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Land cover change analysis in the Aberdare forest ecosystem and practical lessons for nature conservation in Kenya

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Abstract

With significant increase in human activities and ongoing conflicts over land use in the Mau forest complex, this study sought to access the trend in vegetation cover change in the Aberdares between 2008 and 2018 for an up-to-date spatial data. Through remote sensing techniques, this research was broadly aiming at characterizing the dynamics of vegetation cover between this period. Specifically, the study aimed at: identifying the major vegetation cover types in the Abardares; along with determining the rate of vegetation cover change between the study periods. Land cover types were discriminated through supervised and unsupervised classification and spatial reclassification of multi-temporal Landsat imagery. The land cover classes were verified and validated using reported result by CIRAD Consultancy Team for rehabilitation of the Aberdare Forest Ecosystem in 2009. One-way ANOVA showed that the rate of change in vegetation cover between the years was statistically significant ($p< 0.05$). Between 2008 and 2013, the study reported a decrease in forest land by -2.2% while non-forest land increased by 10.7%. However, during the phase 2013-2018, there was an increase in forest land by 3.6% while non-forest land reduced by -5.6%. This has the implication that conservation efforts by the government are bearing results.

Keywords: Biodiversity, conservation, land cover change, forest landscape, Aberdares, wildlife.

Introduction

Protected areas and landscapes are among the world's largest planned land use activity[1], covering 15.4 per cent of the global land area. With a total land area of 582,646 km^2, Kenya is particulary famous for her dense forest landscapes[2]. This is a proportion of 8-11% of the total land area constituting 28 terrestrial reserves, 6 marine reserves, 23 terrestrial parks, 4 marine parks, and 4 national sanctuaries[3,4].

These forests are categorized into montane, dryland, bamboo, afro-montane undifferentiated forests, western rain forests, and coastal forests[2]. Natural forests include the montane and bamboo forests, which were the focus in this study. According to a national land cover inventory by the Kenya Forests Services conducted in 2010, the montane forests landscapes occupied about 2% of the total land area in the country[5]. The same analysis revealed that the country's highland and coastal landscapes are the most forested with 18% and 10% forest cover, respectively[6]. A significant area of 2.13 million hectares consisted of bush land and mangroves while public and private forest plantations comprises of 220,000 hectares[7]. This represents a proportion of 4% and 0.4% of the total land area in Kenya respectively.

These forest landscapes have important uses including providing water catchment areas, sources of livelihood for local traditional inhabitants, ensuring biological diversity, and providing habitat for wildlife habitat[8,9]. However, these important resources have been under continous threat from over exploitation and unsustainable use[10]. This mostly affects the lowland forests adjacent to rural communities who clear them for farming, settlement and livestock rearing[2]. In efforts to mitigate the loss in land cover, the national government through the ministry of Environment and Forestry is undertaking several measures. Examples include the introduction of a Regulatory, Enforcement and Compliance Affairs Department to control, co-ordinate and regulate the use of wildlife and natural resources and their products[11]; and the introduction of the national forests programme, 2016-2030 charged with the main aim to enhance sustainable forest management, and to increase the land area under forests[12]. However, there still exists conflicts between the government and the communities living within the landscapes - An example is the ongoing evictions between in the Mau forest complex.

This study sought to probe and report the current state of the Aberdares by conducting a 10-year vegetation use change analysis. The objectives of this undertaking were: to identify the major land cover types in the Abardare forest landscape; and to determine the rate of vegetation cover change in the study area between 2008 - 2018.

Methodology

The Aberdares landscape, designated into a forest reserve and national park (Figure-1) was the study site. It is situated between Latitude: -0.38546 - 0° 23' 7.656" N and Longitude: 36.63563 36° 38' 8.268" E within Central Kenya and North West of the capital, Nairobi[13,14]. Rainforest takes the larger part of the ecosystem of the forest reserve while ≥40% is covered with bamboo forest[5].

