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Assessing The Impacts Of Land Use And Land Cover Change On The Biodiversity Conservation "A Case Of Akagera National Park"

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ABSTRACT: Around the world, numerous countries are experiencing substantial transformations in their land use and land cover (LULC), largely driven by human-environment interactions. This study aims to evaluate how these LULC changes are affecting biodiversity conservation within Akagera National Park Specifically; to analyze the level of land use and land cover changes, to evaluate change detection of 1992-2002,2002-2012, 2012-2022, and to assess the effect of LULC of specified years on biodiversity conservation within ANP. The study reviewed different literature on Land Use and Land Cover. This research utilized remote sensing (RS) and Geographic Information System (GIS) tools to analyze Land Use Land Cover (LULC) changes in Akagera National Park from 1992 to 2022. High-quality satellite imagery (Landsat images) acquired from USGS was processed through GIS and supervised classification techniques was employed. Purposive sampling was used to select ANP management staff for interviews, with 5 respondents participative. The findings revealed significant LULC changes, including an increase in bare land by 7.6%, and decrease in grassland by 7.2% from 1992 to 2002, impacting species like buffalo and antelope. Between 2002 and 2012, there was further bare land increase by 1.28%, and grassland reduction by -1.63%. From 2012 to 2022, forest, grassland, and wetland decreased by 1.44%,1.93% and 1.26% respectively, leading to the extinction of rhinos and lions. Overall, there was a notable rise in bare land by 11.81% and water bodies by 5.26%, coupled with reductions in forest, grassland, and wetland by. -2.32%,-10.77% and -3.98% respectively. The study emphasizes concerns over habitat loss and fragmentation, exacerbated by human activities like deforestation and poaching, necessitating urgent conservation efforts to mitigate biodiversity impacts in Akagera National Park. The study underscores the critical need for habitat restoration, enhanced law enforcement, and evaluation of conservation interventions to inform evidence-based strategies for biodiversity conservation in Akagera National Park.

KEYWORDS: Land use Land cover, Biodiversity conservation and Akagera National Park

I. INTRODUCTION

Throughout the world, human activities stand out as the primary catalysts for changes in land use and land cover (LULC). Identified as significant drivers of global environmental shifts, human settlement and agricultural practices contribute to LULC alterations on a broad scale (Vink, 2017). Given that agriculture forms the cornerstone of economies in numerous nations, land serves as a crucial source of economic and social advantages for countless communities. Furthermore, changes in land use and land cover reflect the complex relationship between modern human societies and the natural environment (Foreman et al., 2020).

Schneider et al. (2021) emphasize that the main driver of land use and land cover change is the conversion of forested areas into residential and agricultural zones. Deforestation, urban expansion, and agricultural practices have significantly altered the Earth's surface, disrupting crucial ecosystem functions and services (Lebowski et al., 2016). Tropical forests, including those in Amazonia, Central America, and Indonesia, have experienced increased deforestation rates ranging from 0.25% to

1.0% annually since the 1970s due to human settlements and activities like road construction and mineral extraction (Curran et al., 2019). This trend is alarming for biodiversity preservation, as tropical forests host a significant portion of the world's plant and animal species (Wilson, 2018).

Alterations in Land Use and Land Cover (LULC) have profound global implications for both community livelihoods and conservation efforts. Approximately 40% of the Earth's surface, previously covered by natural vegetation, has been converted into agricultural land, driven by the increasing demand for resources to sustain human activities (Meiyappan & Jain, 2012; Meiyappan, 2017). These changes, driven by various factors at local, regional, and global scales, result in the loss of approximately 13 million hectares of tropical forests annually, endangering thousands of species (Long et al., 2007; Cotillon, 2013; MEA, 2005). In regions like sub-Saharan Africa and other developing areas, traditional practices such as low-intensity agriculture or nomadic pastoralism are being replaced by more intensive agricultural techniques (Serneels & Lambin, 2001). Conversely, urbanization is expanding in developed regions, with cities encroaching into rural areas in pursuit of natural amenities (Hansen and Brown, under review). Exurban development, characterized by low-density housing, has become the fastest-growing land use category in the United States since 1950, covering 25% of the contiguous US (Brown et al., under review). These transformations, fueled by population growth, technological advancements, and increased wealth, have significantly impacted natural habitats and reshaped plant and animal communities in managed landscapes in recent decadesIn Rwanda, the assessment of land use and its changes is frequently integrated into environmental sustainability evaluations, such as those conducted in Life Cycle Assessment methodologies (Jolliet, 2016). Recognizing these as adverse outcomes of production underscores the importance of factoring them into true pricing, aligning with internationally endorsed principles regarding the rights of present and future generations. Specifically, the transition from natural ecosystems to agricultural land entails direct ecosystem degradation, resulting in habitat loss, reduced biodiversity, and diminished ecosystem services. Agricultural land use displaces natural habitats, exacerbating biodiversity decline and incurring opportunity costs in terms of ecosystem services. Against this backdrop, the researcher aims to investigate the impact of land use and land cover changes on biodiversity conservation, focusing on Akagera National Park as a case study.

Problem statement

Akagera National Park, covering 1,122 km2 in Rwanda's east, faces biodiversity decline due to rapid land use changes (RDB, 2015). Efforts to restore species like lions and rhinos have seen success since the government intervened in 2015 (RDB, 2015). However, human-induced activities like deforestation and illegal hunting persist, impacting land use. Studying land use patterns is vital for monitoring conservation efforts and understanding their drivers (Fisher, 2011). While global studies exist, local research within Akagera is scarce (Hansen et al., 2013; Hartemink et al., 2008). This study aims to fill this gap, exploring how land use affects biodiversity within Akagera National Park.

Research Objectives

i.To analyze the level of land use and land cover changes in Akagera National Park

ii.To evaluate change detection of 1992-2002,2002-2012, 2012-2022

iii.To assess the effect of LULC of specified years on biodiversity conservation

Significance of the study

The research project holds personal significance for the investigator as it represents an opportunity to bridge theoretical knowledge gained through academic studies with practical applications in biodiversity conservation. As a candidate pursuing a Master's degree in environmental studies, particularly focusing on environmental economics and natural resources management, conducting this research aligns with academic and professional goals. Furthermore, the study's findings will be archived in the UNILAK library, providing a valuable resource for future scholars and researchers interested in this field. By contributing to the existing literature, the report aims to facilitate ongoing learning and exploration in the realms of land use, land cover change, and biodiversity conservation. It is anticipated that this study will stimulate interest among fellow researchers, encouraging further inquiry and advancement in this area of study.

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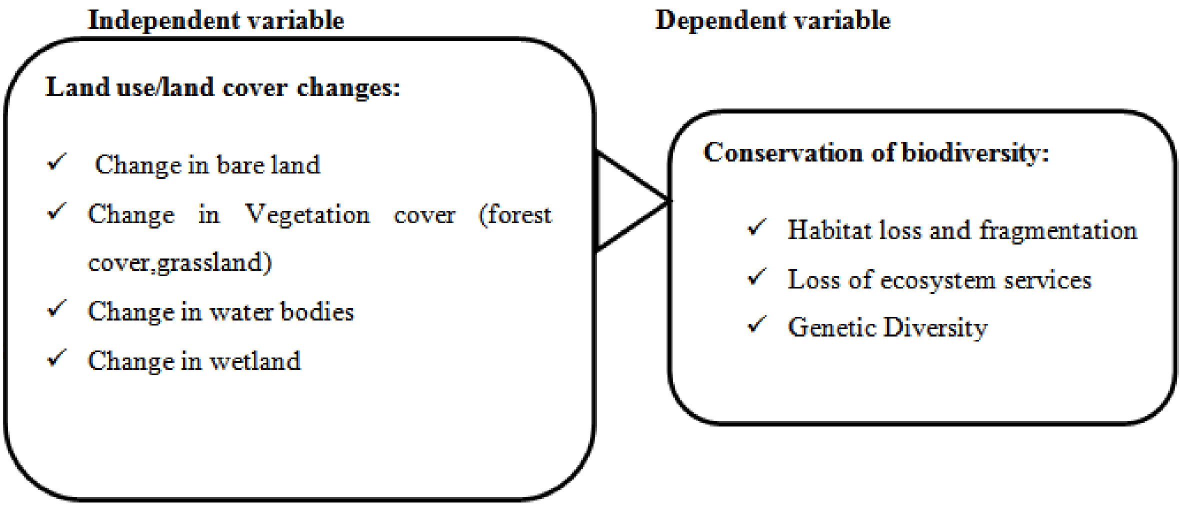

