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Land Use and Land Cover Change Analysis in Ajei Upland Watershed Community Forest, North West Region, Cameroon

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Abstract

This study was carried out in Ajei upland watershed community forest in the North West Region of Cameroon with the aim to analyze spatial and temporal dynamics of land cover and land use from 1988 to 2018 and to identify and characterize the agents, drivers and pressures of this change. The databases used were made up of 3 Lands at satellite images (5 TM of 1988, 7ETM+ of 2003 and 8OLI of 2018). Field survey, interview and focus group discussion methods were used to identify the activities carried out by the local population and to determine agents, drivers and pressures of land use and land cover change. The Ajei community forest is consisted of four main land cover namely; dense vegetation, sparse or degraded vegetation, savanna and bare soil. Between 1988 and 2018, the proportions of dense vegetation and savanna decreased and that of bare soil and sparse vegetation increased. Analysis showed ongoing deforestation with forest cover loss of about 240 ha in 30 years. For the considered time periods 1988-2003 and 2003-2018, deforestation rates were 1.83% per year and 1.49% per year respectively, signifying on average 8 hectares of forest cover undergoing conversion each year. This lost results from the actions of farmers, cattle grazers and wood extractors who through farming, grazing and lumbering activities pressurize and convert the dense forest cover. Economic motives notably the need to increase household income from a frequent demand for farm and wood products in nearby markets represent the drivers of forest cover change. Controlling grazing activities notably in the dry season to check out the use of fires, community sensitization especially among cattle headmen on the importance of the community forest, reforestation activities through natural regeneration or tree planting are needed in the forest.

Keywords

Land Use, Land Cover Change, Agents, Drivers, Pressures

1. Introduction

Forests are valuable resources providing enormous benefits. Forests regulate climate and fresh water flow, protect and enrich soils, control pests and diseases, maintain biodiversity, safeguard water quality, offer beautiful landscapes and enrich humans spiritually [1]. The cameroonian forest, covers an area of about 22,523,732 hectares, which represents about 48% of the national territory [2]. The importance of the forest is related to its multiple and sometimes conflicting uses and functions at local, national and global levels. From a conservation perspective, the forest constitutes a crucial reservoir of biodiversity, including many endemic species, and its contribution to climate regulation and other environmental services [3]. Regrettably, these socio-economic and ecological functions are under threat from high rates of deforestation [4]. According to [5], global forest cover has drastically decreased from 4128 million ha in 1990 to 3 999 million ha in 2015. In the Congo Basin in general, deforestation is increasing, with the rate of deforestation passing from 0.13% throughout 1990 to 2000 period to 0.26% in 2000 to 2005 period [6]. In Cameroon, [7] and [8] estimate the average annual rate of net deforestation at 0.14% for the period 1990-2000, with an average of gross deforestation in the order of 0.20%. With these figures, Cameroon appears as the second country in the Congo basin, after the Democratic Republic of Congo (0.2%), with the highest deforestation rate [7] [9]. Rapid urbanization, anthropogenic and socioeconomic activities, in local and regional levels, are important components responsible for extensive deforestation [1]. According to [10] and [11], in tropical countries the main drivers of degradation and deforestation are the combination of several factors, including the expansion of peasant farming and the extraction of wood.

The need for a healthy environment has given rise to the global fight against deforestation identified as the main problem affecting climate, biodiversity, ecosystems and the usefulness of the forest as a resource [12]. For many authors as [13], change detection analysis is important for planning and management activities for a wide variety of subjects such as the monitoring of deforestation.

To reduce deforestation, forests mapping and the monitoring of their evolution are very important. Mapping areas of forest cover change is essential for developing locally adapted strategies to better control these dynamics [14]. To carry out such monitoring, remote sensing is a less-expensive method that has proven its effectiveness for assessment of forest cover dynamics and degradation over several decades and at different scales [15] [16] [17] [18] [19]. Land use change detection is often conducted to critically discern trends, drivers and their impacts on the landscape to enhance decision making for of conservation biodi-

versity and ecological functions [20].

