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Land Use and Land Cover Dynamics in the Eseka Alluvial Gold Mining District, Centre Region, Cameroon

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Abstract

Local populations in Cameroon thrive on forest resources and the flow of ecosystem services they provide are pivotal in sustaining national economy, improving people's lives, safeguarding biodiversity, and mitigating the impacts of environmental changes. The exploitation of these resources invariably leads to deforestation and forest degradation. This study was designed to evaluate land use land cover change (LULCC) in the Eseka alluvial gold mining district with the aid of Landsat images. In the investigation of forest cover change, four Landsat satellite images for (1990, 2002, 2015 and 2022) were used. Ground-truthing also helped to identify the activities carried out by the local population and to determine agents, drivers and pressures of land use and land cover change. Four main land cover classes namely: forest, agricultural land, settlement/mining camps and water bodies were selected. Between 1990 and 2022, the proportion of forest decreased from 98% to 34% while those of agricultural land and settlement/mining camps increased from 2% to 60% and 0.54% to 6% respectively. Analysis showed ongoing deforestation with forest cover loss of ~98,263 ha in 32 years giving a cover change percentage of 63.94%. Kappa coefficient for the study period ranged from 0.92 to 0.99. Forest cover loss could be attributed to farming activities, wood extraction and alluvial gold mining activities. Economic motives notably the need to increase household income from a frequent demand for farm and wood products in neighbouring towns and the quest for gold were the main drivers of these activities. Hence, this study assesses the impact of human activities from the mining sector on the forest ecosystem in a bid to inform mitigation policies.

Keywords

Land Use and Land Cover Changes, Biodiversity, Alluvial Gold Mining, Drivers, Landsat Images, Ground-Truthing, Mitigation

1. Introduction

Natural resources are vital for human survival and land uniquely forms the basis for all terrestrial ecosystem services [1]. Tropical rainforests based on their characteristic plant cover, are important components of terrestrial ecosystems due to their rich biodiversity and they potentially provide a variety of ecosystem services that serve as the bedrock for human wellbeing [2]. These services range from the supply of wood as well as Non Timber Forest Products (NTFPs), climate regulation, and the release of atmospheric oxygen, the conservation of soil and water resources to the provision of habitats for other living organisms [3]. Forest resources and their provision of numerous ecosystem services play an immeasurable role in supporting both national and regional economies [4], improving livelihoods, protecting biodiversity, and mitigating the impacts of a changing climate [5]. However, the degradation of this priceless resource in the form of land use/land cover (LULC) changes over time has become a severe environmental problem [6]. Deforestation reverses this natural order, causing losses in biodiversity, changing climate conditions, intensifying soil erosion and eminent desertification [7] [8]. Globally, LULC changes have been recorded as the most important cause of the distortion of ecosystem services and Cameroon is not an exception [9] [10]. The extractive industry plays a vital role in this deforestation process since mining encompasses clearing of large expands of land cover. In the tropics, the introduction of mining is also known to bring about an influx of population and major land cover conversions from forest to agricultural land through shifting cultivation [11]. The imbalances caused by these distortions have the potential of mounting enormous pressure on land resources, thus increasing their susceptibility to further change over time.

Cameroon's forest cover represents the second largest tropical rainforest in the Congo Basin after that of the Democratic Republic of Congo. The forest spans a land area of ~22.5 million hectares, corresponding to about 48% of its national territory [12] [13]. The natural forest has reportedly dwindled over time especially resulting from rapid population growth [14], with a population size that has more than doubled in the last three decades and is projected to increase even further by the year 2030 [15]. Forest cover loss of ~4400 ha was recorded between 1990 and 2010 alone [16]. The average annual rates of gross deforestation in Cameroon were estimated at 0.10% for the period 1990 to 2000 and 0.17%

between 2000 and 2005 [17], indicating a drastic increase in deforestation rate during this time span. By the year 2010, the average rate of gross deforestation in the country was in the order of 0.20% [18], ranking Cameroon second in the Congo basin, after the Democratic Republic of Congo (0.22%), with the highest rate of deforestation at the time [18] [19].