Figure 1.1: Conceptual framework

II.LITERATURE REVIEW

Bare land

According to landscape ecology theory, bare land serves as a crucial component of landscape structure, influencing habitat connectivity, species dispersal, and ecosystem functioning (Turner et al., 2001). From a landscape perspective, bare land patches act as ecotones or transitional zones between different land cover types, facilitating species movements and interactions. However, excessive bare land can disrupt landscape connectivity, fragmenting habitats and isolating populations, which can have detrimental effects on biodiversity and ecosystem resilience (With, 2002). Landscape ecology theory emphasizes the importance of considering spatial heterogeneity and landscape configuration in land management and conservation planning to maintain ecological connectivity and mitigate the negative impacts of bare land on ecosystem integrity (Wu, 2008).

bare land represents an early seral stage in ecological succession, characterized by limited vegetation cover, high soil erosion rates, and low biodiversity (Connell & Slatyer, 1977).

Vegetation cover

Understanding vegetation cover within land use and land cover (LULC) contexts incorporates ecological theories like island biogeography, intermediate disturbance hypothesis, and functional diversity. Island biogeography theory by MacArthur & Wilson (1967) elucidates how habitat fragmentation affects species richness and composition. Larger patches support diverse communities, while smaller, isolated ones have lower richness. Applied to LULC, it explains how fragmentation alters vegetation and biodiversity. The intermediate disturbance hypothesis and functional diversity concepts also inform vegetation dynamics in response to disturbances and human activities. (MacArthur & Wilson, 1967).

The intermediate disturbance hypothesis (IDH) posits that moderate disturbances maximize species diversity by preventing competitive exclusion (Connell, 1978). Disturbances like fires or logging create niches for various species, enhancing vegetation diversity. However, excessive disturbance reduces richness. Understanding IDH aids in assessing human impacts on vegetation in LULC studies. For instance, mimicking natural disturbances through management practices can maintain diversity. Functional diversity, involving diverse species traits and roles, influences ecosystem processes (Díaz et al., 2007). High functional diversity ensures stability and resilience. Assessing it in LULC reveals how changes affect ecosystem functioning and services. Monocultures or invasive species dominance diminish diversity, impacting services like pollination or soil stabilization.

Water bodies

Changes in land use, such as deforestation, urbanization, or agriculture, can alter the hydrological cycle by modifying surface runoff patterns, groundwater recharge rates, and streamflow dynamics. For example, increased impervious surfaces in urban areas can accelerate surface runoff, leading to flash floods and erosion, while deforestation may reduce evapotranspiration and alter local precipitation patterns. Understanding the hydrological cycle is crucial for predicting the impacts of LULC changes on water bodies, including changes in water quality, quantity, and habitat availability for aquatic organisms.

The ecosystem services framework, as delineated by the Millennium Ecosystem Assessment (MEA, 2005), elucidates the crucial benefits that ecosystems, particularly water bodies, confer upon human societies. Water bodies play a pivotal role in providing various ecosystem services such as freshwater supply, water purification, flood regulation, and habitat provision for biodiversity. Changes in land use and land cover (LULC) can significantly impact these services, with activities like deforestation and agricultural runoff diminishing water quality and availability. Aquatic habitat fragmentation, defined by Nilsson et al. (2005) as the division of aquatic habitats into smaller, isolated patches due to human activities like dam construction, disrupts hydrological connectivity and impedes the movement of aquatic organisms. This fragmentation alters flow regimes, affects species distribution, and threatens their survival, illustrating the intricate interplay between human activities and aquatic ecosystems.

Wetland

The ecosystem services framework provides a conceptual framework for understanding the benefits that ecosystems, including wetlands, provide to human societies (MEA,2005). Wetlands offer a wide range of ecosystem services, including provisioning services such as water purification, flood regulation, and groundwater recharge; regulating services such as climate regulation, erosion control, and storm protection; cultural services such as recreational opportunities and aesthetic enjoyment; and supporting services such as habitat provision for aquatic and terrestrial biodiversity. Changes in LULC, such as wetland drainage for agriculture or urban development, can affect the provision of these ecosystem services by altering hydrological regimes, water quality, and habitat availability. For instance, wetland degradation can reduce flood regulation capacity, leading to increased flood risks for nearby communities.

Biodiversity losses

Biodiversity loss encompasses both the global extinction of various species and the local decline or disappearance of species within specific habitats, leading to a reduction in biological diversity. The latter occurrence can either be temporary or permanent, contingent upon whether the environmental degradation causing the loss can be reversed through ecological restoration or resilience, or if it is effectively irreversible, such as through land degradation. The ongoing global extinction event, often referred to as the sixth mass extinction or Anthropocene extinction, is driven by human activities that exceed planetary boundaries and has thus far proven irreversible. The primary direct threats to conservation, and consequently the causes of biodiversity loss, can be categorized into eleven main areas: residential and commercial development, agricultural activities, energy production and mining, transportation and infrastructure development, exploitation of biological resources, human interventions disrupting habitats and natural behaviors of species, alteration of natural systems, introduction of invasive species, pollutants, catastrophic geological events, and climate change (Ripple et al., 2017).

Loss of ecosystem services

Ecosystem services (ESS), defined by Kumar (2010), encompass the direct and indirect benefits ecosystems offer to human well-being. These services are categorized into provisioning, regulating, cultural, and supporting services, as outlined by Ranganathan (2008). Costanza et al. (1997) and the Millennium Ecosystem Assessment (MEA, 2005) emphasize the critical role of ecosystems in supplying services essential for human welfare, health, and livelihoods. Various conceptualizations exist, with MEA (2005) and TEEB (2010) defining ecosystem services as benefits obtained from ecosystems or their impacts on human welfare, respectively. Recent studies, such as Burkhard & Maes (2017), define ecosystem services (ES) as contributions to human well-being from ecosystem structure and function, influenced by human, social, and built capital interactions. The "cascade model" proposed by Burkhard & Maes (2017) illustrates ecosystem services as a connection between people and nature, highlighting their integral role in human well-being.

Genetic Diversity

Genetic diversity, the variety of genes within a species or population, plays a crucial role in species' long-term survival and adaptability to changing environments (Frankham, Ballou, & Briscoe, 2002). It provides resilience against diseases, pests, and environmental stressors by offering a pool of genetic variants for natural selection to act upon. In biodiversity conservation, genetic diversity is paramount as it influences populations' ability to evolve and adapt (Reed & Frankham, 2003). Populations with higher genetic diversity are more robust and better suited to withstand environmental changes. Assessing the impact of land use and land cover (LULC) changes

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on genetic diversity is vital for understanding conservation implications (Aguilar et al., 2008). Habitat loss and fragmentation due to LULC changes can reduce gene flow and increase inbreeding, leading to loss of genetic diversity and weakening species' adaptive capacity (Hoban et al., 2013). Incorporating genetic diversity assessments into conservation planning is essential for maintaining biodiversity's resilience and long-term viability (Hedrick, 2001)

III.RESEARCH METHODOLOGY

Research design

Jack (2006) defines research design as the conceptual framework guiding the execution of a study, encompassing the strategies for data collection, measurement, and analysis. It outlines the researcher's journey from formulating hypotheses to analyzing final data. Landsat 4-5, Landsat 7, and Landsat 8-9 satellite images were acquired from USGS and preprocessed using ArcGIS software. This involved tasks like layer stacking and image extraction for further analysis. Training sample data were selected, and land use land cover (LULC) class signatures were created for each image corresponding to different time points (1992, 2002, 2012, 2022). Supervised classification using maximum likelihood techniques was then conducted to generate maps depicting LULC changes over time. The study also compared LULC change detection per decade and overall changes across three decades. Non-probability sampling techniques, specifically purposive sampling, were employed to select key individuals from ANP management staff for interviews. Twenty (5) respondents, including park managers, district environment officers, and field rangers, were interviewed to gather their perceptions on the impact of LULC changes on biodiversity conservation.