In a bid to redress threats and impacts of forest cover lost, to promote community participation and alleviate poverty, the cameroonian forestry wildlife and fisheries law enacted in 1994 enshrined the concept of community forest corresponding to a maximum area of 5000 hectares, granting local community's access, to use and manage substantial portion of the non-permanent forest estate [21]. The Ajei community forest in Ngie subdivision of Momo Division, North West Region of Cameroon was attributed on the 14th of January 2014 [22]. Its valorization stems from the valuable socio-economic and ecological services it offers. This community forest is an important watershed for the village and its neighbors as it supplies water to streams and drinking sources downhill. The riparian landscape of Ajei community forest is one of the few remaining forest patches of the Bamenda highlands and is a source of wood for energy and construction purposes, non-timber forest products (fruits, spices, medicines) for the population residing around the forest. Unfortunately, this forest is threatened by increasing human activities including agriculture, settlement, bush fires, encroachment by grazers [22]. Hence there is a need for a land use management plan. As such, information on land use and land cover status and dynamics of the forest, agents and drivers of this change are greatly needed. In Cameroon, very few studies on land cover and land use change focused on gallery forest and highland. This paper, therefore, initiated a remote sensing-based vegetation baseline assessment that is nonexistent in Ajei upland watershed community forest, as a strategy for informing policy makers involved in the sustainable governance and management of this forest. The objective of this study was to analyze the spatial and temporal dynamics of land use and land cover in theAjei upland watershed community forest and determine agents and drivers of the change.

2. Material and Methods

2.1. Study Site

Administratively Ajei forest is found in Ajei village in Ngie subdivision, Momo division in the North West Region of Cameroon (**Figure 1**). Geographically, the community forest marks the last remaining forest located within the lower limits of the Bamenda Highland ridge along the Cameroon volcanic line within the Mamfe basin. The forest is located between latitudes 5.920˚ - 5.970˚N and longitudes 9.840˚ - 9.890˚E and covers a surface area of 1739.3 ha. Ajei has a population of about 4000 people distributed within six communities (Akwokwi, Akwonjoh, Akweitei, Akwokoh, Akwofei, Akwogom). Ajei falls in the transitional zone between the wet tropical or equatorial climate in south Cameroon and the Sudanese climate of North Cameroon. Annual precipitation ranges from 2200 to 3000 mm from March through October with an average of 240 rainy days with an average temperature of 21˚C (minimum 15˚C and maximum 30˚C). The

