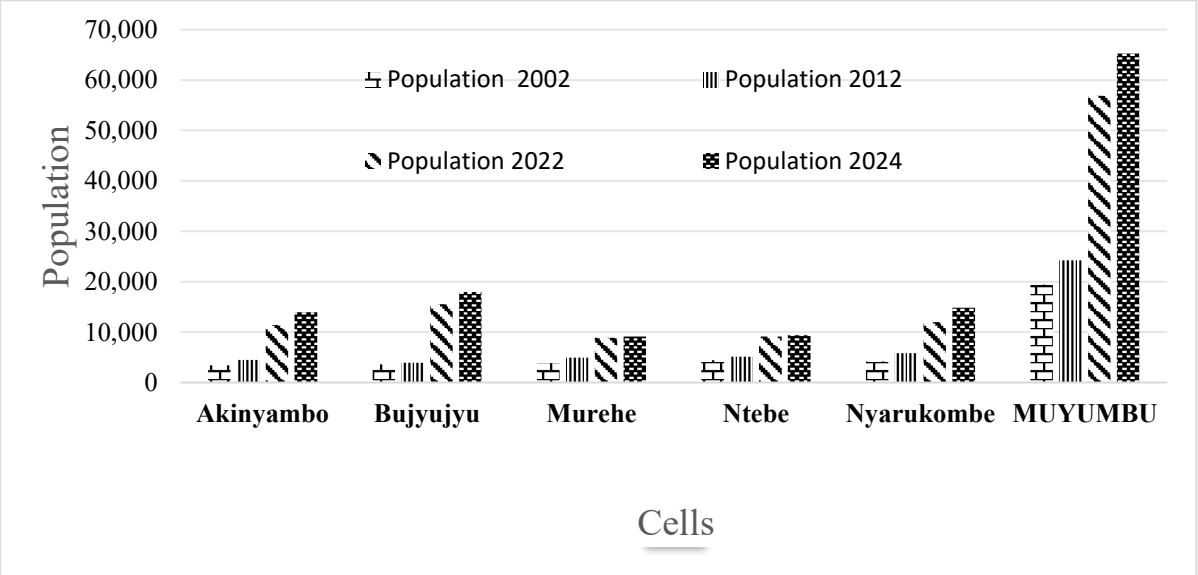
In 2002, a population census was conducted to update demographic information following significant events in the early 1990s, aiming to provide a more accurate understanding of the population's size, structure, and distribution (NISR, Fifth Population and Housing Census, 2022).

From 2002 to 2012, the population of Muyumbu increased to 24,242 from 19,438 with an increment of 4,804. However, the substantial increase observed between 2012 and 2022 suggests a trend of rapid population growth in the study area (32,639 people were added).

The expansion of the population significantly influences changes in land use and land cover (LULCC), especially, in rapidly developing areas like Muyumbu Sector, where the Increased demand for housing leads to the expansion of urban areas and villages, Conversion of agricultural and forested land into residential and commercial zones. Deforestation and vegetation loss where more land is cleared for farming, construction, and infrastructure, infrastructure development, like expansion of roads, schools, health centers, and markets to accommodate population needs.

The increase in population notably affects changes in land use and land cover, driving urban expansion, deforestation, agricultural intensification, and environmental degradation. As more land is converted for settlements, infrastructure, and farming, natural ecosystems are altered, leading to biodiversity loss, soil erosion, and climate change effects.

Figure 3: Population Trends of Muyumbu Sector from 2002 to 2024



Between 2002 and 2024, Muyumbu sector in Rwanda underwent notable changes in population demographics and density. The sector's population was 19,438 residents, representing 8.81% of the Rwamagana District's total population in 2002. Due to population growth and urbanisation, the sector's population increased from 24,242 residents in 2012 to 56,881 residents in 2022, representing 11.73% of Rwamagana District's total population (NISR, Fifth Population

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and House Census, 2022). From Rwamagana District database Muyumbu population increased to 65,237 in 2024 from 56,881. This indicates that 8,356 population increment in only 2 years after the national population census (2022). All this population are concentrated on 50.3 square kilometres, and this implies that on one square kilometre there are 1,297 people (1297/km^2). Some areas within Muyumbu emerged as the most populated, while others exhibited lower densities. High-density areas were characterised by increased urban settlements, while rural-dominated areas experienced relatively lower population growth.