Description of study area

This research was carried out within Akagera National Park, situated in the Eastern Province of Rwanda. Covering an area of 1,122 square kilometers (433 square miles), the park borders Tanzania and comprises diverse habitats including savannah, montane, and swamp areas. Established in 1934, the park derives its name from the Kagera River, which flows along its eastern boundary and feeds into Lake Ihema and various smaller lakes. The park's landscape features a complex network of lakes and interconnected papyrus swamps, constituting over a third of its total area, making it the largest protected wetland in Eastern-Central Africa. Originally spanning 2,500 square kilometers (970 square miles), Akagera National Park was established by the Belgian government during its occupation of Rwanda. Renowned for its rich biodiversity, the park once boasted a significant population of African wild dogs, earning it the nickname "Parc aux Lycaons." However, a disease outbreak led to a decline in the wild dog population, with the last sightings recorded in 1984 (Vande Weghe et al., 1990).

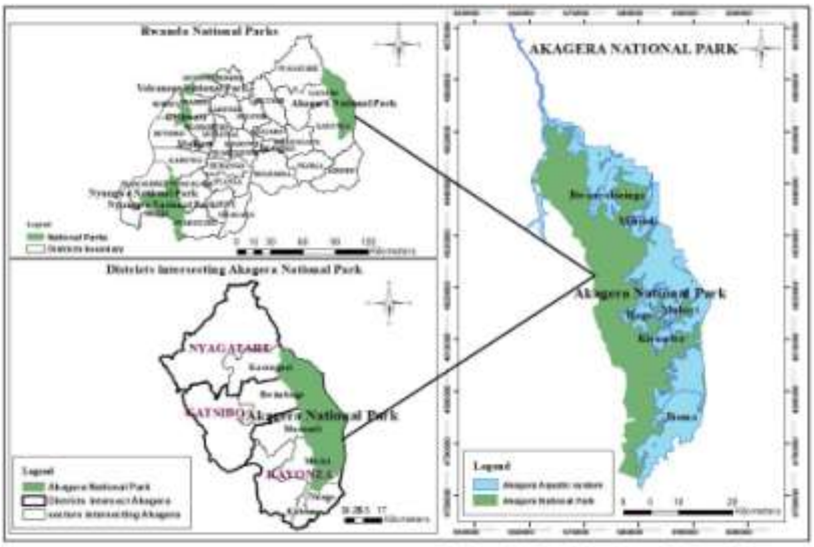


Figure 3.1: Map of study area

Source: Researcher's compilation (2024)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

Sample size and sampling procedure

For this study, a purposive sampling method was used to develop the sample of the researchThe study targeted 5 respondents from within public institutions including RDB, REMA and District environmental Officers from Districts intersecting with Akagera National Park (ANP) and ANP management staffs including park manager, field rangers.

Types of data

The researcher used face-to-face interview as a method of data collection to gather necessary information as primary data.

Secondary data:The study targeted data ranged from 1992 to 2022 but specifically used data from 1992-2002-2012-2022 for land use and land cover changes in Akagera National Park. Secondary data was retrieved from various sources including United State Geological Survey (USGS) where Land sat images such as Landsat 4-5 TM for 1992-2002, Landsat 7ETM+ for 2002-2012 and Landsat 8-9 OLI/TIRS for 2012-2022 were downloaded.

Details of Satellite datasets used in the study

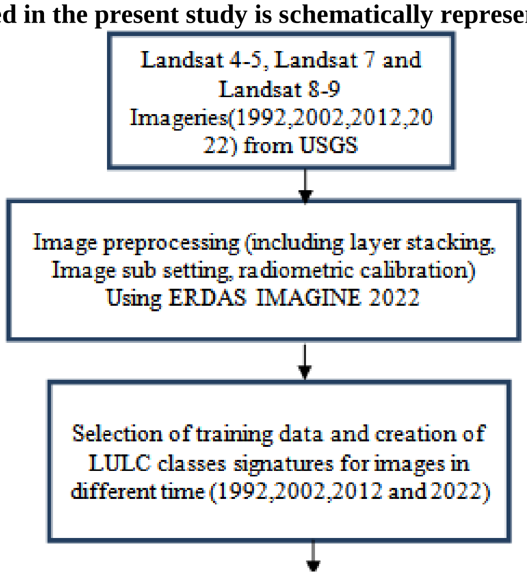
Years	Acquisition date	Path/Row	Spatial resolution(m)	Description
1992	8 Jan-27Dec	172/061	30	Landsat 4-5 TM
2002	3Jan-31Dec	172/061	30	Landsat7 ETM+
2012	11Jan-25Oct	172/061	30	Landsat 5 TM
2022	5Jan-30Dec	172/061	30	Landsat 8-9 OLI-TIRS

Source: Researcher's compilation (2024)

Data analysis

The processed satellite imageries of 2000; 2012 and 2022 was virtually interpreted and classified using supervised classification. The produced maps were compared with the respective satellite images and was cleaned by re-coding. After classification, the land use and land cover (LULC) datasets were converted to the UTM coordinate system (Zone 2, WGS 64 datum) to facilitate the calculation of change statistics for area measurement Satellite image interpretation was adopted as the appropriate analytical tool for the acquired data. This study also analyzed the reports of Akagera National Park in order to know the trends in loss of major diversity species by using trend analysis.

The overall methodology used in the present study is schematically represented in thefollowing



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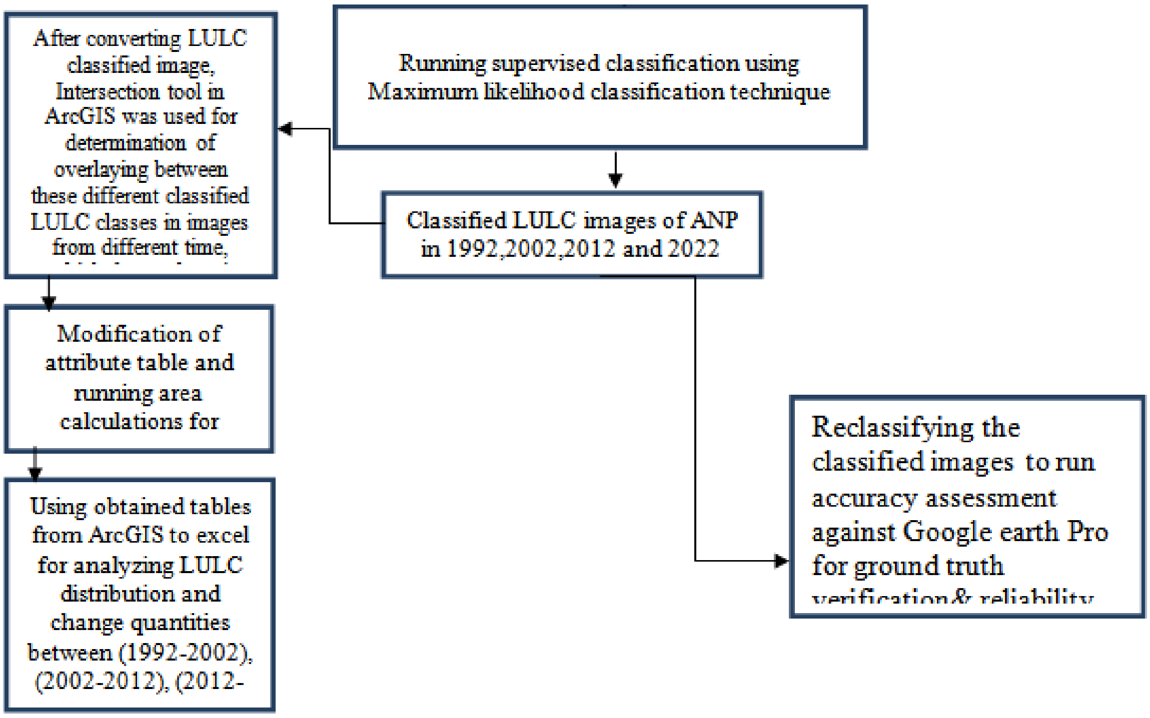

Figure 3.2: LULC Data analysis
Source: Researcher's compilation (2024)