Sample collection: This research project was desktop based, utilizing remote sensing techniques through an open access site (Satellite images were downloaded via https://earthexplorer.usgs.gov/) to extract cloud-free satellite images (where cloud free images were not found, a cloud cover of <10% was used) of the study area over the period 2008-2018[15]. Land cover classification was verified through reported result by CIRAD Consultancy Team for rehabilitation of the Aberdare Forest Ecosystem in 2009. Change in forest cover was analyzed to make interpretation and synthesis[16], and offer answers to the objectives[17]. Forest shape files of the study area were also sought. To aid in identification and discrimination of land-cover types and to generate forest cover maps within the study area, unsupervised classification was performed in ArcGIS[18]. Using the results of unsupervised classification, Google Earth imagery, and general familiarity of the study area, possible land-cover classes were identified for Landsat images between the study periods and used to make conclusions on land cover trend[15,19]. Inter year variability between the different types of vegetation was estimated based on reported pixels against assigned spectral signature for each class.

Satellite image selection: Forest cover change was studied by using satellite imagery for the years 2008, 2013 and 2018. Before downloading satellite imagery, possible image errors including cloud cover and gapped areas were taken into consideration. The gaps may result due to image transmission and instrumentation error[20].

Reconstruction of damaged image and cloud cover removal require additional time to process and affects the quality of results[20]. Satellite imagery used for 2013 and 2018 was free of errors. However, for 2008, all available scenes (LS 7 and LS 5) had the problem of cloud cover and gapped areas. However, considering the importance of analysis, 2008 (Feb) image with 6% cloud cover was selected for the study.

