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Recent Deforestation on the Eastern Flank of Mount Cameroon and Its Perceived Consequences

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Abstract

Deforestation on the eastern flank of Mount Cameroon has accelerated in recent decades, posing serious ecological and socio-economic challenges. This forested region, located outside the Mount Cameroon National Park, is ecologically rich yet increasingly threatened by human pressure. Rapid urbanization in Buea, combined with agricultural expansion, logging, and weak enforcement of forest policies, has accelerated land use and land cover (LULC) changes. Despite conservation efforts, forest degradation continues to threaten biodiversity, ecosystem services, and the livelihoods of surrounding communities. This study determined the extent of LULC changes between 2010 and 2025, identified the perceived drivers of deforestation, and assessed their perceived consequences. Satellite imagery from Landsat data for 2010, 2015, 2020, and 2025 was analyzed alongside semi-structured questionnaires administered to 200 residents of ten forest-adjacent villages. Key findings revealed a total loss of 12774.56 hectares of dense forest over the 15-year period, with significant increases in agricultural land (+11041.35 ha) and built-up areas (+1539.67 ha). The average annual rate of dense forest loss was approximately 851.64 ha/year. Main drivers of deforestation identified were smallholder farming, logging, urban expansion, bush fire, and population growth. Perceived consequences included water scarcity (36%), biodiversity loss (24%), human-wildlife conflict (12%) climate variability (10%), increased soil erosion and decline in NTFPS (7% each). The study concludes that deforestation in this region is both a socio-economic and environmental challenge, requiring integrated strategies that promote sustainable land use, community engagement, policy reform, and the establishment of a functional buffer zone around the protected area.

Keywords

Deforestation, Eastern Flank, Mount Cameroon, Land Use Change, Perceived

Drivers, Perceived Consequences

1. Introduction

Globally, forests act as carbon sinks, regulate water cycles, and support a wide array of species (Kumar et al., 2022). However, human activities such as agricultural expansion, logging, and infrastructure development are driving forest loss at an unprecedented rate, with severe consequences for both local and global ecosystems. The Food and Agriculture Organization (FAO) reported that over 420 million hectares of forest have been lost since 1990 (FAO, 2020). Deforestation is the conversion of forest to an alternative permanent non-forested land use for agriculture, grazing, or urban development (Van Kooten & Bulte, 2000). Deforestation is the alteration of the forest to non-forested land caused by the human due to demand for certain services, which might be promoted for conversion of land that is dominated by naturally growing trees into a land that suitable for the needs of the growing population (Kumari et al., 2019).

Infrastructural development, agricultural expansion and economic development or population constitutes the major factor of deforestation (Tchatchou et al., 2015). Deforestation reduces forest area, causes biodiversity loss, alters climate regulation, and reduces the provision of vital ecosystem services in tropical developing countries, which calls for concern (Usongo, 2024; Barraclough & Ghimire, 2000). Findings from Cameroon indicate an annual agricultural expansion of 0.02 ha in the Mount Cameroon Region (MCR) (Kah et al., 2008) due to increased population and their demand for food acting as driving cause of conversion of agricultural land from forest areas in mount Cameroon forest (Fonge et al., 2015). The burgeoning human population and global economic growth are strongly increasing the demand for land resources and changing the dynamics of land use and land cover (LULC) (Hatab et al., 2019).

The Congo Basin, spanning several Central African nations including Cameroon, constitutes the second-largest tropical rainforest in the world, with over 17 million hectares loss of tree cover between 2001 and 2020 (Global Forest Watch, 2021). Between 1990 and 2020, Cameroon lost about 4.4 million hectares of forest, roughly 18% of its total forest cover (FAO, 2020).

The main driver is agricultural expansion; both subsistence farmers and commercial agribusinesses clear land to grow cocoa, bananas, and oil palm (Fonge et al., 2015; Fonge et al., 2019; Usongo, 2024). Mount Cameroon, is both ecologically and geologically significant as the most active volcano in Africa (Ntoko & Schmidt, 2021). Its volcanic soils are highly fertile, which attracts farming and intensifies deforestation through land clearance and illegal resource extraction (Usongo, 2024). Buea, located on the eastern flank of Mount is a rapidly growing urban center, whose population growth of recent times has increased the demand for resources from the forest (Enomah, 2022).