IV.RESULTS AND DISCUSSIONS

Demographic Information

	Frequency	Percentages
GENDER		
Male	3	60
Female	2	40
AGE		
25-30	1	20
31-35	1	20
36-40	2	40
Above 40	1	20
QUALIFICATION		
Bachelors	2	40
Masters	2	40
PHD	1	20

Figure 4.1 LULC 1992
Source: Researcher's compilation (2024)

The level of land use and land cover changes in Akagera national park
Land use Land cover Change 1992

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Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

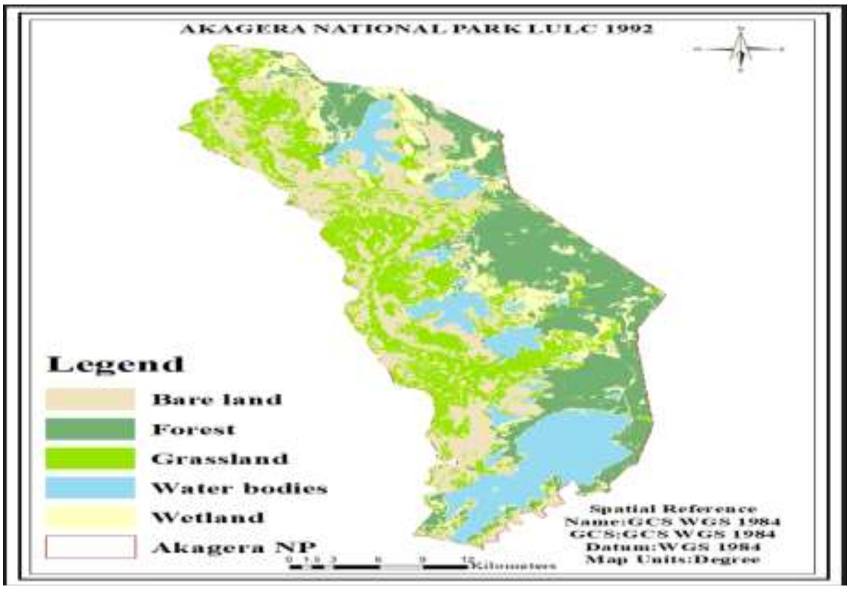

Figure 4.1: LULC 1992

Source: Researcher's compilation (2024)

Data analysis from Landsat 4-5 TM images captured in 1992 revealed significant insights into the land cover distribution within Akagera National Park. Bare land occupied 7.67% of the park area, equivalent to 7,866.41 hectares. Forested areas comprised 10.11% of the total park area, totaling 10,374.08 hectares. Grassland was predominant, covering 67.31% of the park area, with a total of 69,052.21 hectares. Water bodies accounted for 9.8% of Akagera National Park's total area, covering 5,680.30 hectares.

Furthermore, the study reflected that wetland covered 5,680.30 hectares, accounting for 5.54% of the total area of Akagera National Park. These detailed findings highlight the dynamic nature of LULC changes over the specified period and provide valuable intuition into the distribution and composition of various land cover types within the park.

Land use Land cover Change 2002

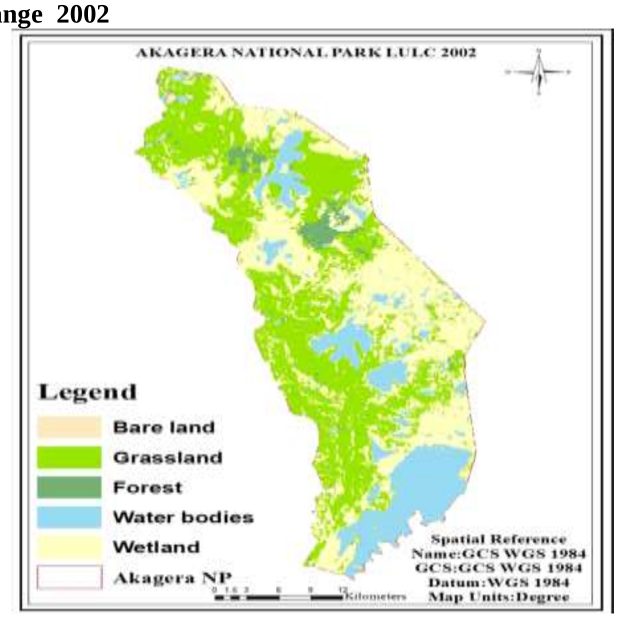

Figure 4.1.1:LULC 2002

Source: Researcher's compilation (2024)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

The analysis of data from Landsat 4-5 TM in the year 2002 brought to light significant intuition into the land cover dynamics within Akagera National Park. The research findings indicated that 15.3% of the total park area, equivalent to 15,648.40 hectares, was classified as bare land during this period. Forested areas constituted 8.1% of the park, covering 8,263.84 hectares.

Utilizing image classification techniques, it was determined that grassland dominated a substantial portion of Akagera National Park, encompassing 61,657.16 hectares or 60.1% of the total area. Water bodies, including lakes and rivers, accounted for 12.0% of the park's landscape, covering an extent of 12,335.40 hectares. Moreover, the research revealed that wetlands covered 4.6% of Akagera National Park's total area, amounting to 4,689.30 hectares. These detailed findings provide a comprehensive understanding of the distribution and proportions of various land cover types within the park during the specific period under consideration.

Table 4.3: LULC Area 1992 and 2002

LULC Class	1992		2002	
	Area in Hectares (Ha)	**Percentage (%)**	**Area in Hectares (Ha)**	**Percentage (%)**
Bareland	7866.41	7.67	15648.40	15.3
Forest	10,374.08	10.11	8263.84	8.1
Grassland	69052.21	67.31	61657.16	60.1
Water bodies	9621.11	9.38	12335.40	12.0
Wetland	5680.30	5.54	4689.30	4.6
Total	102594.10	100	102594.10	100

Source: Researcher's compilation (2024)

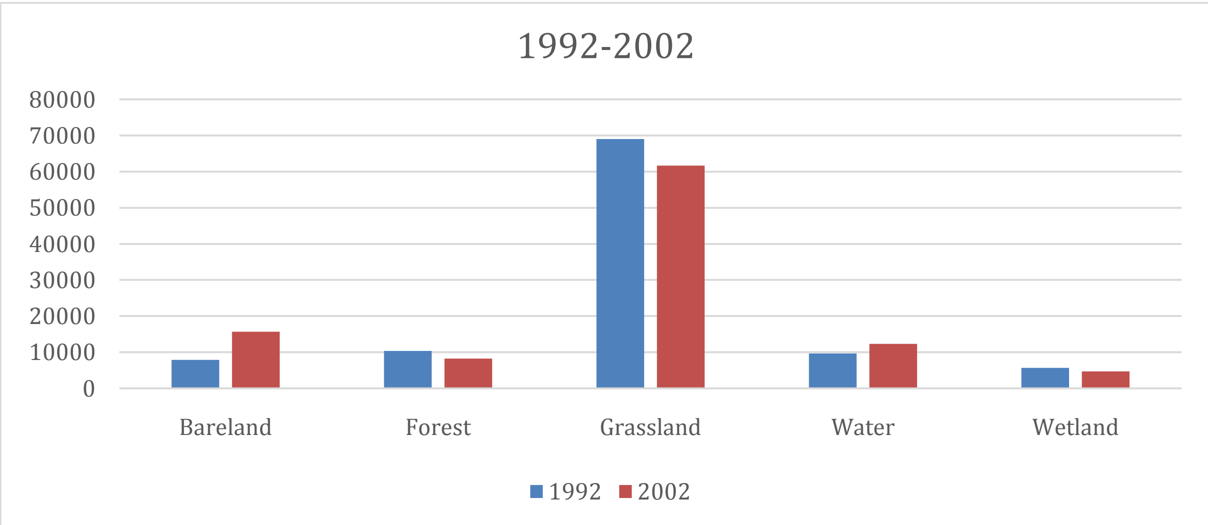

Figure 4.2: illustration of Area of 1992,2002

Source: Researcher's compilation (2024)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

Table 4.4: Accuracy assessment 1992-2002

LULC	1992		2002	
	User accuracy (%)	Producer accuracy (%)	User accuracy (%)	Producer accuracy (%)
Bareland	90.20	75.00	90.04	92.10
Forest	85.00	86.00	95.40	100.00
Grassland	85.40	88.20	100.00	86.30
Water	95.00	100.00	92.10	94.00
Wetland	85.00	94.00	95.30	100.00
Overall Accuracy	**88.00**		**94.00**	
Kappa	**0.85**		**0.93**	

Source: Researcher's compilation (2024)

The accuracy assessment indicated that the overall accuracy of the data for 1992 and 2002 was 88.00% and 94.00%, respectively. This implies that the information collected and analyzed during the assessment process had a high degree of accuracy, aligning with the ground truth or reference data by 88% and 94.00%, respectively.