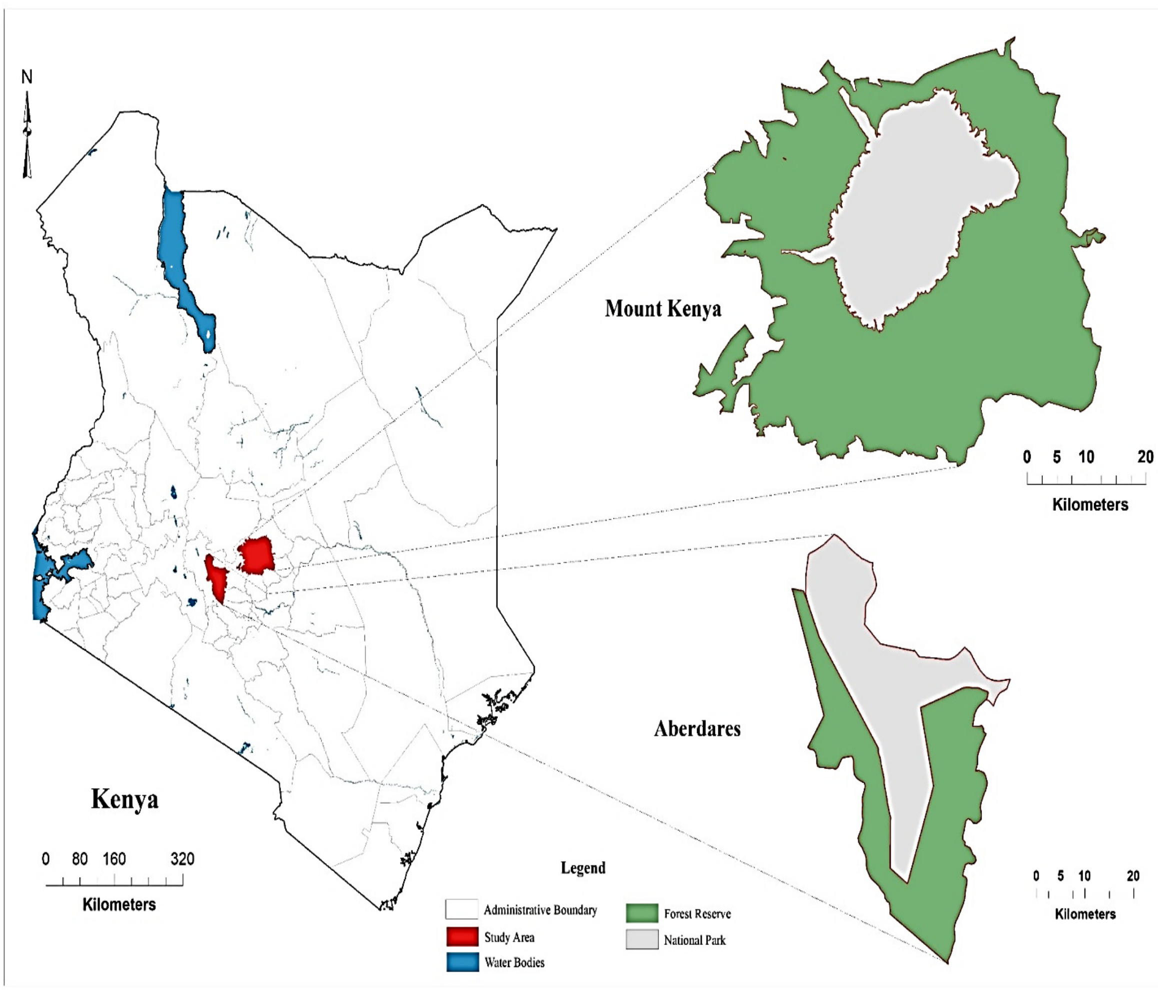

Figure-1: The map of Kenya showing the study area, the Aberdares.

Images were processed and analyzed for detection of forest change. Image processing, enhancement, Maximum likelihood classification (unsupervised classification), feature extraction, and advanced classification (supervised) techniques were performed for the desired result[21,22]. Arc Map 10.3 was used to process and analyze images using NDVI spectral reflectance bands for Landsat 7 (ETM+) and Landsat 8 (OLI and TIRS)[15].

To determine reliability and accuracy of the results, supervised classification techniques based on spectral signature was used to classify land cover between different types of vegetation[15]. Land cover classes were verified with the help of reported result by CIRAD Consultancy Team for rehabilitation of the Aberdare Forest Ecosystem, 2009[23]. However, ground truthing is required for higher accuracy[24]. On the basis of vegetation classification, area and percentage of landcover were calculated by using zonal geomatry tools in ArcGIS[25,26]. The annual rate of forest cover change was determined by using percentage increase or decrease formula.

Results and discussion

Using GIS and Remote sensing techniques, a spatial-temporal analysis was carried out to estimate change in forest cover in the Aberdares between 2008 and 2018. The study reported the mean and standard error of the land cover change at 95% confidence interval over the 10 year study period. One-way ANOVA showed that rate of change in vegetation cover was statistically significant ($p < 0.05$) for the years 2008, 2013 and 2018.

Land cover analysis in 2008: Land cover analysis in the Aberdares showed that the area is covered with bamboo and mountain forest significantly ($p < 0.05$). Other vegetation types identified include grassland, agricultural crop, moorland and alpine forest.

The findings highlighted that nearly 7% of the area was under cultivation. Approximately 44% of the area was found to be covered with bamboo forest, 39% with mountain forest while a small portion of 0.1% was burnt land (Figure-2). Figure-2 shows the spatial and statistical distribution of the area based on Land use for the year of 2008.

Land cover analysis in 2013: Analysis for the study site also showed a significant distribution ($p < 0.05$) of mountain and bamboo forests. Other vegetation types identified include grassland, agriculture crop, moorland and alpine forest. The statistics shows that 25.7% of the total reserve was covered with mountain or closed forest, 34.74% covered with bamboo forest, and 13.04% with Alpine Moorland and 17% under agricultural (Figure-3).