The contributions made by extractive industries in general and alluvial gold mining even at artisanal levels in particular to these changes within the country cannot be undermined. Gold is alluvial with evidence of its primary accumulation in different quartz veins [20] and its extraction thereof begins with vegetation clearing which brings about other environmental changes on the landscape. Therefore, to better plan and sustainably manage these natural forest resources, an in-depth knowledge on the land use and land cover is required, as well as the establishment of a change detection mechanism. This is an important tool in the assessment of the environment and its evolution over time.

Eseka is one of the ancient towns of Cameroon and hosts an important terminal of the Cameroon railway line (CAMRAIL) that has been at the centre of the transportation of both goods and humans in and out of the area. The 91.78 km stretch of road from Boumyebel through Eseka down to Lulodolf in the South Region of Cameroon that was paved in the 1980s and got rehabilitated recently in 2010, increased Eseka's accessibility to neighbouring towns including the capital city, Yaoundé. This has further eased the production and transportation of food and cash crops to bigger neighbouring markets.

Data generated by the National Institute of Statistics Cameroon, reveal that Eseka has experienced population fluctuations over the years due to its socio/political history before independence and more recently from 23,242 in 2005 to 22,221 in 2014. The main economic activities include agriculture, food crop production, small holder schemes for cocoa, oil palm and plantation agriculture (SOCAPALM), extraction of other NTFPs and hunting of bush [21], in a bit to generate income and create employment opportunities for the local population. The area has also seen the exploitation of mineral resources like iron ore and in recent times, gold at artisanal levels [22].

LULC changes play a significant role in spatio-temporal environmental stability especially because it is linked to local, regional, and global climate conditions, biodiversity stability, clean water, agriculture, and food security [23] [24]. Critical thinking and research in the domain of land change science is therefore inevitable in understanding global environmental change and sustainability. It enables public agencies and private organizations understand and make comprehensive plans for future intervention and for the designation of effective land management policies and decision making [25] [26]. It is also crucial for understanding the processes involved in environmental change and the problem that must be addressed for a sustainable improvement of living conditions and standards [27]. Interventions on the dynamics of LULC changes however need to be timely for an in depth understanding of the relationships and interactions between human and natural phenomena. This will go a long way to enhance management of natural resource bases which serve as a main source of livelihood for people living in rural areas [28]. This calls for global attention for continuous evaluation of the LULC changes, and remote sensing presents itself as a fundamental technological tool to assist in the spatial and temporal planning of land use types and vegetation cover evolution [29] [30]. This study therefore investigated LULC in an area recently inundated by artisanal gold mining activities. It quantified LULC in the Eseka alluvial gold mining district and attempted to highlight the constant challenge of balancing earth's resource extraction and environmental protection.

2. Materials and Methods

2.1. Description of the Study Area

Eseka is the administrative headquarter of the Nyong Sub Division in the "Nyong et Kelle" Division of the Centre Region of Cameroon. It is located between latitudes 2˚24' - 4˚39'North and Longitudes 9˚59' - 11˚31'East [31]. It is covered by low land rainforest and generally characterised by a rugged to undulating topography with steep hills and topographic highs of approximately 600 m above sea level (**Figure 1**). It comprises dissected plains, isolated and complex hills and mountains that are prone to intense erosion [32].