Land use Land cover 2012

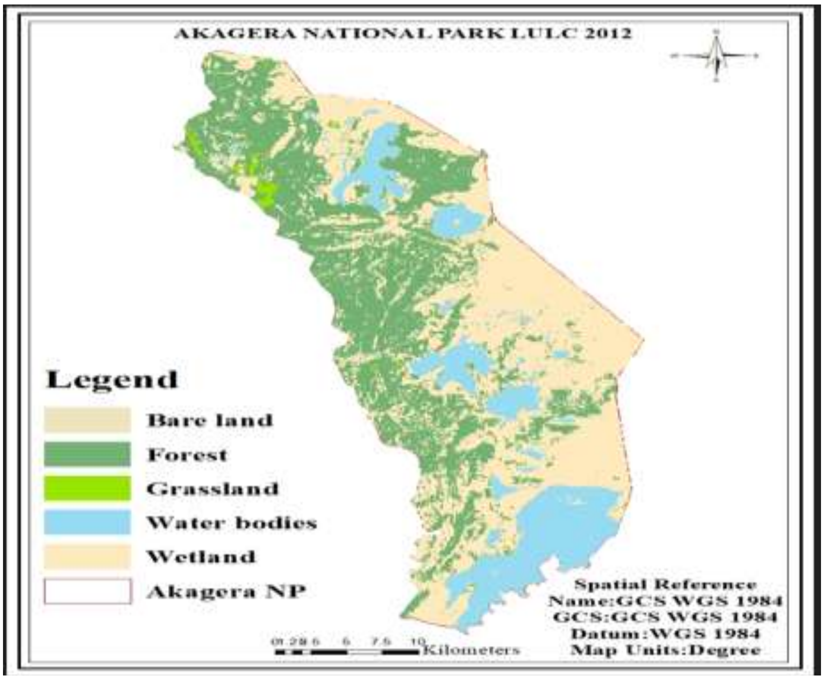

Figure 4.3 LULC 2012

Source: Researcher's compilation (2024)

The study investigating LULC in 2012 indicated the distribution of land use land cover within Akagera National Park. Results showed that 16.53% of the park was bare land, totaling 16,961.20 hectares. Forested areas accounted for 9.23% of the park, covering 9,470.30 hectares. Grassland dominated, comprising 58.46% of the total area, with 59,980.04 hectares. Water bodies, including lakes and rivers, represented 12.95% of the landscape, covering 13,287.49 hectares. Additionally, wetlands covered 2.82% of the park, totaling 2,895.11 hectares. These findings offer a detailed overview of the changing proportions and distribution of land cover types within Akagera National Park during 2012.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

Land use Land cover 2022

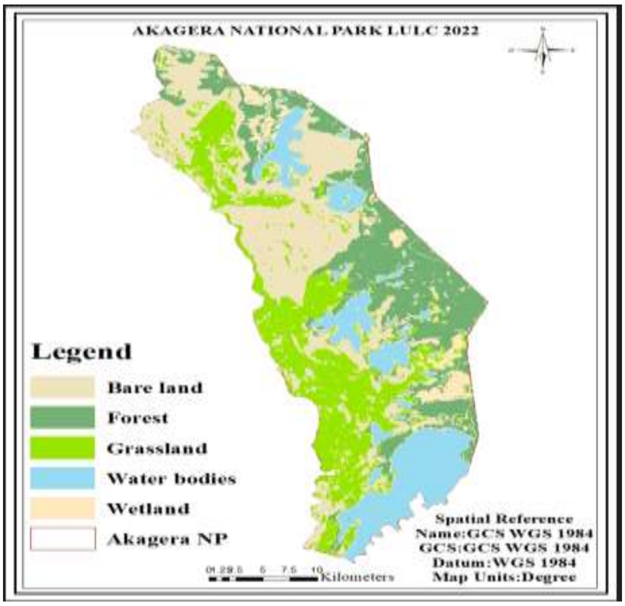

Figure 4.3.1: LULC 2022

Source: Researcher's compilation (2024)

The findings of the research conducted by analyzing Landsat 8-9 OLI-TIRS to find out LULC of 2022 brought to light significant insights into the evolving land cover within Akagera National Park. It was revealed that 19.5% of the total park area, equivalent to 19,978.67 hectares, was characterized as bare land during this particular period. Forested areas constituted 7.8% of the park, covering 7,994.67 hectares.

Employing image classification techniques, the study determined that grassland continued to dominate a substantial portion of Akagera National Park, encompassing 56.5% of the total area or 57,999.90 hectares. Water bodies, comprising lakes and rivers, accounted for 14.6% of the park's landscape, covering an extent of 15,020.59 hectares.

Additionally, the research highlighted that wetland covered 1.6% of Akagera National Park's total area, amounting to 1,600.26 hectares. These extensive results provide valuable understanding of the continuous alterations in the distribution and proportions of various land cover categories within the park during the specified period in 2022.

Table 4.5: LULC area and percentages 2012-2022

LULC Class	2012		2022	
	Area in Hectares	**Percentage**	**Area in Hectares**	**Percentage**
Bareland	16961.20	16.53	19978.67	19.5
Forest	9470.30	9.23	7994.67	7.8
Grassland	59980.04	58.46	57999.90	56.5
Water	13287.49	12.95	15020.59	14.6
Wetland	2895.11	2.82	1600.26	1.6
Total	102594.1	100	102594.10	100

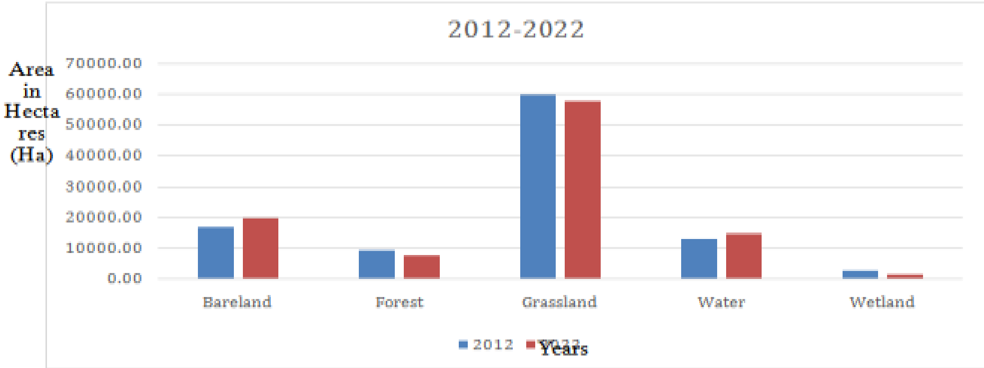

Figure 4.4: Illustration of area LULC 2012-2022

Source: Researcher's compilation (2024)

Table 4.6: Accuracy assessment of 2012-2022

LULC	2012		2022	
	User accuracy (%)	**Producer accuracy (%)**	**User accuracy (%)**	**Producer accuracy (%)**
Bareland	81.30	75.10	90.00	100.00
Forest	79.80	86.00	85.00	72.58
Grassland	76.60	89.06	83.00	85.40
Water	84.91	87.87	100.00	96.80
Wetland	85.32	76.94	87.00	100.00
Overall	**79.94**		**90.70**	
Kappa	**0.76**		**0.86**	

Source: Researcher's compilation (2024)

The accuracy assessment indicated that the overall accuracy of the data for 2012 and 2022 was 79.94% and 90.70%, respectively. This implies that the information collected and analyzed during the assessment process had a high degree of accuracy, aligning with the ground truth or reference data by 79.94% and 90.70%, respectively.