Table 1: Muyumbu Population (2002, 2012, 2022 and 2024)

Cells	Population 2002	Population 2012	Population 2022	Population 2024
Akinyambo	3,414	4,468	11,403	13,964
Bujyujyu	3,610	3,894	15,526	17,949
Murehe	3,845	4,918	8,887	9,122
Ntebe	4,409	5,152	9,107	9,369
Nyarukombe	4,160	5,810	11,958	14,833
MUYUMBU	**19,438**	**24,242**	**56,881**	**65,237**

Source*: 2002, 2012 and 2022, Population census; 2024, Rwamagana District database*

These findings underscore significant shifts in habitation and population distribution within the sector over the specified period. Figure 3 illustrates the changes in population growth, showing an increase in urbanised regions and a decline in rural-dominated areas. Generally, for all areas in Muyumbu sector, the population increased between 2012 and 2024. These findings provided insights into the demographic characteristics and spatial distribution of the population within Muyumbu sector, and this information is crucial for understanding urbanisation trends, planning infrastructure development, and addressing socio-economic challenges within the sector. The study utilised high-resolution submeter imagery of 2002, 2012 and 2024 to analyse land cover changes and urbanisation trends effectively.

Analyse Land Use and Land Cover Change Over Twenty Years (2002-2024)

In this study, we used the land metrics index as Class Area (CA), which was understood as the total area covered by all classes of the respective class type, measured in hectares. Therefore, the landscape patterns were calculated and examined at both class and landscape levels to spatially characterise the study area. Land cover classification was conducted to distinguish changes in the size of land for agriculture, vegetation, water, and built-up area in Muyumbu sector, Rwamagana district, urban areas. However, due to human activities growth dominated by infrastructure and urbanisation development, the land for agricultural activities has continued to reduce over the years. Using the classified images of land cover, different classes were noticed, as illustrated by Figure 4. The study detected considerable changes in land use and land cover between 2002 and 2024, as shown in Table 2. Currently, changes in land for vegetation and cultivation have led to variations in different types of vegetation and animal species. The total landscape area was estimated at **5,037 Ha**. Table 2 summarises the analysis conducted to assess the alterations that took place in every land cover category over the 22-year timeframe being examined. The formula below was used to calculate the percent change in land use/land cover.

$$\text{Percentage change} = \frac{\text{Calculated area change(from Classifed image)x 100\%}}{\text{total Area}} \quad \ldots\ldots\ldots\ldots 2$$

The primary objective of this research was to assess the level of urban growth in Muyumbu (2002-2024). The results illustrated that landscape fragmentation and spatial pattern change affected land use and land cover in the study area during the last twenty-two years, between 2002 and 2024.

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Article DOI: https://doi.org/10.37284/eajenr.8.2.3340

From 2002 to 2024, Muyumbu sector experienced a significant increase in urbanisation, as evidenced by a steady rise in population density and infrastructure development. This rapid urban expansion can be attributed to factors such as rural-urban migration, driven by economic opportunities in trade and industry, as the Muyumbu sector borders Kigali city. As a result, there has been a notable shift in land use patterns, with agricultural land being converted into residential and commercial areas. While urbanisation has brought about improvements in access to basic services such as education and healthcare, it has posed challenges such as increased demand for housing, strain on public utilities and environmental degradation due to unsustainable development practices.

On the other hand, Muyumbu sector has witnessed significant changes in land use and land cover change. Deforestation rates have accelerated, particularly in areas undergoing urban expansion and agricultural expansion. This loss of natural habitat has had detrimental effects on land use and land cover. Despite conservation efforts, such as the establishment of protected areas and community-based conservation initiatives, more concerted efforts are needed to reverse these trends and promote sustainable management of land resources.

Table 2: Land Use and Land Cover Change in the Muyumbu Sector

Land cover Class	Area in 2002 (Ha)	Area in 2012 (Ha)	Area in 2024 (Ha)	Area change 2002-2012 (Ha)	Area change 2012-2024 (Ha)	Area change 2002-2024 (Ha)	% change (2002-2024)
Agriculture Land	3,158.51	2,363.90	2,187.73	-794.61	-176.17	-970.78	-19.27
Forest (Natural Vegetation)	730.12	293.52	269.25	-436.6	-24.27	-460.87	-9.15
Built-up (Houses and Infrastructure)	32.85	228.43	646.40	+195.58	+417.97	+613.55	+12.18
Bareland (Sand Mining and Quarry Sites)	1,116.10	2,152.51	1,933.64	+1,036.41	-218.87	+817.54	+16.23
TOTAL	**5,037**	**5,037**	**5,037**				

The findings indicate a significant expansion of urban areas, with the main factors behind this growth being the influx of individuals migrating to Muyumbu sector. This shift leads to an increase in population within Muyumbu sector, resulting in a demand for land to construct both residential and commercial buildings. Both the area covered by vegetation and agricultural land have experienced changes as indicated by the results in Table 2.