Despite the establishment of Mount Cameroon National Park, deforestation persists due to weak law enforcement, limited monitoring, and continuous human pressure (Laurance et al., 2009). Lack of a buffer zone around the park, has left the forest edges directly exposed to encroachment. Research gaps exist in quantifying deforestation rates, identifying drivers, and assessing socio-economic consequences at the local level in Buea. Therefore, this study aims to quantify LULC changes in the Eastern flank of Mount Cameroon and to produce geospatial maps covering the period from 2010 to 2025 using remote sensing and GIS techniques. By analyzing land use trends over the study period of time, this research will provide valuable insights for managing future changes and encourage sustainable land-use practices.

2. Materials and Methods

2.1. Description of Study Site

The study was conducted in the Eastern flank of Mount Cameroon, covering Buea Municipality, located in the South West Region of Cameroon. Geographically, the flank spans from 04˚8.036'N to 04˚12.627'N and 009˚13.104'E to 009˚18.675'E. (Egbe et al., 2023). The area is mountainous with thick and evergreen forest vegetation at the lower slope of the mountain and there are transitional changes along altitudinal gradient (Kato et al., 2025). The area covers approximately 5695.5 km^2 and has an estimated population of 800,000 inhabitants by 2023 (Kah et al., 2008). The study area is characterized by fertile soil and receives annual rainfall ranging from 4000 to 6000 mm and has an equatorial climate with a rainy season (March to October) and a dry season (November to February). The region supports a diverse range of ecological zones from lowland rainforest to subalpine grassland. Given the high soil fertility, the legendary hospitality of the indigenes, the high educational hub and commercial development, there is a consequential increase in human population and pressure on land resources, making it necessary to study land use and land cover changes, consequences and to ensuring sustainable land resource use.

2.2. Evaluation of Land Use and Land Cover Changes

Change detection, a component of land monitoring, Remote Sensing (RS) and Geographic Information Systems (GIS) were employed to detect, classify, and quantify LULC changes from 2010 to 2025. The classification workflow method was adapted from Ewane & Lee (2021). Satellite images were acquired from the United States Geological Survey (USGS) through NASA's Earth Explorer platform. Landsat 7 ETM+ (was used for the years 2010 and 2015), Landsat 8 OLI (2020) and Landsat (2025) scenes were selected with less than 10% cloud cover during dry season months (**Table 1**). Cloud-free images ensure unobstructed visibility of the Earth's surface, allowing for precise identification and classification of land features (Mashala et al., 2023). Images were subjected to radiometric correction, pan sharpening, and layer stacking to improve classification accuracy

(Brabyn et al., 2014). A hybrid classification approach combining unsupervised (k-means) and supervised (maximum likelihood (MLC) and support vector machine (SVM)) methods were applied (Arun et al., 2012; Mensah et al., 2017). The MLC method enhances classification accuracy by incorporating the statistical distribution of training data for each category, producing a precise LULC map (Njoku & Tenenbaum, 2022). The LULC of the study area was classified into six classes, namely, Dense Forest, Secondary Forest, Agricultural Land, Grassland, Lava/Bare Rocks, and Buildups/Bare Soils (**Table 1**). Three satellite images were employed for this research. The satellite image was captured at intervals between 2010-2015, 2015-2020, and 2020-2025. Accuracy was assessed using error matrices and the Kappa index (Rosenfield & Fitzpatrick-Lins, 1986). Kappa coefficient (Kappa) was measured to determine the interdependence between the classes. Change detection was performed using the cross-tabulation module in ArcGIS and different LULC were used in the study (**Table 2**).

Table 1. Remote sensing inputs, path/row, acquisition date and Spatial resolution.