4.3. Evaluation of change detection for 1992-2002,2002-2012, 2012-2022

ANP LULC Change Detection 1992-2002

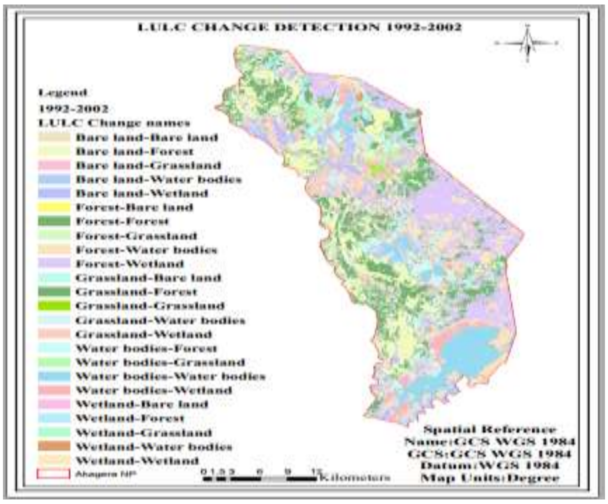

Figure 4.5: LULCD 1992-2002

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

Table 4.7: LULC CD 1992-2002

LULC change Detection 1992-2002		
LULC Class	**Area in Hectares**	**Area in Percentage (%)**
Bare land	7782.0	7.6
Forest	-2110.2	-2.1
Grassland	-7395.0	-7.2
Water	2714.3	2.6
Wetland	-991.0	-1.0

Source: Researcher's compilation,2024

The findings of the study unveiled notable transformations in the LULC composition of Akagera National Park. Specifically, there was a discernible 7.6% increase in Bare land, accompanied by a 2.1% reduction in forest cover. During the time series spanning from 1992 to 2002, research identified a 7.2% decline in grassland, a 2.6% augmentation in water bodies, and a 1.0% decrease in Wetland areas. These results contribute to a more comprehensive understanding of the dynamic shifts occurring within the park's ecological landscape over the specified periods

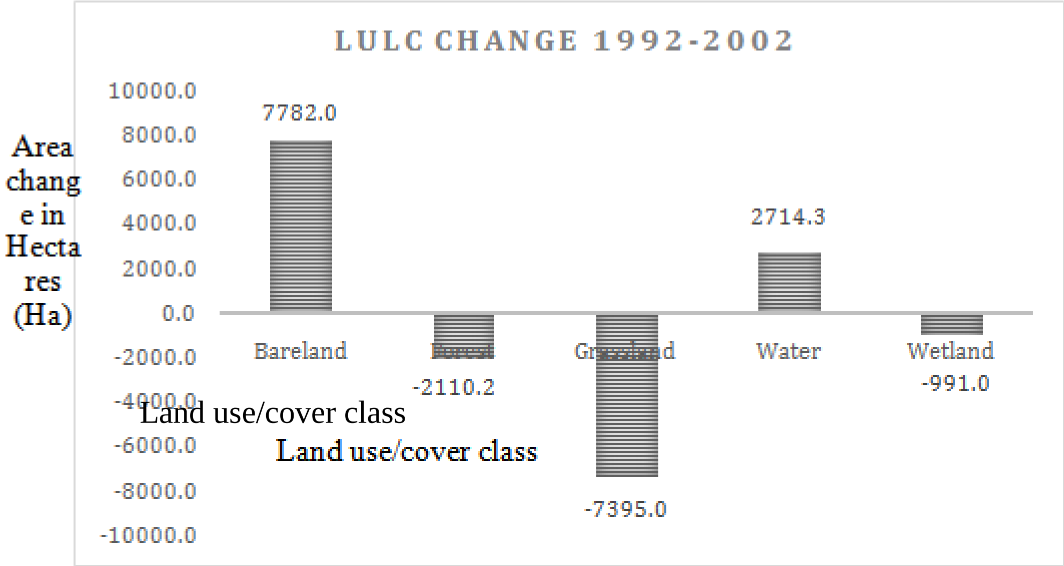

Figure:4.6:Net Change of 1992-2002

Source: Researcher's compilation (2024)

Figure 4.6 illustrates the net changes over a decade (1992-2002), revealing a noteworthy increase in bare land area by 7.6%, indicative of substantial deforestation. There was a reduction of forested areas by 7,782.0 hectares and a parallel decrease in grassland by 7,395.0 hectares, as highlighted by image classification. Moreover, the research findings unveil an increase in water bodies by 2.6% of Akagera National Park's total area, equivalent to 2,714.3 hectares. However, it is concerning that wetlands experienced a reduction of 1.0% from 1992 to 2002.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

ANP LULC Change Detection 1992-2002

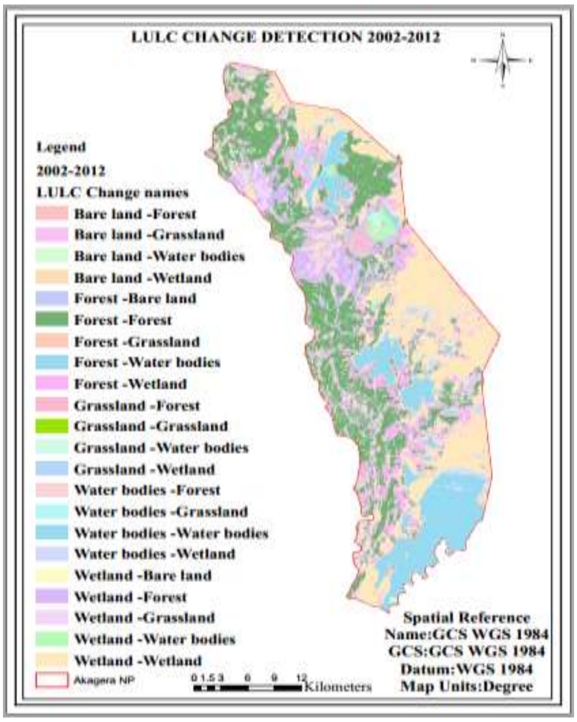

Figure 4.7: LULCCD 2002-2012

Source: Researcher's compilation (2024)

LULC change Detection 2002-2012		
LULC Class	**Area in Hectares**	**Percentage (%)**
Bare land	1312.80	1.28
Forest	1206.46	1.18
Grassland	-1677.12	-1.63
Water	952.09	0.93
Wetland	-1794.19	-1.75

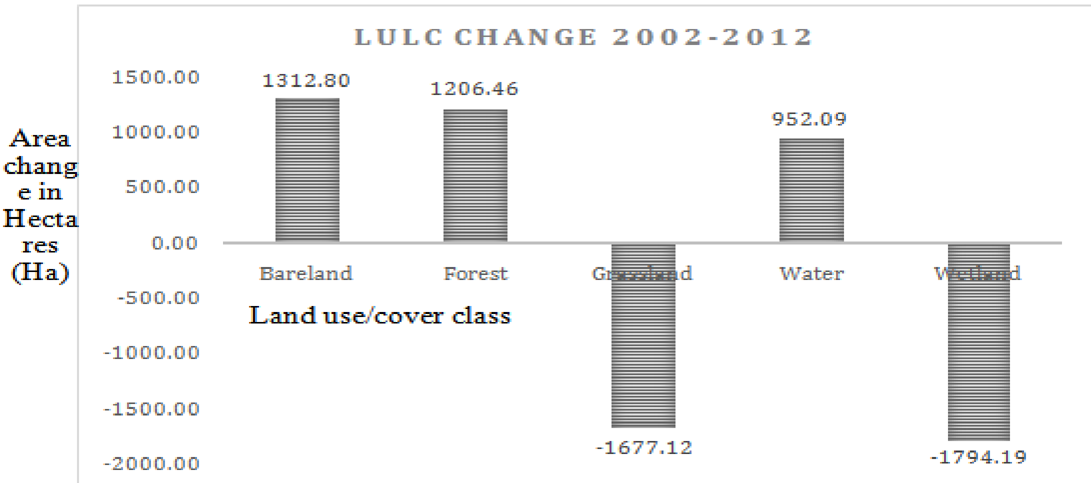

Figure 4.8: Net change of 2002-2012

Source: Researcher's compilation (2024)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

Figure 4.8 provides a detailed representation of the net changes observed in Akagera National Park between 2002 and 2012. The investigation revealed an expansion in Bare land, Forest, and water by 1.28% (equivalent to 1312.80 hectares), 1.18% (corresponding to 1206.46 hectares), and 0.93% (amounting to 952.09 hectares), respectively. In contrast, there was a decrease in grassland and wetland areas, registering a reduction of 1.63% (equivalent to 1677.12 hectares) and 1.75% (totaling 1794.19 hectares), respectively.