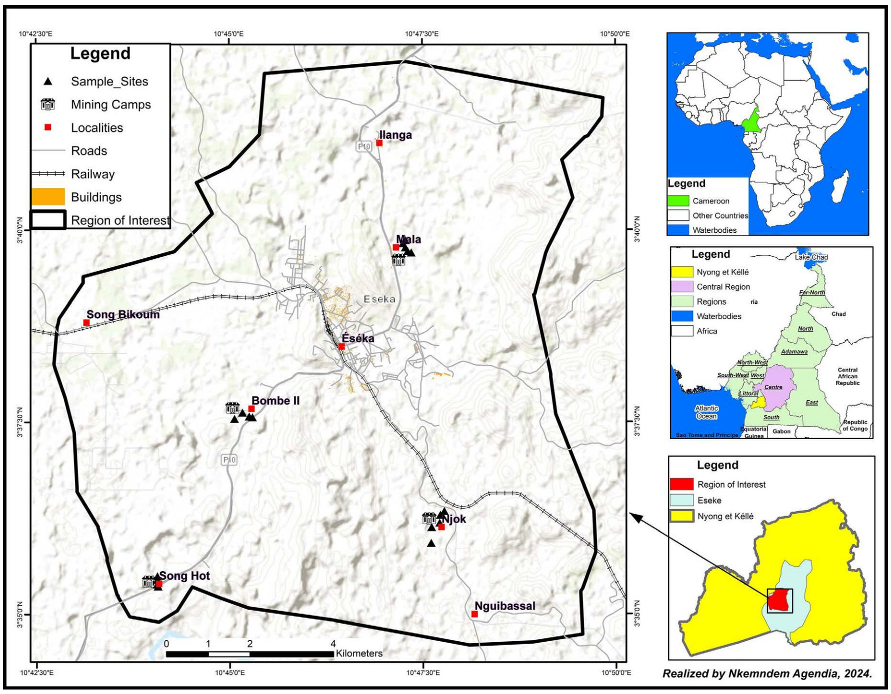


Figure 1. Location of the study area (Eseka).

The soil types in the area are mainly lateritic soils, which are typically unsaturated and yellowish brown, sandy, clay at the surface with reddish clayey material at depth [33]. These soils are acidic and characterised by low nutrient content with a relatively low cation exchange capacity. They have very low nitrogen contents due to the rapid degradation of the organic material, and are generally deeply weathered and deficient in phosphorus [34]. The soils become hydromorphic, particularly in the wetland areas. The drainage of the study area is dendritic and dominated by the River Nyong and its tributaries which carries its waters into the Atlantic Ocean at Kribi [35]. Areas of watersheds affected by these rivers are not very wide but drain rapidly because of the associated steep slopes and heavy rainfall.

Eseka has a tropical monsoon climate that is hot and humid all year round. The area experiences a bi-modal pattern of rainfall with four seasons each year: two rainy, and two dry seasons. The long dry season spans from December to March, the short rainy season from March to June, the short dry season in July and August, and the long rainy season from September to December [36]. Rainfall averages 1500 - 2000 mm per year and precipitation sometimes occurs even during the dry seasons. The highest amounts of rainfall are measured in the months of September and October [37]. The average annual temperature is 25.6˚C and annual average relative humidity ranges between 83% and 90% [38]. The study area represents part of the dense and humid rainforest of Cameroon, where available data shows that its flora is very diverse and represents over 60% of the country's biodiversity [39].

The vegetation cover is mainly made up of large primary forest and secondary shrubs with grasses. Some of the exploitable species in these forests include *Triplochyton scleroxylon* K.Schum. (Ayous), *Mansonia altissima* (A. Chev.) A. Chev. (Bete), *Entandrophragma cylindricum* (Sprague) Sprague (Sapelli), *Terminalia superba* Engl. and Diels (Frake), *Milicia excelsa* (welw) (Iroko), *Guibourtia tessmannii* (Harms) (Bubinga), and *Nauclea gilletii* (Bilinga). The forest also plays host to a number of Non Timber Forest Products (NTFPs) like *Garcinia kola* Heckel (Bitter cola), *Gnetum africanum* (Welv.) (okok or eru), *Irvingia gabonensis* (Aubry-Lecomte ex. O'Rorke) Baill. (Bush mango) and *Elaeis guineensis* Jacq. (Oil palm) [40]. The secondary forest mostly occurs near the villages and comprises mosaic cultures and secondary forests of different ages and plays host to a variety of fauna ranging from micro fauna to giant reptiles like snakes and mammals like bats, monkeys, gorillas and chimpanzees. The existing fallows in the locality are mainly colonized by grasses like *Chromolaena odorata* (L) R. M King & H. Robinson and trees like *Ceiba pentandra* (L.) Gaertn. (Boma), *Musanga cercropioides* R. br. (parassolier), *Cecropia cercropioides* (L.), *Cecropia peltata* (L.) and *Eupatorium* sp.