There was a drastic increase in bare land (burnt area) to over 4% from 0.1% in 2008. The same scenario was observed for the land under cultivation which increased by over 10% up from 7%. Figure-3 shows the spatial and statistical distribution of the area based on Land use for the year of 2013.

Land cover analysis in 2008: Currently, land cover analysis shows that the Aberdares forest landscape is densely covered with the bamboo forest followed by mountain/closed forest at 46% and 41% respectively (Figure-4). Other vegetation types identified include grassland, agriculture crops, moorland and alpine forest. From the statistics, a significant increase in the area under forest cover (mountain and bamboo forests) is observed ($p<0.05$).

10% of the area comprises of Alpine Moorland while a small portion of 2.7% is currently cultivated. A negligible stretch of land is bare. This is a reduction from the preceding analysis where both agricultural and burnt lands had covered an area of over 20% (Figure-4).

Table-1: Descriptive Statistics of Study Area for Land cover type (2008-2018).

Study Area	Land-Cover Types	Mean	95% Confidence Interval		Stv. Deviation	St. Error
			Upper Bound	Lower Bound		
The Aberdares	Mountain Forest	35.2783	14.47	56.08	8.37	4.83517
	Bamboo Forest	41.3773	26.9228	55.8319	5.81875	3.35946
	Alpine Moorland	10.8473	6.0322	15.6624	1.93834	1.11910
	Agriculture crop	9.1493	-10.2292	28.5279	7.80092	4.50386
	Sparse Grassland	1.2483	-2.3525	4.8491	1.44952	.83688
	Grassland	1.1290	-2.7638	5.0218	1.56707	.90475
	Burned area	1.4037	-4.6337	7.4410	2.43036	1.40317

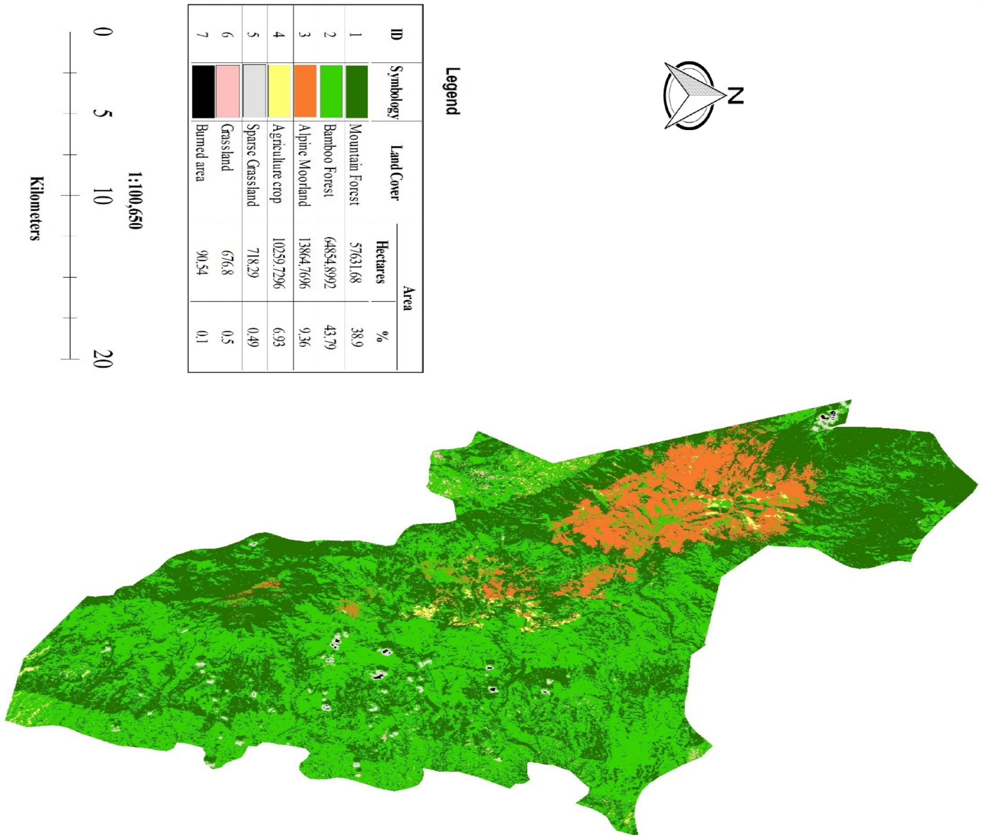

Figure-2: Landsat 7 2008: Land Cover Classification of Aberdares Forest Reserve, Kenya.