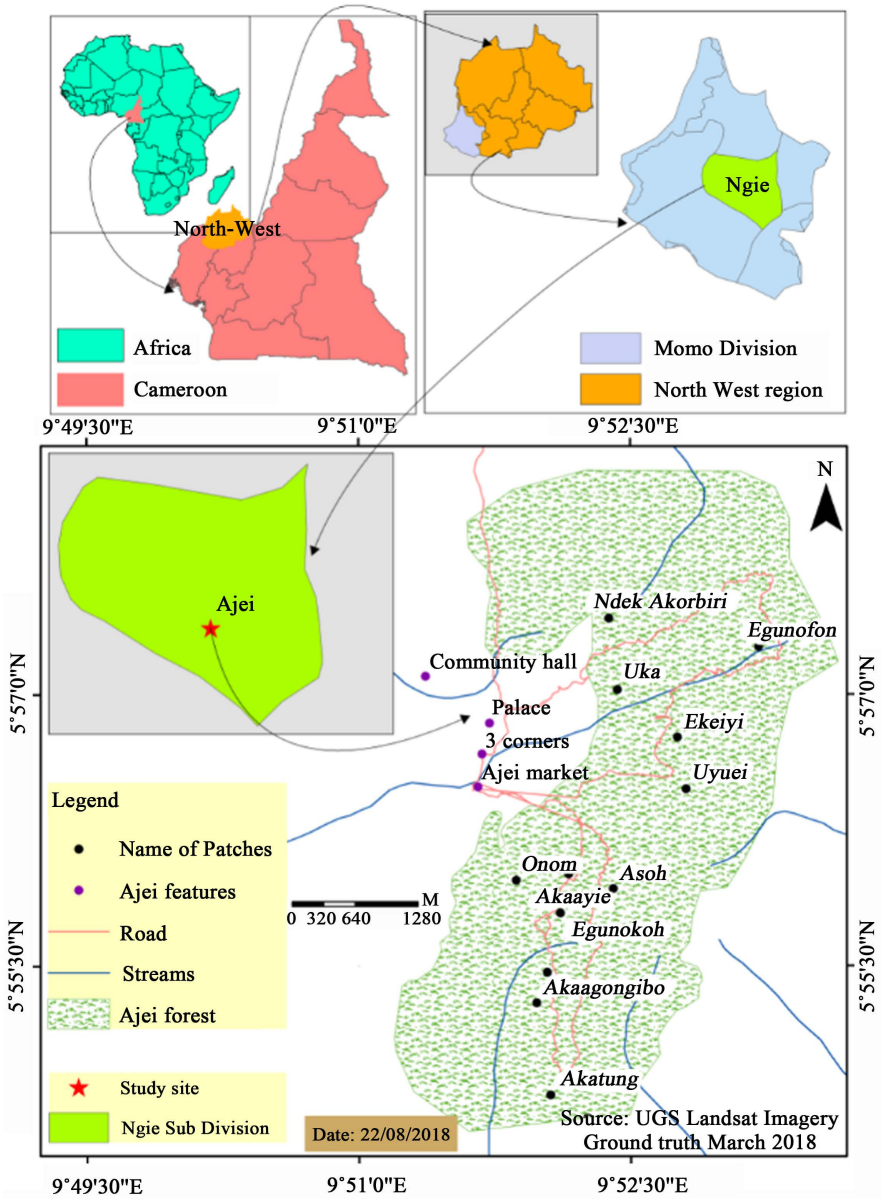

Figure 1. Localization of the AJei upland community forest.

rugged topography and relief of Ajei village and its environs ranging between 1500 m above sea level cumulating at the highest peak of Ndek Akorbiri 2040 m is typical of an area underlain by granitic basement rocks. Soils derived from this parent rock material are generally poor, being rapidly depleted of fertility through cropping and the erosive action of rain [22].

2.2. Data Collection and Analysis

Assessment of land cover change was made using Landsat 5TM, Landsat 7ETM+ and Landsat 8OLI satellite images taken in 1988, 2003 and 2018 respectively. Imagery data for the study were downloaded from the United States Geological Survey (USGS) website (http://glovis.usgs.gov/). Images were acquired approx-

imately for the same period, at the dry season (January) to ensure that they were clear and cloud free and that the phenological stages of plant cover were not too different between dates.

These different images were processed using ENVI 4.5 software to extract desired information. Landsat images were subjected to image enhancements activities such as pan sharpening, normalized difference vegetation index calculations, layer stacking and color composition activities were carried out to ameliorate the brightness, contrast and visibility of objects, to reduce omission and confusion errors to increase accuracy in spectral differencing of objects during classification. Extraction of the study zone was made using a geo-rectified vector map (UTM 32 WGS 84).

A hybrid image classification method consisting of unsupervised and supervised image classification was executed. Unsupervised classification was conducted to determine spectral differences in land cover classes for the creation of 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 Landsat scenes. Error matrixes to assess the accuracies and errors of the classification were computed. The Kappa index (the ratio of the number of well-ranked pixels to the total of the pixels surveyed) was calculated.

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 were imported into Arc Map 10.2 software for the extraction of the layers to be used, digitization, generation of databases, and production of maps. **Figure 2** shows the different phases of image processing.