Study Year	Sensor	Path/Row (WRS-2)	Acquisition Date	Spatial Resolution
2010	Landsat 7 ETM+	187/057	12/11/2024	1, 2, 3 and 4
2015	Landsat 7 ETM+	187/057	1/11/2024	1, 2, 3, 4, 5, 6, 7 and 8
2020	Landsat 8 OLI	187/057	1/11/2024	1, 2, 3, 4, 5, 6, 7 and 8
2025	Landsat 9 OLI-2	187/057	9/1/2025	1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11

Table 2. Description of land use and land cover classes.

LULC Class	Description
Dense Forest	Trees closely growing together, creating a thick, overlapping canopy
Secondary Forest	Woodland that has regenerated naturally after a major disturbance
Agricultural Land	Land for crop cultivation
Grassland	Ecosystem with non-woody plants and grasses
Lava/Bare Rocks	Exposed bedrock or solidified volcanic material
Buildups/Bare Soils	Areas of human settlement and infrastructure/open space

The rate of change in the different LULCC classes were calculated using the equation;

$$R = P - Q \tag{1}$$

where R is rate of change in the different LULCC;

P is LULCC class of the last year and Q is baseline year.

The annual change (A) was calculated using the difference between baseline year (2010) and the recent year (2025), considering 15 years in between the years as shown in Equation (2);

$$A = \frac{P - Q}{15} \tag{2}$$

2.3. Socioeconomic Survey

A qualitative research design was adopted from Akinwumi et al. (2000). Semi-structured questionnaires and interviews were administered to residents in ten villages within Buea municipality (Muea, Mile 16, Bonakanda, Bokova, Ndongo, Molyko, Bokwaongo, Boteva, Bwitingi, and Bova) presenting 20 questionnaires per village. A purposive sampling technique was used to select 200 participants aged 30 years and above who had lived in Buea for at least 20 years. The questionnaire was partitioned into three sections: demographic information, drivers of deforestation and perceived consequences of deforestation. Occupation of respondents, drivers of change and perceived consequences had multiple responses. Informed consent was obtained from all participants prior to questionnaire administration.

2.4. Data Analysis

LULC change data were analyzed using ArcGIS cross-tabulation tools to compute change matrices. Community survey data were coded and entered into Microsoft Excel and analyzed using SPSS version 25. Descriptive statistics (frequencies, percentages, mean, and standard deviation) were computed. Chi-square tests were used to assess associations between categorical variables. Qualitative responses were analyzed through thematic coding. Results are presented using tables and figures.

3. Results

3.1. Land Use and Land Cover Changes (2010-2025)

The area of the classified polygon was calculated in ArcGIS from the pixel count of the classified raster multiplied by the pixel (cell) area from the total area of 5695.5 km^2 of the municipality. Satellite image analysis revealed substantial LULC changes on the Eastern flank of Mount Cameroon over the 15-year study period (**Figure 1**).

There was a substantial variation in the LULC in the study with Agriculture increasing (from 1373.09 ha to 12414.44 ha) in area while dense forest decreases from 16228.34 to 3453.78 ha (**Table 3**).

The most dramatic change occurred between 2010 and 2015, when dense forest declined by 6362.9 ha (39.21%) and agricultural land increased by 5194.50 ha (378.31%). Between 2020 and 2025, a further sharp decline in dense forest was recorded: a loss of 5642.20 ha (62.03%) accompanied by an agricultural land gain of 4892.60 ha (65.04%) over the study period. The annual change in LULCC was equally higher in agricultural land as more land was gained from either dense forest and or secondary forest. Equally Buildups increased from 1115.83 (ha) in 2010 to 2655.50 (ha) in 2025, with an annual change of +736.09 (ha) and +102.64 (ha) for agricultural land and buildups respectively (**Table 4**).

The accuracy assessment of the classification matrices demonstrated the reliability of the LULC data across all four time periods, with overall accuracy values and Kappa coefficients meeting the minimum threshold for acceptable classification (Rosenfield & Fitzpatrick-Lins, 1986). **Table 5** shows the accuracy assessment of the classification for each of the 4 different years classified, showing the overall accuracies and their corresponding kappa coefficients. The combine classification approach was useful and produced high classification accuracies.