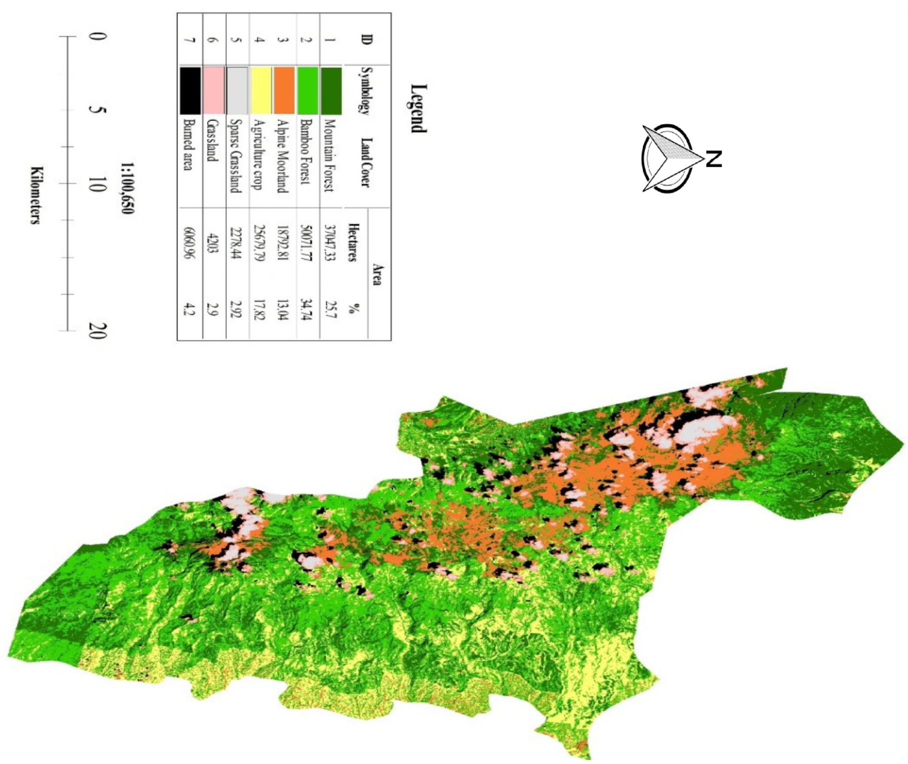

Figure-3: Landsat 8 2013: Land Cover Classification of Aberdares Forest Reserve, Kenya.