2.2. Data Collection

This process involved image acquisition, processing and interpretation. The principal data source for land use land cover classification and change analysis over the study area were remotely sensed data through a series of Landsat ETM+ imagery. This was based on the Landsat ETM+ satellite images for 1990, 2002, 2015 and 2022 respectively. Images were obtained from the United States Geological Survey-Global Visualization Viewer's (USGS) Earth Data Acquisition

Website via http://glovis.usgs.gov where an account was first created and images downloaded. In order to reduce cloud cover, images from the dry season were selected for this study. Pre-processing of the images included atmospheric and geometric corrections, suitable band selection, layer stacking and image enhancements which were applied before performing the classification of the remote sensing data [41]. To combine time series image data sets for change detection at pixel level for the data sets were registered to their corresponding Landsat image based on automated image-to-image registration approaches using a set of ground control points (GCPs). Unsupervised image classification was carried out for the Landsat images where the algorithm categorized all the pixels in the images into land-cover classes or themes based on their reflectance values. Thus the algorithm assigned the image's pixel to a defined number of classes based on their value in different channels (*i.e.* no training areas were used). Spatial enhancement technique (that is, focal analysis) was applied on the Landsat ETM+ images in order to improve the image quality. The images were geo-referenced (Universal Transverse Mercator-UTM, WGS84) from the data set provider. Unsupervised classification was conducted to determine spectral differences in land cover classes without creation of any particular training parcels for field verification and eventual use for a supervised image classification.

The supervised image classification via maximum likelihood algorithm was used to classify all the Landsat EMT+ scenes. In classifying the images into various themes, the supervised approach to classification was adopted using the ENVI 4.1 software. The pixel categorization process was supervised by specifying to the computer algorithm numerical descriptors of the various land cover types present in the scene. This was to ascertain the type and spatial extent of various land-use/land-cover types. To do this, representative sample sites of known land-cover types, called training areas or training sites were used to compile a numerical interpretation key. The key was then used to describe the spectral attributes for each feature type of interest. Each pixel in the data was then compared numerically to each category in the interpretation key and labelled with the name of the category it resembled closely. All the LULC type classes (vegetation, hydrology, settlement etc.) were carefully studied for the different images to detect any differences between them. These were compared over the time span of the study to elucidate the rate of environmental change that might have occurred. The reference data for these years were collected through visual interpretation of the raw data of the Landsat ETM+ images of the respective years.

Accuracy assessment is a critical component for maps generated from any remote sensing data and therefore error matrixes to assess the accuracies and errors of the classification is imperative. Computing the error matrix is in the most common way to present the accuracy of the classification results. Overall accuracy, user's and producer's accuracies, and the Kappa index (the ratio of the number of well-ranked pixels to the total of the pixels surveyed) were calculated for the data and statistics derived from the error matrices. The Kappa statistics incorporated the off diagonal elements of the error matrices and represented agreement obtained after removing the proportion of agreement that could be expected to occur by chance.

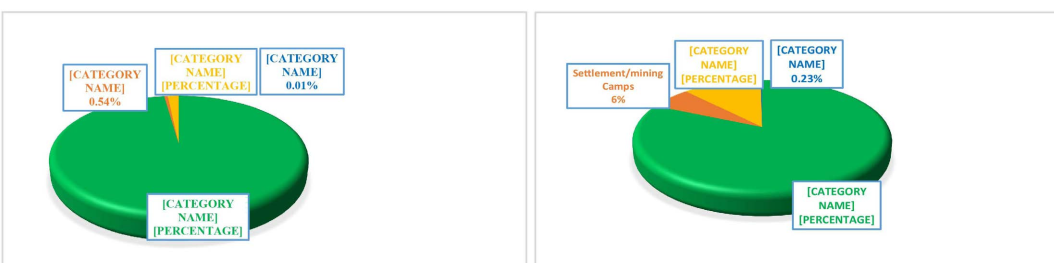
2.3. Data Analyses

The Landsat image of each study year was independently classified with supervised classification technique using ground truth data on existing LULC. Maximum likelihood classifier (MLC) algorithm was applied to classify the LULC types in ERDAS Imagine 2014 software. The total area covered by each land use was then calculated using ENVI 4.1 and values obtained used to produce tables representing the different land use classes in Microsoft excel version 16. Post classification change detection method was used to compare independently produced classified images. This was achieved via an extraction of statistics for time series analysis and trends of change of the different identified land uses and land cover classes. Finally, vectors derived from digital processing in ENVI 4.1 were imported into Arc Map 10.2 software for the extraction of the layers used for digitization, generation of databases, and production of the maps.