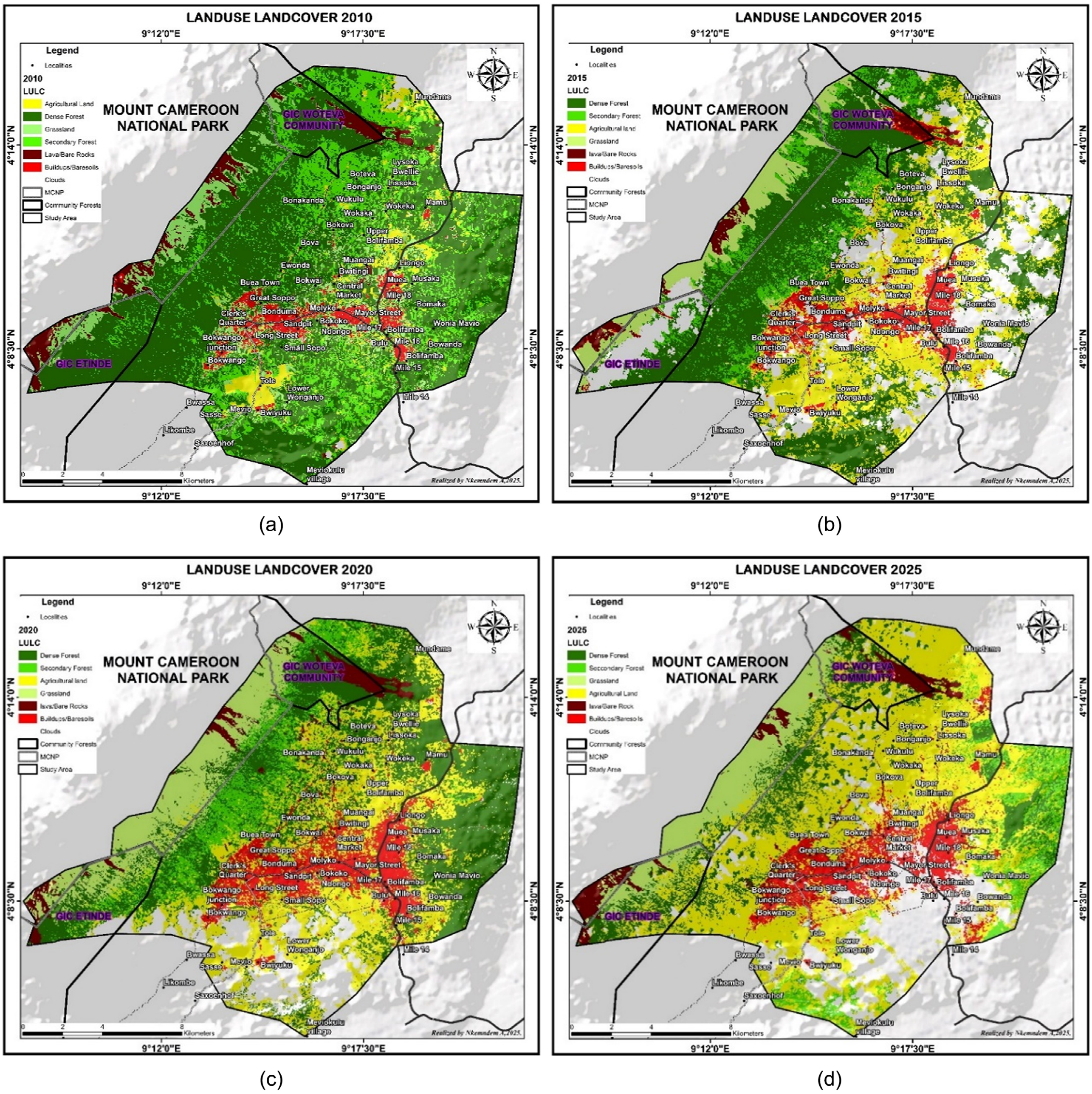

Figure 1. LULC the different years; (a) 2010, (b) 2015, (c) 2020, (d) 2025.

Table 3. LULCC between 2010-2025 in the eastern flank of mount Cameroon.