To identify the agents and drivers and pressures of change, the DPSIR (drivers, pressure, state, Impact and response) frame work approach designed by the European Union alongside field observations and questionnaires were used. The ultimate purpose of the field survey conducted was to collect qualitative and quantitative information on Agents and pressures of land use and land cover change and their area of manifestation in the forest, while questionnaires were used to identify the principal driving forces setting agents and pressures in motion within the forest. The interviewed persons (39 in total) were wood and non-timber forest product harvesters, hunters, owners of cattle, farmers, quarter heads and members of the community forest managing board. Interviews were conducted using structured questionnaires consisting of both open and closed-ended questions. The Key items of the questionnaires included demographic data, education, size of households, activities carried out in the forest, perception and attitude of the community towards community forest exploitation, community forest management and causes of forest degradation and measures to minimize forest degradation.

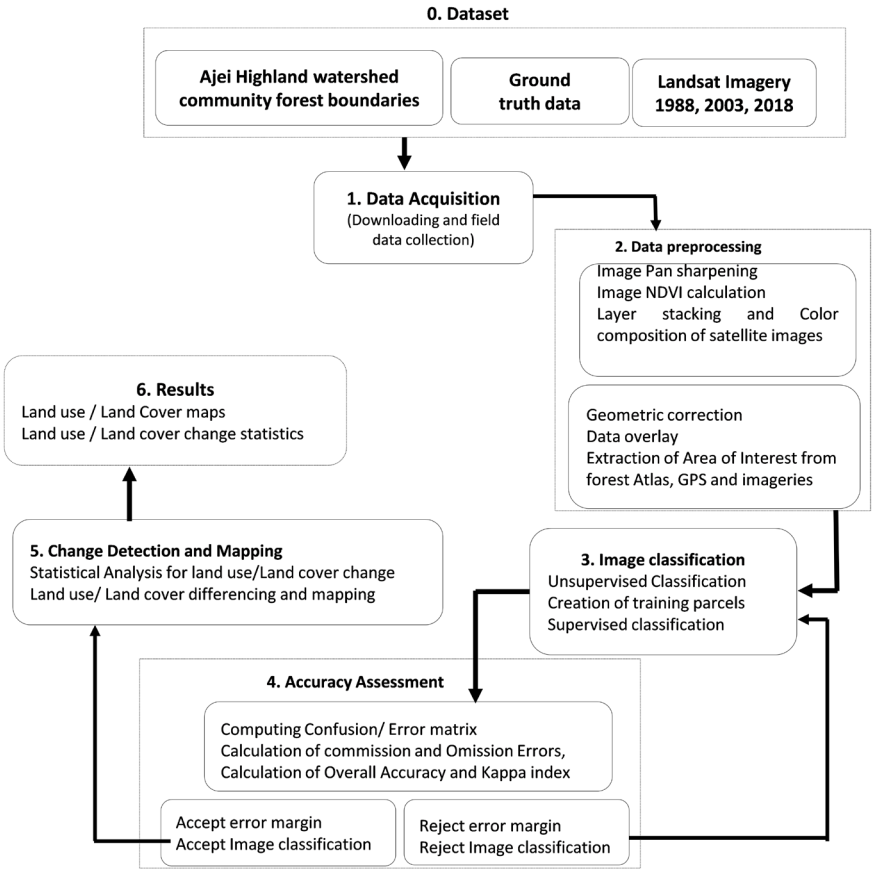

Figure 2. Different stages of satellite images processing to obtain the land cover map.

3. Results

3.1. Forest Status and Dynamics

From the hybrid image classifications of Landsat scenes of 1988, 2003 and 2018, four main land cover classes were identified namely; dense vegetation, sparse or degraded vegetation, savanna and bare soil (Table 1).