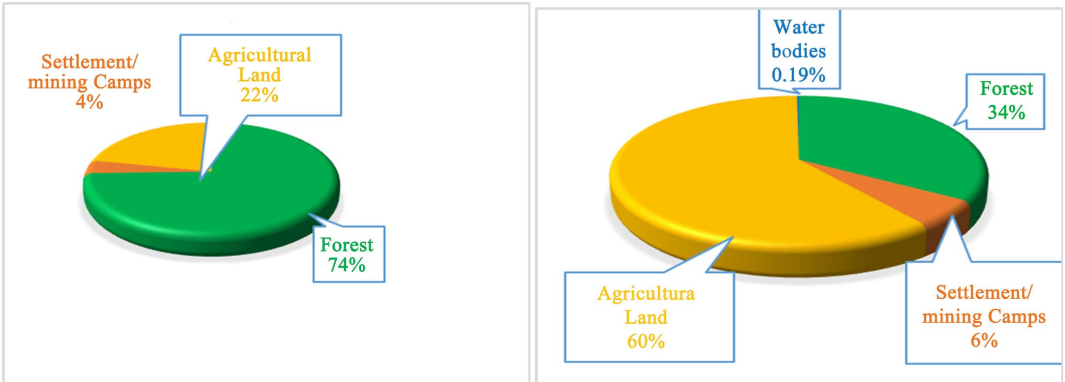
3. Results

Image classification of Landsat scenes of 1990, 2002, 2015 and 2022 are presented in four main land cover classes namely; forest, settlement/mining camps, agricultural land and water bodies. The classified Landsat EMT+ of the 1990 scene (**Figure 2(a)**) revealed that, of the total surface area (153,678 ha), 97.78% was covered by forest, 2.0% by agricultural land, 0.54% settlement and water bodies 0.01%. The 2002 image showed that forest cover was 82%, agricultural land 12%, settlement 6% and water bodies 0.23% (**Figure 2(b)**). Landsat image for 2015 showed that the forest cover stood at 74%, agricultural land 22% and settlement 4%. The category for water bodies was not detected by the satellite for this period. (**Figure 2(c)**) and finally, the 2022 image revealed that the forest cover was 34%, agricultural land 60%, settlement 34% and water bodies 0.19% (**Figure 2(d)**).

The colour changes on the classified Landsat EMT+ maps represent the different land cover categories in the study (**Figures 3(a)-(d)**). The region of interest (ROI) had a total surface area of 153,678 ha and its distribution into the different land cover class categories for the four study periods is represented below (**Table 1**).