Land use and land cover	**Year**			
	2010	**2015**	**2020**	**2025**
	Land used in HA			
Agricultural land	1373.09	6567.56	7521.89	12414.44
Buildups/Baresoils	1115.83	1718.13	2428.87	2655.50
Dense Forest	16228.34	9865.49	9095.95	3453.78
Grassland	2833.90	1704.19	3049.82	2552.46
Lava/Bare Rocks	1104.23	621.80	1280.80	1161.75
Secondary Forest	5311.03	1948.95	2305.46	1707.52
TOTAL	**27,966.14**	**27,966.14**	**27,966.14**	**27,966.14**

Table 4. Rate of change in LULC categories between 2010-2025.

Land Use/Land Cover	**2010 (ha)**	**2025 (ha)**	**Change (ha)**	**% Change**	**Annual Change (ha)**
Dense Forest	16228.34	3453.78	−12774.56	−78.72	−851.64
Secondary Forest	5311.03	1707.52	−3603.51	−67.85	−240.23
Agricultural Land	1373.09	12414.44	+11041.35	804.12	+736.09
Grassland	2833.90	2552.46	−281.44	−9.93	−18.76
Buildups/Bare Soils	1115.83	2655.50	+1539.67	137.98	+102.64
Lava/Bare Rocks	1104.23	1161.75	+57.52	5.21	+3.83

Table 5. Accuracy assessment of the classification matrices in the study period.

Class	2010		2015		2020		2025	
	Prod. Acc (%)	User Acc (%)	Prod. Acc (%)	User Acc (%)	Prod. Acc (%)	User Acc (%)	Prod. Acc (%)	User Acc (%)
Agricultural land	94.72	98.18	96.79	88.86	99.26	95.95	71.69	69.86
Dense forest	100	99.64	81.62	90.08	56.79	90.2	73.52	70.38
Grassland	99	100	99.40	98.84	100	95.56	62.62	69.17
Secondary forest	97.6	93.44	94.64	99.32	99.79	99.89	98.81	98.32
Lava/Bare rock	100	99.62	97.36	98.42	99.68	100	98.02	98.32
Buildups/bare soil	99.6	98.67	96.72	97.92	99.91	99.97	98.01	99.09
Clouds	96.53	99.18	75.45	74.77	91.1	96.13	100	87.14
Overall Accuracy	92.27		96.28		98.70		91.05	
Kappa Coefficient	0.96		0.95		0.98		0.87	

3.2. Demographic Characteristics of Respondents

A total of 200 respondents participated in the community survey. The majority were between 46 and 50 years old (56.0%), with 33.5% aged over 50 years. More than half were male (54.5%), while females constituted 45.5% ($\chi^2 = 62.11$, df = 2, $p < 0.001$). Farming was the dominant occupation (85.0%), followed by teaching (18.5%) and business (5.5%) ($\chi^2 = 200.7$, df = 2, $p < 0.001$). The majority resided in Muea (33.5%) and Bonakanda (24.5%). Most respondents were married (89.0%) and had 2 - 4 children (67.0%). Regarding education, 47.0% had attained primary-level education, followed by secondary (34.0%), vocational (13.0%), and no formal education (6.0%).

Table 6. Selected variables to drivers of deforestation.

Category	Response	Frequency	Percentage (%)	χ^2	*p*
Human activities contributing to deforestation	Farm expansion	181	90.5	194.9	<0.001
	Fuelwood harvesting	162	81.0		
	Bush burning	153	76.5		
	Logging	67	33.5		
Agricultural expansion	Yes	178	89.0	150.1	<0.001
	No	22	11.0		
Type of farming	Mixed farming	167	83.5	147.9	<0.001
	Subsistence farming	63	31.5		
Wildlife conflict	Yes	175	87.5	120.3	<0.001
	No	25	12.5		
Animals interfering	Antelope	160	80.0	391.9	<0.001
	Monkey	58	29.0		
	Squirrel	37	18.5		