ANP Land Use Land Cover Change Detection 2012-2022

In this part, researcher delve into the dynamic landscape of Akagera National Park, focusing specifically on the changes observed in land use and land cover over the period from 2012 to 2022. Understanding the alterations in land use and land cover within the park is essential for assessing the impacts of LULC on biodiversity conservation.

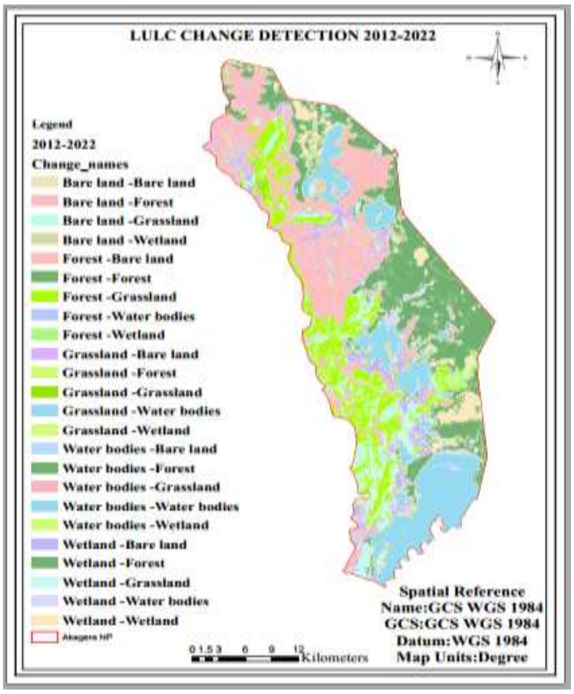

Figure 4.9: LULC CD 2012-2022

Source: Researcher's compilation (2024)

Table 4.9: LULCCD 2012-2022

LULC change Detection 2012-2022		
LULC Class	**Area in Hectares**	**Percentage (%)**
Bare land	3017.47	2.94
Forest	-1475.63	-1.44
Grassland	-1980.14	-1.93
Water	1733.10	1.69
Wetland	-1294.85	-1.26

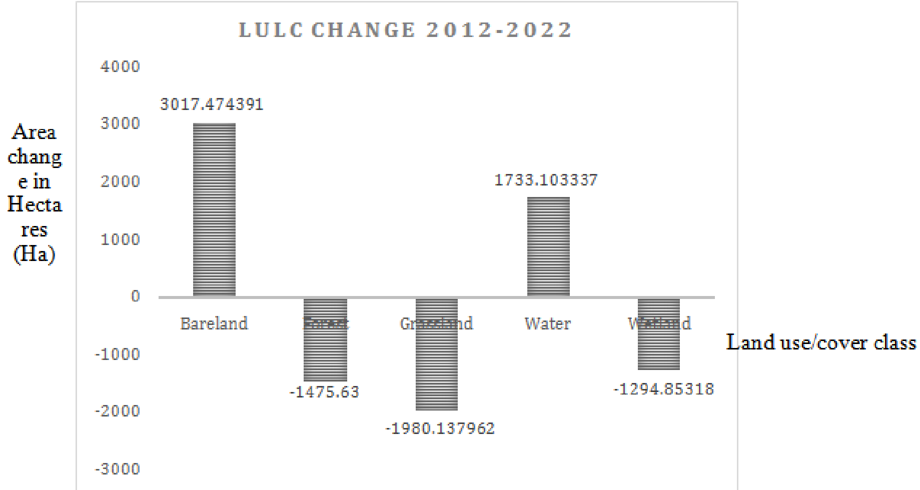

Figure 4.10: Net Change of 2012-2022

Source: Researcher's compilation (2024)

Figure 4.10 illustrates the net changes in the period 2012-2022 within Akagera National Park, reflecting the alterations in Land Use and Land Cover (LULC) classes over a decade. During this timeframe, there was an increase of bare land by 2.94% (equivalent to 3017.47 hectares) and an expansion of water bodies by 1.69% (1733.10 hectares).

It also illustrates a reduction in forest cover by 1.44% (equivalent to 1475.53 hectares), grassland by 1.93% (amounting to 1980.14 hectares), and wetland by 1.26% (totaling 1294.85 hectares).

ANP overall LULC Change Detection 1992-2022

In this segment, the investigation delves into LULC of Akagera National Park, with a particular emphasis on the shifts witnessed in land use and land cover from 1992 to 2022. showing the change in land use and land cover within the park is crucial for evaluating their influence on biodiversity conservation.

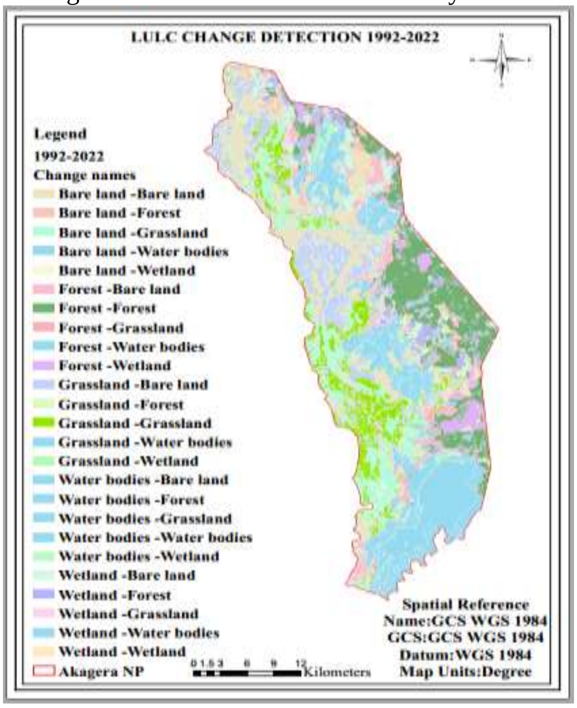

Figure 4.11: LULC Change detection of 1992-2022

Source: Researcher's compilation (2024)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

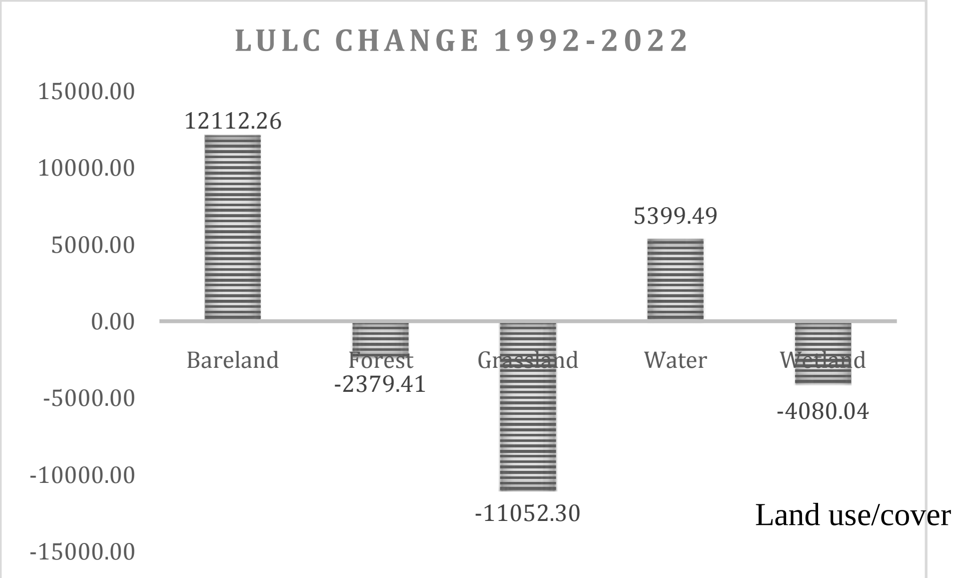

Figure 4.12: Net Change 1992-2022

Figure 4.12 depicts the comprehensive distribution of Land Use and Land Cover (LULC) over a span of 30 years, showcasing a notable surge in both bare land and water bodies. This increase accounts for 11.81% of the total landscape, equivalent to a substantial 12,112.3 hectares for bare land and 5.26%, corresponding to 5,399.5 hectares, for water bodies. These findings underscore the dynamic changes in the LULC pattern, emphasizing the significant expansion of bare land and water bodies within the studied timeframe. from the past 30 years there was reduction of forest, grassland and wetland by 2379.4 hectares, 11052.3 hectares and 4080.0 hectares respectively.