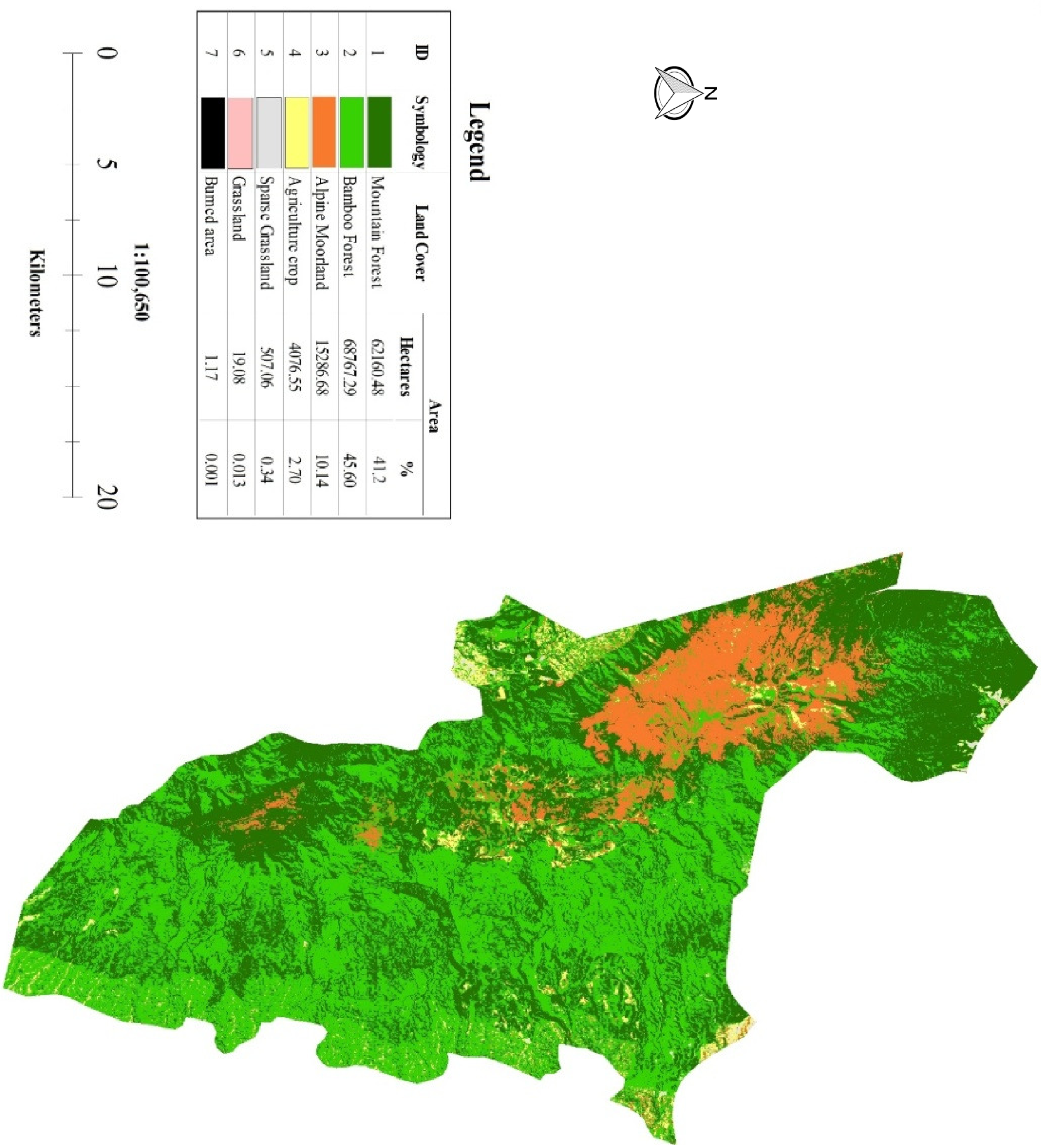

Figure-4: Landsat 8 2018: Land Cover Classification of Aberdares Forest Reserve, Kenya.

The findings from Aberdare forest change analysis reported a significant ($p<0.05$) decrease (-2.2%) in the forest cover (mountain and bamboo) between the years 2008-2013 (Table-4). The statistics also show a sharp decline in the agricultural crop farming in 2013-2018. However, an increase in bamboo and mountain forest was noted (Table-4).

From a general perspective, non-forest cover significantly increased between the period 2008-2013 as forest cover reduced (Table-5).

Negative growth was reported for non-forest cover in the second phase, 2013 to 2018 and an increase of forest cover (Table-5).

Table-4: Annual rate of vegetation change in the Aberdares - 2008 to 2018.