Between 2002 and 2024, significant transformations in Muyumbu urban area were evident. The Muyumbu Sector experienced population growth with an annual growth rate of 5.07% from 2002 to 2024, driven by an influx of immigrants from nearby regions, which negatively affected agricultural land during this time, leading to a notable decrease. The extent of vegetation continued to decline as a result of agricultural practices and the construction of residential and infrastructure facilities. As indicated in Table 2, there were considerable changes in vegetation and agricultural areas from 2002 to 2024, with urban areas and bare land showing an upward trend.

Over the past decades, Muyumbu Sector in Rwamagana District, Rwanda, has experienced significant land cover changes, as illustrated in Figure 4. These maps reveal a marked decline in agricultural land and forest (natural vegetation), accompanied by a noticeable increase in built-up

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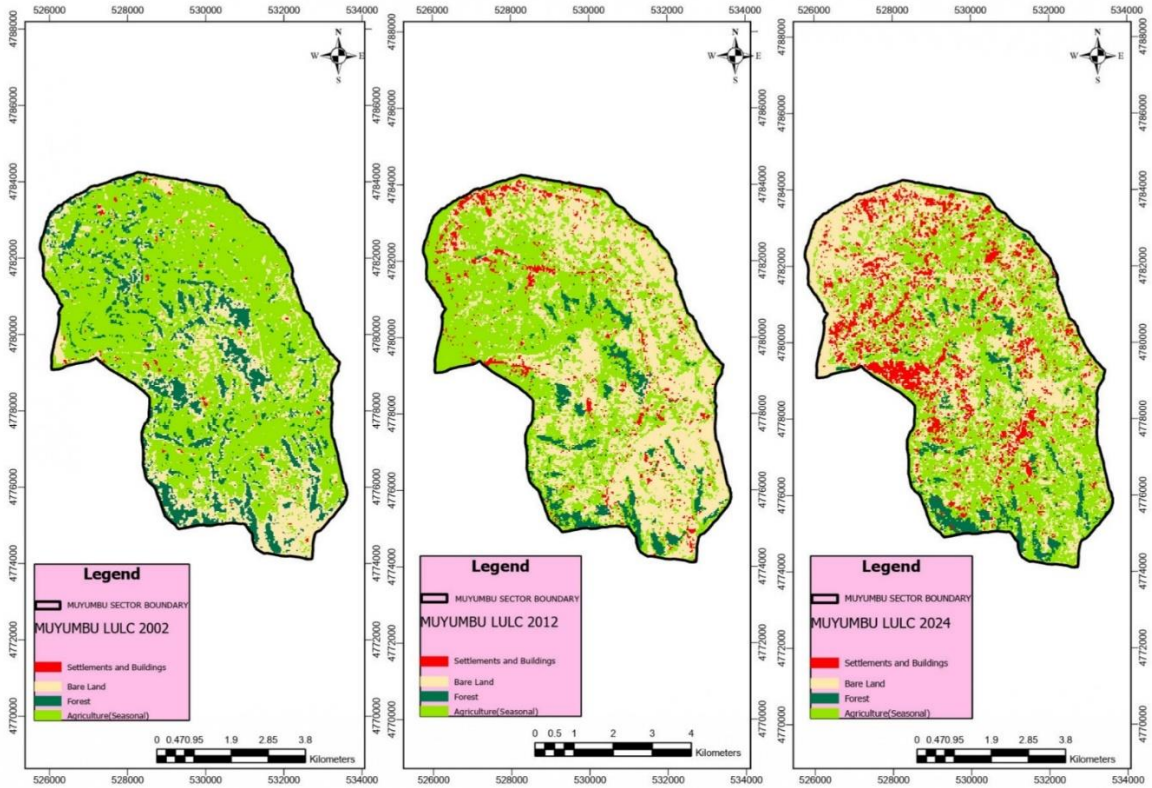
areas and sand mining/quarry sites. Urbanisation and infrastructure development, particularly road construction, have led to the transformation of forests and cropland into urban structures and extraction sites for construction materials. Specifically, spatial analysis indicates that agricultural land has decreased by 19.27%, and natural vegetation has deteriorated by 9.15%. Conversely, built-up areas have expanded by 12.18%, and bareland, including sand mining and quarry sites, has increased by 16.23%. These changes are concentrated around newly developed infrastructure and transportation networks, highlighting that a direct relationship exists between the growth of urban areas and the decrease of natural environments.