- The dense vegetation constitutes a concentration of trees that are intact, still in possession of a majority of their natural state and have undergone limited or no transformation; that is limited or no tree removal.
- The sparse vegetation represents sections of the forest where in trees are losing their natural state, being harvesting or dead and undergoing decay.
- The Savanna is an assembly of grass and herbs. This cover is at the boundaries of sparse vegetation representing formally sparsely dense surfaces that have lost their tree covering.
- Bare surfaces are partly boulders of stones and rocks and sections of the soil with insignificant vegetation cover or no vegetation cover at all. They constitute sections of lands obtained from savanna cover as a result of scorch heat action or drought conditions and fires.

In 1988 (Figure 3), dense vegetation was dominant, over all other land cover classes with an area of 549 ha, representing a 31.58% occupation of the total

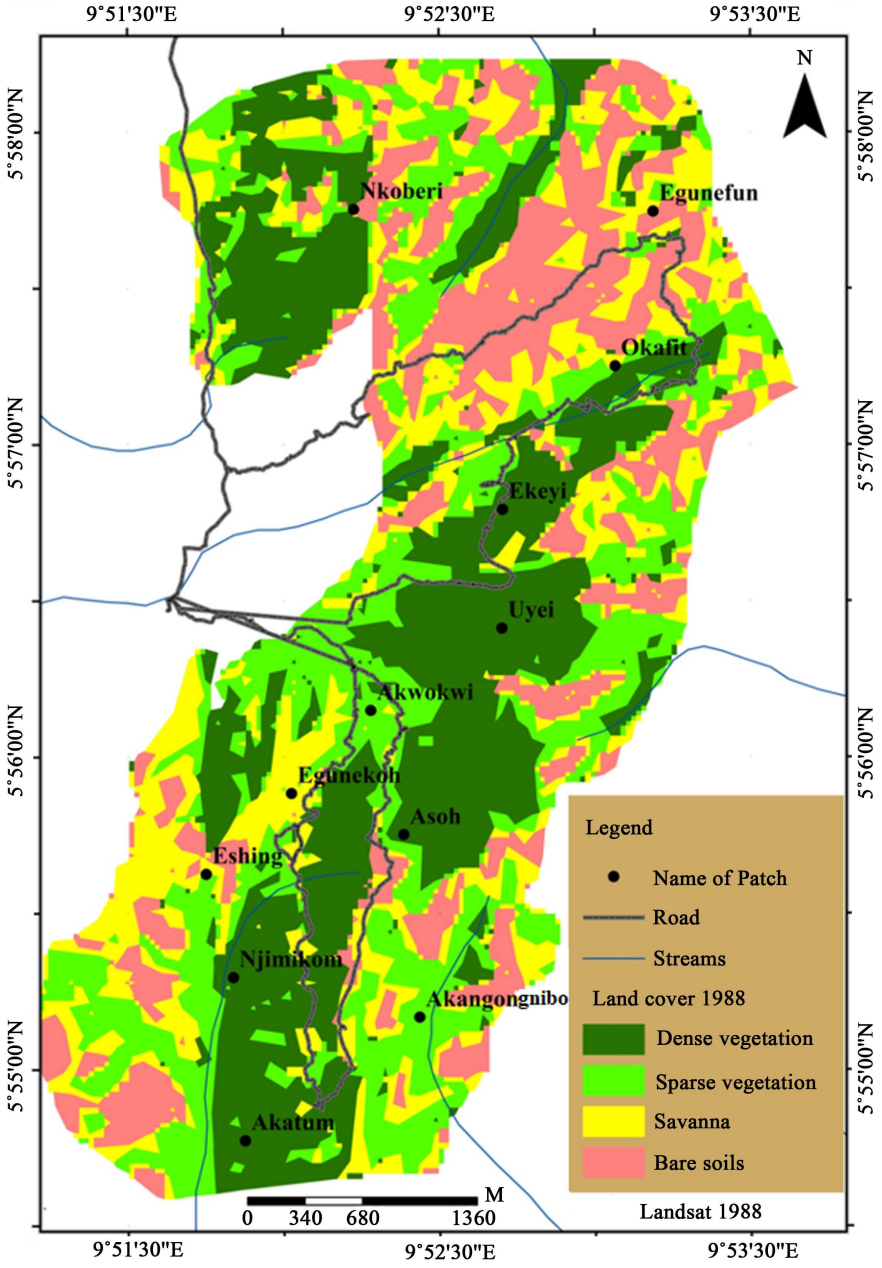

Figure 3. Land cover of AJei community forest in 1988.