Land-Cover Types	Annual Rate of change (%)	
	2008 - 2013	2013 - 2018
Mountain Forest	-4.3	5.0
Bamboo Forest	-2.2	2.6
Alpine Moorland	2.4	-1.9
Agriculture crop	5.1	-7.1
Sparse Grassland	6.9	-7.4
Grassland	7.0	-8.3
Burnt area	8.3	-8.3

Table-5: Annual rate of Forest cover change in the Aberdares forest landscape.

Land cover type	2008		2013		2018		Annual rate of change (%)	
	Hectares	%	Hectares	%	Hectares	%	1st Period	2nd Period
Forest	122486.58	82.7	87119.1	60.44	130927.77	86.8	-2.24	3.63
Non- Forest	25610.129	17.3	57015	39.56	19890.54	13.2	10.72	-5.55

Discussion: Kenyan forests are biologically diverse containing many endemic species of plants and animals[2,27]. Knowing how and why forest areas fragment and change over time is important for managing forests sustainably because such changes may result in long-term losses[27-30].

From the results of the study, there is a general loss of forest land and an increase in non-forestland between 2008 and 2013 in the study area. This could be attributed to the fact that the areas are highly suitable for agricultural activity and horticultural production[27,31,32] given their geographical location, elevated topography, favourable environment, and monsoonal climate patterns[31]. This opens the areas from unsustainable exploitation by the general public causing deforestation[33]. An increase in agricultural activity confirms this (Table-4).

In the same note, typical developments have been reported in the area adjacent to the catchments, making them susceptible to deforestation and drastic changes in land use patterns[27,34-36]. There could also have been a population increase causing a possible corresponding demand for land. For instance, Muthoni reported a 3.2% population growth rate in Nyandarua county in a study conducted in 2014. This causes encroachment in search of space to settle, rear livestock, acquire forest resources such as timber, charcoal, firewood and grazing land[34-38]. This is supported by the presence of burnt land (bare land) (Figures-2, 3 and 4 which could be a sign of illegal logging of trees to supply timber, charcoal and firewood[39]. This eventually leads to a decline in per capita forest area constituting forest degradation.

However, the period 2013-2018 reported an increase in forest land and a decrease in non-forest areas (Table-5). This could be attributed to the fact that the government of Kenya has been taking serious initiatives for the rehabilitation and conservation of forest landscapes[40,41]. This is because the Aberdare forests are among the main catchment areas in Kenya[42], causing them to be gazetted[37,43].

Additionally, the government embarked in a community involvement approach through rural policing and direct engagement into conservation efforts through tree planting[37]. Besides, there have been several enactments in regards to habitat protection that may have also contributed to the forest revival recorded[45]. These include the Forest Policy of 2006, the Forests Act of 2005, the Kenya Forest Service, and the Kenya Forest Service Strategic Plan 2009/2014[44]. The acts of the parliament directly affect forest cover protection and could have attributed to the recovery. Other acts include the Conservation and Management Act and the Water Act, 2002 and the Environmental Management and Coordination Act (EMCA) of 1999 that protects the general environment and catchment areas[44].

There is also the effect of the several flagship programs under vision 2030 such as the Nyandarua County Integrated

Development Plan and the Aberdares Forest Reserve management plan (2010 to 2019) that started in 2010[5,45]. Additionally, there have been several conservation efforts undertaken by the government under the Kenya Forest Service management plan (2010 to 2019)[37,46]. For instance, the government set buffer perimeter zones around forest landscapes to designate forest areas[37]. These rehabilitation and conservation initiatives could have attributed to the recovery of the forests by 3.63% in the Aberdares[40] (Table-5).

Conclusion

The positive result in montane forest is an important representation of the reforestation efforts by the authorities in liaison with the local communities. A further study on other forest landscapes is, however, recommended as these results may not necessarily be a true representation of the status of the country's protected forest landscapes[47,48]. Besides, the geopolitics of one landscape may be completely different from others. This study could natheless be an important pacesetter.

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