Figure 4 not only shows the extent of land cover changes but also highlights the fragmented nature of the remaining natural habitats, indicating potential challenges for land use and land cover change. Overall, the spatial distribution maps of Muyumbu sector of Rwamagana district vividly illustrate the dynamic nature of land cover change, driven by urbanisation and human activities, and underscore the significant implications for the region's biodiversity and ecosystem benefits.

Figure 4: The Spatial Distribution of All Land Cover Change 2002, 2012 and 2024



The Impact of Urbanisation on Land Use and Land Cover Change in Muyumbu Sector (2002-2024)

Deforestation and Loss of Natural Vegetation

Over the past two decades, Muyumbu Sector has experienced significant deforestation and vegetation loss due to rapid urbanisation, agricultural expansion, and infrastructure development. This has had profound environmental and socio-economic impacts. Causes of Agricultural Land Loss are: Urbanisation and Infrastructure Development: the growing population led to the expansion of residential areas, reducing farmland. Roads, schools, and commercial buildings were constructed on previously cultivated land. About 12.18% of cultivated land was converted into urban developments during this period. Deforestation and Land Degradation: Forest clearing for settlements and farming led to soil

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erosion, making some land unsuitable for cultivation. Overuse of land without proper conservation measures reduced soil fertility, leading to land abandonment. Population Growth and Land Fragmentation: With increasing population, land was subdivided into smaller plots, making farming less viable. Some families sold their land for housing and commercial use, reducing agricultural production.

The deforestation and vegetation loss in Muyumbu Sector from 2002 to 2024 have significantly affected the environment and livelihoods. While urbanisation and economic growth have driven development, they have also contributed to ecological damage. Continued conservation efforts and sustainable land management practices are crucial to restoring the ecosystem and ensuring long-term environmental resilience.

Loss of Agricultural Land

Between 2002 and 2024, Muyumbu Sector experienced a significant loss of agricultural land due to rapid urbanisation, infrastructure expansion, and population growth. This transformation has affected food security, livelihoods, and the local economy. The growing population led to the expansion of residential areas, reducing farmland. Roads, schools, and commercial buildings were constructed on previously cultivated land. About 12.18% of cultivated land was converted into urban developments during this period. The loss of agricultural land in Muyumbu Sector between 2002 and 2024 has significantly affected food security, employment, and the environment. While urbanisation has brought economic benefits, it has also reduced farmland and affected traditional livelihoods. Sustainable land management and modern agricultural practices are essential to maintaining food production and environmental stability in the future.

CONCLUSION

Using GIS Pro and remote sensing, this research demonstrates the capability to assess the spatial patterns of land use and land cover changes without the necessity of physically traversing the entire site area. It was found that urbanisation in Muyumbu Sector was improved at a high rate in the last two decades, but the extent to which it contributes to land use and land cover needs to be harmonised.

As urban development continues to grow positively, agricultural land shows a declining trend, as expected; the findings of this same study, projected over the next 20 years, would be shocking. The expansion of urban areas due to the decrease in both vegetation and farmland could result in serious issues in the future if adequate protective measures are not implemented. Overall, it can be stated that the rate of urban growth results in a significant loss of agricultural and green land. This study recommends the Government of Rwanda to effectively implement Rwamagana Land Use Development Master Plan, introduction and development of inspection technology like the use of drones and satellites to prevent illegal construction activities, unauthorised deforestation, and enforce laws and related sanctions to whoever doing contrary to the zoning regulations and adaptation of a robust monitoring system that tracks land use changes, deforestation rates, and the success of reforestation initiatives can provide critical data for decision-making.

The Urban planners are recommended to use urban growth boundaries to prevent sprawl and protect natural ecosystems, support peri-urban agriculture and vertical farming initiatives to balance urban expansion with food security; Local communities are recommended to encourage developments that combine residential, commercial, and recreational spaces to reduce land consumption and alert local authorities about unauthorised land clearing, deforestation, or waterway pollution. Finally, future researchers are urged to advocate for the integration of green spaces and environmental considerations in urban planning.

Rwanda's urbanisation policy is considered a key priority as it promotes the concentration of people in designated areas, making it easier to deliver and

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distribute essential services. Policymakers are encouraged to address this issue proactively, before it potentially worsens. Planning for sustainable development requires the integration of environmental, social, and economic factors. If any one of these three components is neglected, the concept of sustainability cannot be maintained.

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Article DOI: https://doi.org/10.37284/eajenr.8.2.3340

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