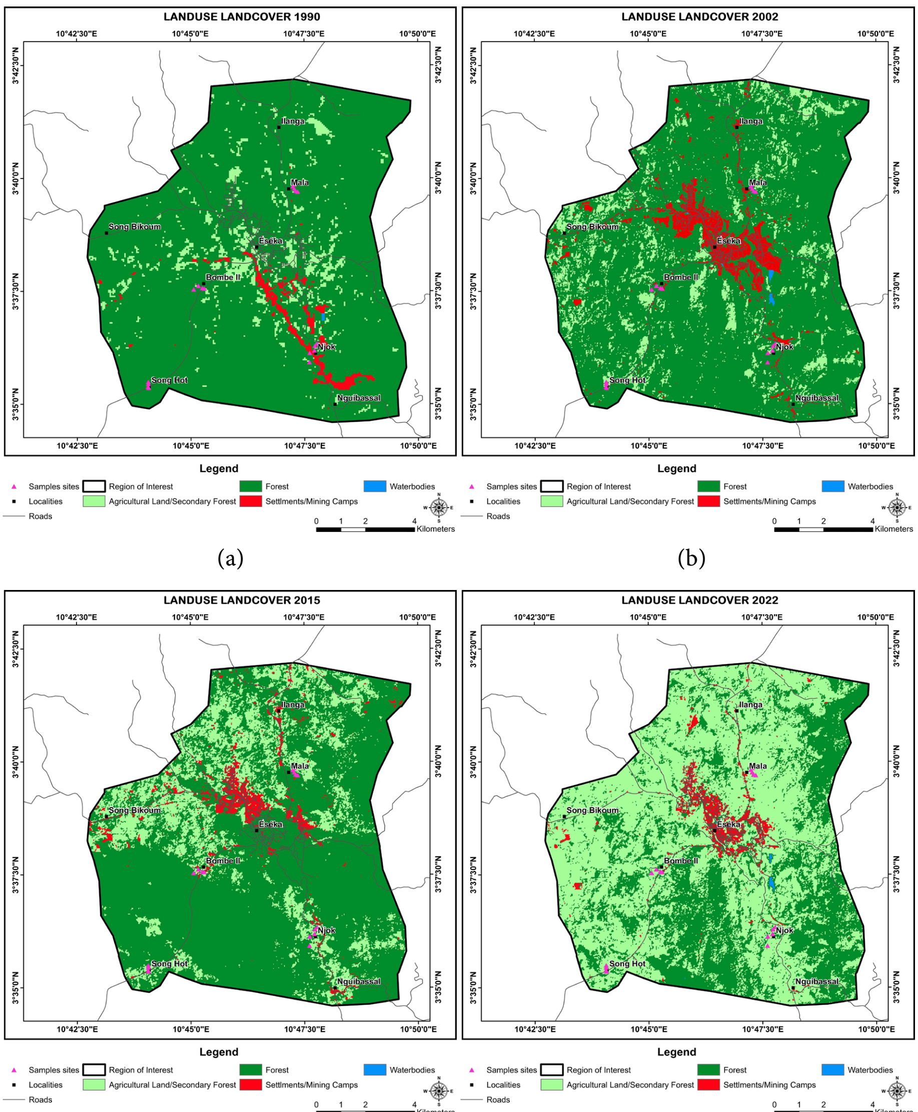


(a) (b)



(c) (d)

Figure 2. (a) Land cover status for 1990; (b) Land cover status for 2002; (c) Land cover status for 2015; (d) Land cover status for 2022.



(a) (b)

(c) (d)

Figure 3. Land use and land cover change categories from 1990 to 2022 as revealed by satellite imagery.

Table 1. Land Cover categories (surface area and percentages) of the Eseka Alluvial Gold Mining Area from 1990 to 2022.

Class type	1990		2002		2015		2022		1990-2022	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	AC (ha/yr)	%CC
Forest	150263.0	97.78	125,635	81.75	114,624	74.59	52,000	33.84	−3070	−63.94
Settlement/ mining camps	823.0	0.54	9728	6.33	5757	3.75	8836	5.75	2811.5	5.21
Agricultural Land	2582.0	1.68	17,965	11.69	33,297	21.67	92,550	60.22	250.406	58.54
Water bodies	10.0	0.01	350	0.23	/	/	292	0.19	8.813	0.18
Total	153,678	100	153,678	100	153,678	100	153,678	100	0.719	−0.01

The computed error matrices for the classified images (Table 2) portrayed an overall classified confusion of less than 10% with overall accuracy varying from 94.26% to 99.54% and degree of representation of ground truths (Kappa index) ranging between 0.90% and 0.99% for the different Landsat images.

Table 2. Accuracy, classified confusion matrix and Kappa coefficient for 1990, 2002, 2015 and 2022 Landsat images.

	1990		2002		2015		2022	
Land use Classes	Prod. Acc. (%)	User. Acc. (%)	Prod. Acc. (%)	User. Acc. (%)	Prod. Acc. (%)	User. Acc. (%)	Prod. Acc. (%)	User. Acc. (%)
Forest Area	99.36	93.03	100	98.44	99.62	99.88	99.44	90.34
Agricultural land	95.26	98.53	100	100	96.82	100	86.69	98.97
Settlement/mining camps	97.58	96.80	100	100	100	89.74	95.59	99.54
Water bodies	40.00	95.83	90.63	100	/	/	85.88	100
Overall Accuracy	**94.97**		**99.28**		**99.54**		**94.26**	
Kappa Coefficient	**0.92**		**0.99**		**0.96**		**0.91**	