The perceived drivers of deforestation on the eastern flank of Mount Cameroon were dominated by agricultural expansion (39%), followed by urban expansion (31%) and infrastructure development (14%). Fuelwood and charcoal production and population growth were each reported by 5% of respondents. Logging (legal and illegal) was cited by 4% and fire by 1%. The distribution of drivers was statistically significant ($\chi^2 = 95.09$, df = 6, $p < 0.001$). The majority of respondents (89%) affirmed that agricultural expansion has contributed to deforestation in their area ($\chi^2 = 150.1$, df = 1, $p < 0.001$). The dominant farming type was mixed farming (83.5%), followed by subsistence farming (31.5%) and cash crop farming (7.5%). The most commonly cultivated crops were yam (64.5%), plantain (58.5%), and cocoyam (55.0%), with farms most frequently located in Bonakanda (43.5%) and

Bova (20.5%). Tree removal was common, with 82.5% of respondents reporting that trees were present when they first acquired their farmland. Most trees were cut down (53.5%) or burned (36.5%). The trees most affected included *Milicia excelsa* (38%), *Cecropia peltata* (33.5%), *Swietenia macrophylla* (23%), and *Persea americana* (17%). Fuelwood was the primary use of harvested trees (67%), followed by house construction (10%), timber (8%), and medicine (6.5%). Primary drivers of deforestation identified were farm expansion (90.5%), fuelwood harvesting (81%), and bush burning (76.5%) ($\chi^2 = 194.9$, df = 4, $p < 0.001$). Most respondents (68%) had farms in multiple locations, and 61% reported higher yields from recently cleared forested land compared to other areas. The main reasons for farming in distant locations were fertile soil (61.5%) and land availability (50.5%). About 67.5% of respondents were aware of protected areas such as the national park, and 87.5% reported conflict with wildlife from protected areas ($\chi^2 = 120.3$, df = 1, $p < 0.001$), with antelopes (80%), monkeys (29%), and squirrels (18.5%) being the most common crop-raiding animals (Table 6).

3.3. Perceived Consequences of Deforestation

The most frequently reported consequence of deforestation was water scarcity (36%), followed by biodiversity loss (24%), human-wildlife conflict (12%), climate variability (10%), and soil erosion and decline in non-timber forest products (NTFPs) (7% each). Disease outbreak was mentioned by 4% of respondents. The distribution of consequences was statistically significant ($\chi^2 = 56.10$, df = 6, $p < 0.001$).

A total of 78% of respondents reported that deforestation had negatively impacted water availability in their communities while 84.5% noted a decrease in fuelwood availability. The main water sources were boreholes (68%), rainwater (48.5%), and streams (43.5%). Additionally, 89% of respondents stated that deforestation had worsened road conditions through soil erosion and flooding ($\chi^2 = 124.16$, df = 1, $p < 0.001$), and 83% reported over 7 hours of daily rainfall in the past 24 years ($\chi^2 = 93.52$, df = 1, $p < 0.001$). Most respondents (62.5%) indicated no traditional practices supporting forest conservation in their community (Table 7).

Table 7. Perceived consequences of deforestation in study.

Category	Percentage (%)
Water Scarcity	36
Biodiversity loss	24
Human wildlife conflict	12
Climate variability	10
Soil erosion	7
Decline in NTFPs	7
Disease outbreak	4

4. Discussion

The LULC analysis confirms a substantial transformation of the forest landscape on the eastern flank of Mount Cameroon, with dense forest declining by 78.72% over just 15 years. These findings are consistent with Ewane & Lee (2021), who documented similar forest-to-farmland conversions in the Mount Bamboutos Caldera area of Southwest Cameroon. Comparable trends have been reported in the Congo Basin (Megevand et al., 2013), linking forest loss to agricultural expansion and infrastructure development. The rate of dense forest loss in this study (851.64 ha/year) is particularly alarming and suggests that, at current trends, dense forest could be nearly eliminated from this landscape within a generation. Similar result has been reported by Mensah et al. (2017). in Ghana. The modest gains observed in secondary forest in the 2015-2020 period do not compensate for dense forest loss, as secondary forests are ecologically less diverse and provide fewer ecosystem services (Fonge et al., 2015). The sharp acceleration in forest loss between 2020 and 2025 is calls for concern and may reflect both population growth and reduced effectiveness of conservation enforcement, consistent with findings by Usongo (2024), who noted that conservation policies are poorly enforced and perceived negatively by forest-adjacent communities.