Table 1. Land cover surface areas and percentages from 1988 to 2018 in Ajei community forest.

Land cover	1988		2003		2018	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Bare soil	343.10	19.73	519.07	29.84	539.74	31.03
Sparse vegetation	460.42	26.47	527.35	30.32	533.34	30.66
Dense vegetation	549.30	31.58	398.25	22.90	308.88	17.76
Savanna	386.48	22.22	294.63	16.94	357.34	20.55
Total	1733.3	100	1733.3	100	1733.3	100

forest area. The 2003 classified image (Figure 4) showed a dominance of sparse vegetation with a surface area of 539 ha representing 31.03% of the forest. In2018, bare soil was dominant with a surface area of 519 ha representing a 29.84% occupation of the total forest area (Figure 5). Table 1 shows the dynamic of different land cover surface areas from 1988 to 2018.

It appears from this table that between 1988 and 2018, the proportions of dense vegetation and savanna decreased and that of bare soil and sparse vegetation increased.

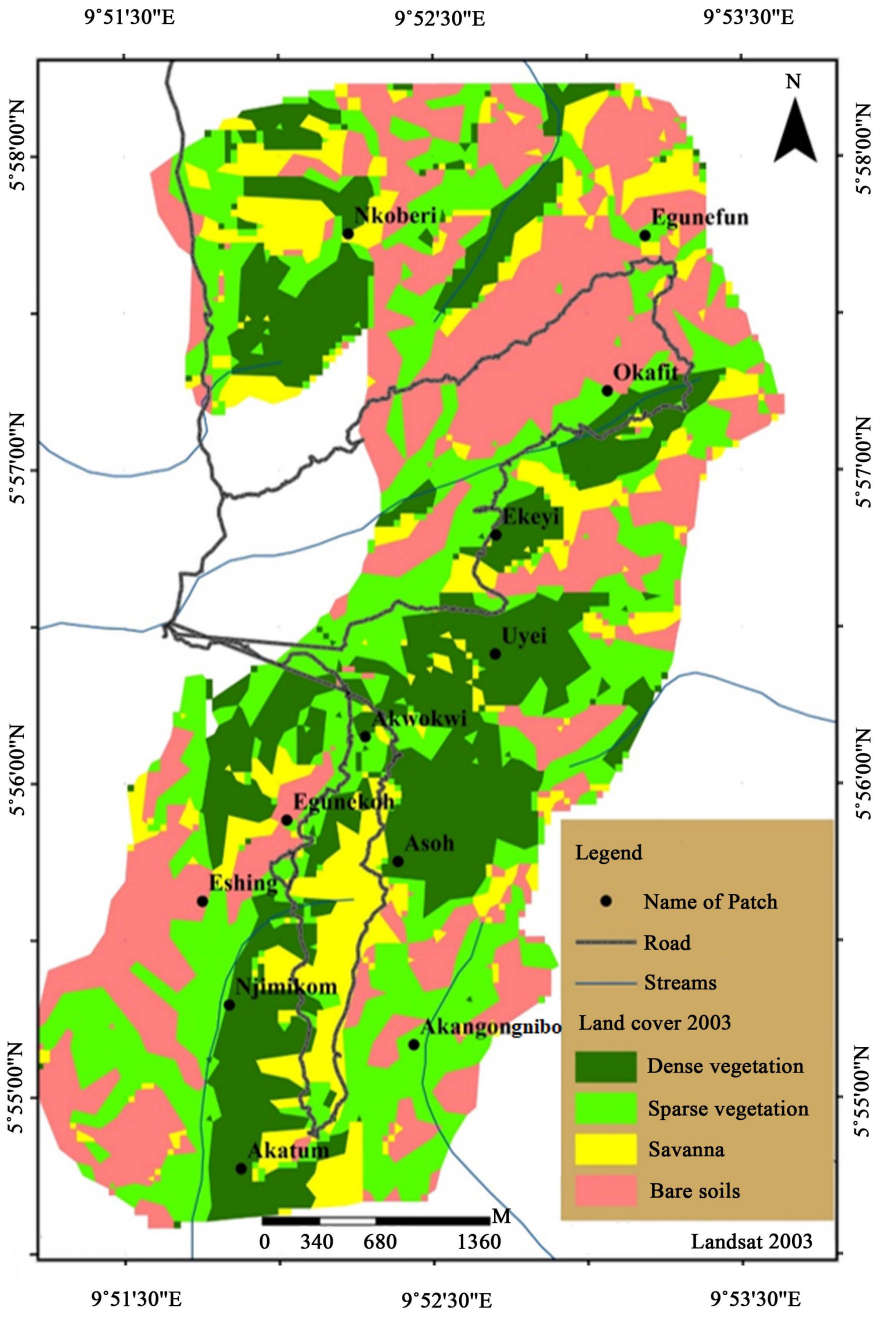

Figure 4. Land cover of AJei community forest in 2003.