4. Discussion

Major LULCC have occurred in all biomes, with significant replacement of forest and natural vegetation by pastures and agriculture the world over. Research findings in the Amazon basin indicate that LULCC have imposed important local and remote influences on the temperature, precipitation and cloudiness that have affected plants and ecosystems of South America as a whole [42]. These have induced changes in the composition and structure of the natural vegetation, leading to significant local warming and also circulation changes. The response of the natural vegetation to the LULCC-induced changes in climatic conditions in this rainforest biome is particularly strong during the dry season, even though hydrological cycle over major parts of the areas have intensified during the wet season [43]. Trends similar to these have been reported in the Congo River Basin [44]. Documented that the Kasai catchment of the Congo River Basin is experiencing poor land use planning that is causing sediment deposition thus impacting the stream flow [45]. Equally reported that the rate of deforestation among countries in the Congo Basin increased drastically in recent decades with population expansion and agricultural activities serving as the main drivers. The trends in our study corroborate these findings.

The results demonstrated four major LULC types and revealed that the Eseka alluvial gold mining district has undergone remarkable changes in its LULC over time. Overall, vegetation experienced a regression in land cover, which was particularly evident in the consistent reduction in the forest cover area from 150,263 ha in 1990 to 125,635 ha in 2002 down to 114,624 ha in 2015 and finally to 52,000 ha in 2022, amounting to a net loss of 98,263 ha over the 32 years span of the study. Summarily, there were more net losses in the forest category compared to other land use types, recording a percentage cover change of −63.94%. The study period equally saw net gains in the categories of water volume (0.18%), settlement/mining camps (5.21%) and agricultural land uses (58.54%) (**Table 1**). Analysis of the rates of deforestation for the study period revealed that between 1990-2002, the rate stood at 1.34% per year. From 2002- 2015 the rate of deforestation dropped to 0.55% per year and the rose to 5.82% between the years 2015-2022. The global rate of deforestation in the area over the study period stood at 1.99% per year.

The steady decrease in forest cover area that amounted to −98,263 ha during this period could be attributed to drivers of ecosystem change which could either be direct or indirect. While direct drivers exert tangible impact on the land surface, indirect drivers represent the underlying causes of the direct drivers brought about by direct anthropogenic drivers. The driving forces of LULCC are often a mix between anthropogenic (social, political, economic, demographic, technological, and cultural) and biophysical factors with direct or indirect impacts which may necessitate mitigation on curative actions in response. The main driver of forest cover change in the study area was established to be socio-economic. Land cover sequences like conversion from forest to agricultural land, and to a little extent, settlement/mining camps were principally responsible for the changes observed. The increasing rates of deforestation in the area could be attributed to increasing agricultural practices driven by population booms that equally brought about an increase in settlement area (**Figure 2**) and hence a rise in household income. The rehabilitation of the road network across the study area also granted easy access to agricultural investors who came in to farm from out of town and transportation of their produce was much guaranteed. The establishment of the SOCAPALM plantations in Eseka during the study period saw the rehabilitation of old farms and the creation of new ones at the cost of primary forest area. Other researchers in the country, Africa and around the world have documented similar findings [18]. Outlined similar trends in the Ajei community forest area in Ngie, North West Cameroon as a result of anthropogenic activities into the forest area [46]. Equally reported declining forest cover in Tubah Sub division, Cameroon between 1986 and 2017 for similar reasons. Other recent studies around Cameroon [47] [48] also showed that even classified forests are facing many anthropogenic pressures that lead to deforestation and degradation.

The commencement of artisanal and small scale gold mining activities that boomed in the centre and southern parts of Cameroon in the early 2000s was also a contributing factor to the changes observed in the landscape as farmers were forced to leave their old farms and sought new ones further into the forest. The influx of gold merchants from within the country and Africa as a whole during peak seasons got the sector buzzling, increased cost of living and further increased the rate of deforestation for the exploitation of this valuable resource. Findings by [49] who reported that the proportion of mining-related deforestation across the Peruvian Amazon increased outside the mining corridor due to the expansion of a few major mining sites in protected area buffer zones and certain indigenous communities. This could have been accounted for by the millions of poor people involved. Moreover, reforms aimed at formalizing ASM pay more attention on measures to improve equity and protect workers but say little about how such measures will protect forests or wetlands.