Agricultural expansion was confirmed as the dominant driver of deforestation, consistent with findings across Cameroon and sub-Saharan Africa (Epule et al., 2012; Alemagi & Kozak, 2010; Ordway et al., 2017). The fertile volcanic soils of the Mount Cameroon region make the area particularly attractive for cultivation, especially for yam, plantain, cocoyam, and cash crops. The high incidence of mixed farming (83.5%) and the practice of clearing forested land to achieve higher yields highlight the link between food security, poverty, and forest degradation. The short fallow periods reported (60% of respondents leaving land fallow for less than one year) indicate unsustainable land management practices that reduce forest recovery. Urbanization as a driver aligns with studies from other rapidly growing Cameroonian cities (Enomah, 2022) and globally, where urban infrastructure development accounts for over 6% of total deforestation (Curtis et al., 2018). Fuelwood collection is closely linked to energy poverty, as over 83% of respondents relied on forest collection for fuel, consistent with estimates that over 90% of Sub-Saharan African populations depend on wood energy (UNEP, 2021). Logging, both legal and illegal, further compounds the problem; an estimated 25% - 30% of annual timber production in Cameroon is extracted illegally (Topa et al., 2010). Weak law enforcement, the absence of a buffer zone around Mount Cameroon National Park, and limited community involvement in conservation planning emerged as structural factors enabling continued forest loss (Che et al., 2021). The perceived consequences reported by communities align closely with documented ecological and socio-economic impacts in the literature. Water scarcity as the most cited consequence (36%) reflects the well-established role of forests in regulating catchment hydrology and maintaining perennial water sources (Buh et al., 2021; Kimengsi & Sani, 2015). Biodiversity loss (24%) is consistent with the region's status as a global biodiversity hotspot, where endemic and threatened species including *Piliocolobus preussi* and *Pternistis camerunensis* are directly threatened by habitat destruction (Oates et al., 2004; BirdLife International, 2020). Human-wildlife conflict (12%) reflects the displacement of forest wildlife into agricultural areas as habitats shrink (Attia et al., 2018). With 87.5% of surveyed farmers reporting wildlife incursions, this constitutes a significant socio-economic burden for communities, particularly given that the dominant response was passive ("do nothing"; 37%), suggesting inadequate coping mechanisms. Climate variability, cited by 10% of respondents, echoes regional studies on the impact of deforestation on local rainfall and temperature patterns (Molua & Lambi, 2006). The reported decline in fuelwood availability (84.5%) and road deterioration from erosion (89%) further highlight the socio-economic dimensions of forest loss.

5. Conclusion

Deforestation on the eastern flank of Mount Cameroon is advancing at an alarming rate, driven primarily by agricultural expansion, urbanization, logging, and fuelwood collection. Land use and land cover analysis between 2010 and 2025 confirms a loss of 12,774.56 ha of dense forest, accompanied by an increase in built-up areas and agricultural land. Community perceptions underscore the complex interplay between livelihood needs, policy failures, and inadequate enforcement contributing to forest degradation. The consequences are wide-ranging, including biodiversity loss, water scarcity, soil erosion, climate instability, and rising human-wildlife conflict. Without urgent and coordinated action, the ecological and socio-economic foundations of the region will continue to deteriorate. Based on the findings of this study, the following recommendations are proposed: the government should establish and enforce a functional buffer zone around Mount Cameroon National Park to protect forest edges from agricultural and settlement encroachment. Sustainable agricultural practices such as agroforestry and conservation farming should be promoted to reduce pressure on forest resources while maintaining food production. Local communities must be actively involved in conservation planning to foster ownership and compliance.

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Author Contributions

Arrey D. B. designed the work, Neba G. A & Asoh B. A. did the field work. All three read, drafted and proofread the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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