LULC Class	Table 4.11:LULC Change Detection 1992-2022	
	Area in Hectares	Percentage
Bare land	12112.3	11.81
Forest	-2379.4	-2.32
Grassland	-11052.3	-10.77
Water	5399.5	5.26
Wetland	-4080.0	-3.98

Figure 4.11: LULC Change detection of 1992-2022

Source: Researcher’s compilation (2024)

4.4. Assessing the effect of LULCCD of specified years on biodiversity conservation

Figure 4.7 illustrates significant LULC changes from 1992 to 2002, notably a 7.6% increase in bare land and a 7.2% decrease in grassland. Consultations with key stakeholders revealed that these changes reflect the impacts of human activities on biodiversity conservation in Akagera National Park (ANP). The lack of fencing during this period allowed unrestricted access for poaching and land encroachment, exacerbated by the reduction in park size for Rwandan refugee settlement. This underscores the profound impact of LULC changes on biodiversity. The decline in grassland, crucial habitat for various wildlife species, is attributed to deforestation, leading to species extinction. Despite a 2.6% increase in water bodies, concerns arise regarding water pollution from surface runoff, threatening aquatic species. Additionally, a -1.0% reduction in wetland area further highlights environmental challenges within the park.

Respondents emphasize the critical role of wetlands in enhancing ecosystem resilience against climate change impacts. Wetlands' capacity to absorb and retain water helps mitigate floods and droughts within the park. The decline in wetlands from 1992 to 2002 has heightened the park's vulnerability to extreme weather events, exacerbating climate change challenges.

Effect of LULCCD 2002-2012 on biodiversity conservation

The research findings from 2002 to 2012 revealed changes in land cover, including increases in bare land, forest, and water areas by 1.28%, 1.18%, and 0.93%, respectively, alongside reductions in grassland and wetland by 1.63% and 1.75%, respectively. Akagera National Park (ANP) management staff and stakeholders emphasized the significant implications of these changes for biodiversity conservation. While increases in certain habitats provided new ecological niches for species like reptiles and birds, reductions negatively impacted species dependent on grassland and wetland environments, potentially altering biodiversity patterns. The ongoing construction of the park's western boundary fence is crucial for biodiversity conservation efforts, yet delays have allowed elephants and buffalo to leave the park, causing crop damage and necessitating costly interventions. Additionally, invasive species pose threats, with efforts to remove them requiring substantial resources. Effective land use and cover management, including boundary fencing completion and invasive species removal, are vital for maintaining the park's ecological integrity and biodiversity. Law enforcement efforts, particularly against poaching, play a significant role in preserving the natural habitat and ecosystem balance by targeting key species and supporting conservation initiatives.

Effect of LULCCD 2012-2022 on biodiversity conservation

Table 4.9 reveals a 2.94% increase in bare land and a 1.69% rise in water bodies, prompting queries to ANP management about their impact on biodiversity. They attribute bare land expansion to activities like forest clearing, overgrazing, and habitat conversion, disrupting ecosystems and threatening wildlife habitats. Rapid water body growth raises concerns about water quality and pollution from human activities. Reductions in forest, grassland, and wetland areas by 1.44%, 1.93%, and 1.26%, respectively, have deprived wildlife of vital habitats, leading to population declines, especially among birds, lions, and rhinos. Diminished habitats pose challenges for species to find food and suitable living spaces, while deforestation exacerbates climate change and alters local climate patterns. The loss of biodiversity, including iconic species like lions and rhinos, underscores the need for conservation efforts. To address this, the Rwandan government introduced additional lion species and imported white rhinos, resulting in a resurgence in lion populations since 2015.

Overall effect of LULCCD 1992-2022 on biodiversity conservation

Figure 4.12 highlights significant increases in bare land and water bodies by 11.81% and 5.26%, respectively. ANP management staff attribute the rise in bare land to habitat loss, leading wildlife to migrate into human settlements, increasing human-wildlife conflicts. Expanding water bodies have also brought wildlife closer to human settlements, posing conservation and conflict management challenges. Additionally, increased water bodies have altered water quality, posing concerns about pollution from human activities.

Over the past 30 years, there have been reductions in forest, grassland, and wetland areas by 2379.4 hectares, 11052.3 hectares, and 4080.0 hectares, respectively. This loss affects wildlife habitat and disrupts the food chain, impacting the park's biodiversity. Wetland reduction has further affected water quality and availability for wildlife, impacting the ecosystem's overall health.

The loss of ecosystem services, including water regulation and nutrient cycling, poses a grave concern for ANP's ecological balance and biodiversity. Reduced genetic diversity within wildlife populations exacerbates these challenges, reducing species' adaptive capacity and increasing vulnerability to extinction.

In conclusion, urgent conservation efforts are necessary to mitigate habitat loss, restore degraded habitats, and safeguard biodiversity within Akagera National Park. Enhancing genetic diversity within wildlife populations is also crucial for their long-term survival and resilience in the face of ongoing environmental changes.

V.CONCLUSION AND RECOMMENDATION

Conclusion

The research findings highlight significant changes in Land Use Land Cover (LULC) within Akagera National Park (ANP) from 1992 to 2022.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 927-946 www.ijaem.net ISSN: 2395-5252

These changes have substantial implications for biodiversity conservation, as evidenced by change in habitat composition and landscape dynamics. The increase in bare land and decline in grassland over the years raise concerns about habitat loss and fragmentation, particularly for species reliant on these environments for survival. Human-induced factors such as deforestation and poaching exacerbate these threats, posing challenges to wildlife populations and ecosystem health. Furthermore, the expansion of water bodies and reduction in wetlands affect aquatic ecosystems, leading to concerns about water quality and habitat availability for aquatic organisms. Overall, these findings underscore the urgent need for conservation efforts to mitigate the adverse effects of LULC changes on biodiversity within ANP.

Recommendation

For RDB and Akagera National Park Management (ANP)

► Should prioritize habitat restoration projects to counteract the loss of forest, grassland, and wetland areas.

► Replanting native vegetation and implementing erosion control measures can help restore degraded habitats

► Should intensify law enforcement efforts to combat poaching and illegal activities within the park. This includes increasing patrols, enhancing surveillance technologies, and implementing stricter penalties for offenders.

► Should actively engage with local communities to foster a sense of stewardship and promote sustainable land use practices. Collaborative conservation initiatives involving local stakeholders can help mitigate human-wildlife conflicts and support biodiversity conservation efforts.

For Local Leadership

► Should advocate for policies and practices that prioritize sustainable development and environmental conservation. This includes promoting eco-friendly agricultural practices, supporting alternative livelihoods for communities near the park, and investing in renewable energy projects.

► It is advisable to endorse educational initiatives focused on conservation in schools and communities to enhance understanding of the significance of preserving biodiversity and adopting sustainable land management practices. This can help instill a culture of conservation among local residents and future generations.

► Ensure regular mobilization of local community on environmental protection especially conservation of biodiversity in protected area

For Future Researchers

► Should conduct longitudinal studies to monitor changes in LULC patterns and biodiversity over time. Long-term data collection efforts are essential for understanding ecosystem dynamics and informing conservation strategies.

► Should explore the socio-economic influence of LULC changes on local individuals surrounding ANP. This includes assessing the effects of habitat loss on livelihoods, food security, and human-wildlife conflicts.

► Should evaluate the effectiveness of conservation interventions implemented in ANP, such as habitat restoration projects, anti-poaching efforts, and community engagement initiatives. This can help identify best practices and inform evidence-based conservation strategies moving forward.

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