The lower rate of deforestation (0.55%) for the second study period (2002-2015) was probably due to a decline in human activities within the forest zone. SOCAPALM for example after its establishment faced stiff resistance from the local population of Eseka in attempting to replant pieces of land on which palms were already very old. The locals argued that, only the palms were privatized by the Government to the company and not the land. The company also suffered from high level stealing of fresh fruits bunches by the locals who often encroached into the plantation. This mishap coupled with the old age of the palms drastically increased the cost of production for the company which could not break even and consequently led to a series of layoffs of some company workers at Eseka. Similar trends have been reported by [50], in the rainforest of the Littoral Region of Cameroon. Rural exodus to neighbouring roadside communities like Boumnyebel and to capital city Yaoundé, in the quest for better living standards could also have been a contributing factor. The rates of deforestation (1.34%) observed in the study area between 1990-2002 was lower than that of 1.83% reported by [18] in Ajie community forest, North West Cameroon and even far higher than that of 0.65% reported by [51] for 1990-2000 period in Eastern Region of Cameroon and also greater than that of 0.13% found by [52] for the Congo basin for the same period which doubled to 0.26% between 2000-2010. This rate drastically increased to over 5% during the last phase of the study period. This could be attributed to the commencement of ASGM in the later part of 2015, the intensification of illegal logging activities and agroforestry that is ongoing in the area. An indication that ASGM activities together with other anthropogenic activities like, logging and farming had a great toll on the vegetation cover of the area. Similar results have equally been reported around the country.

Infrastructural development and poor governance also have a significant role to play in the land cover dynamics of the study area. The creation of road networks within the forested area to facilitate movement of goods and persons in and out of the forest patches can further intensify the state of this already fragmented forest. In as much as there are land use policies in the country, the management still has challenges especially in its implementation phase. Difficulties in initiating and scaling up community participation especially on rational harvesting and exploitation of wood products, and the intensive use of the land still pose problems. Similar findings of such direct and underlying drivers of deforestation have been reported by [53] [54] [55] in other parts of Africa and beyond.

The overall confusion in the classification of the downloaded maps was less than 10% and Kappa index values ranged between 0.91 and 0.99 for the entire study period. This is an indication that the classifications performed are reliable according to the scale of [56].

5. Conclusion

The conversion of land to other uses is increasingly threatening the forest cover and therefore the biodiversity of the forest area of Eseka in the Nyong and Kelle Division in the Center Region of Cameroon. From the study, statistics show that the natural forest cover reduced from 64.30% period to 48.67%, indicating a high rate of deforestation during the study period. Even though the rate of deforestation (1.99%) recorded in this study is lower than those reported in other forests across the country, it is equally a very significant loss (15.63% loss in dense forest cover) in 32 years. The above loss (impact) in forest cover is a result of pressure on the ecosystem brought about by actions led by farmers, wood extractors, logging and ASGM activities which convert the forest cover to these other land uses. Of all pressures, agriculture and ASGM are at the centre of forest cover losses in the area. Economic gains notably the need to increase household incomes facilitated by frequent demand for agricultural, wood products and gold at peak seasons in markets represent the main drivers of this forest change. However, the complex and diverse interactions among these social-ecological systems make it difficult to identify and quantify the main drivers of LULCC. A holistic approach across disciplines with a focus on direct and indirect influences causing land cover changes is needed for a comprehensive driver analysis which is still rarely conducted in land system science. Furthermore, an assessment of LULCC should include, as much as possible, the impact of the change on natural resources availability and/or disaster risks. Knowledge of relevant driving forces and their impact on gains and losses in ecosystem services contributes to provide consultations for sustainable development by delivering improved decision criteria and policy statements. These findings are expected to contribute to the discussion on the reduction in CO_2 emissions from deforestation and forest degradation (REDD+) and serve as reference for this period.

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Author Contributions

Project is part of the Ph.D. thesis of SVLN supervised by ABF and CES. SVLN drafted the manuscript while AGN, AKI and ET took part in the satellite image data processing and field works. All authors read, reviewed and approved the manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest and all data used are available from the first author.

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