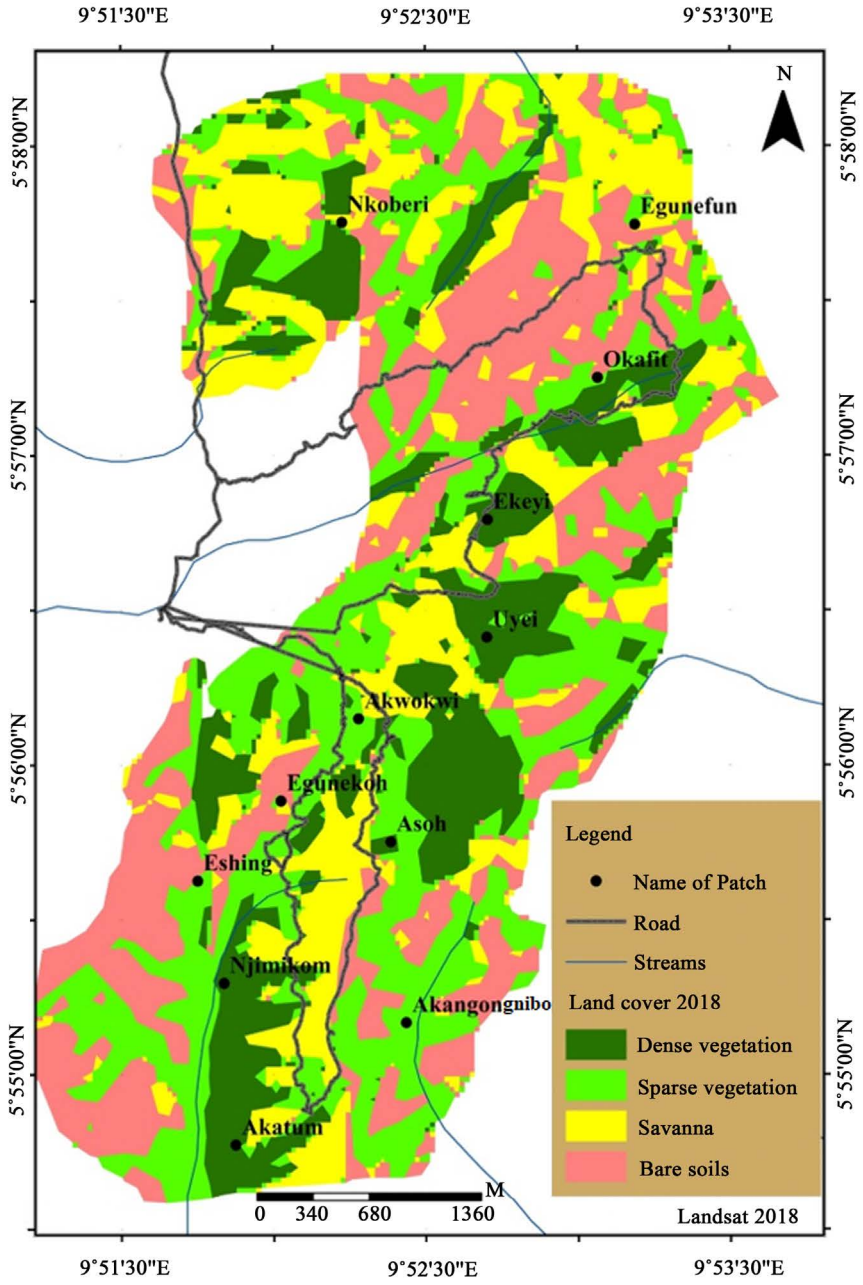

Figure 5. Land cover of AJei community forest in 2018.

Analysis on the change in the state of the forest cover as perceived from Table 2, shows a total lost in dense cover from 1988 to 2018 of about 240 ha obtained from a 151 ha (representing 27.49%) lost in dense vegetation cover from 1988-2003 and another 89 ha (representing 22.44%) lost in dense vegetation from 2003-2018. Contrary to the lost registered in dense vegetation cover, there are gains of 175.97 ha (51.28%) in bare soils, and gains of 66.93 ha (14.53%) in-sparse vegetation in 1988-2003. In 2003-2018, there are increases of 20.67 ha (3.98%) in bare soiland 5.99 ha (1.13%) in sparse vegetation. Savanna firstly decreased from 91.85 ha (23.76% of its initial surface area) between 1988 and 2003,

Table 2. Land Cover change 1988-2003, 2003-2018 and 1988-2018 in Ajei community forest.

Land-cover	1988-2003		2003-2018		1988-2018	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Bare soil	175.97	51.28	20.67	3.98	196.64	57.12
Sparse vegetation	66.93	14.53	5.99	1.13	72.92	15.83
Dense vegetation	−151.05	−27.49	−89.37	−22.44	−240.42	−43.76
Savanna	−91.85	−23.76	62.71	21.28	−29.14	−7.53

Negative values signify a lost while positive values signify gains in hectares and percentages.

before an increase in size (62.71 ha) in 2003-2018. From Table 2, it appears that the deforestation rate is higher in 1988-2003 (27.49%, *i.e.* 1.83% per year) than in 2003-2018 (22.44%, *i.e.* 1.49% per year). The average deforestation rate for the all thirty years is 1.45%.

The computed error matrixes for the classified images (Table 3) revealed an overall confusion of less than 15% with overall accuracy and degree of representation of real world ground truths (Kappa index) of more than 85% and more than 0.8 respectively. With these levels of errors and accuracies the image classifications were found acceptable given the fact that, in all three cases, sources of confusions are between classes almost possessing the same spectral characteristics that is between dense and degraded vegetation and between savanna and bare soils classes.

3.2. Agents, Drivers and Pressures of Land Use Change

3.2.1. Agents of Land Use Change

From field observation it was noticed that, farmers practicing slash and burn farming techniques, cattle head men are the principal agents causing land use change. They are accompanied by loggers who harvest wood for construction and housing purposes in the forest. All these agents play a key role in the fragmentation of the forest through the opening up of roads and tracks for movement within the patches. Cattle head men who graze cattle in the forest set the forest on fire in the dry season for new grass to geminate in the coming rainy season for their cattle and to check out any chances of forest reconstitution. Pests and diseases also constitute natural agents at work in the forest, these agents attack trees, provoke their death and decay.

3.2.2. Drivers of Land Use Change

Sectorial drivers shaping gallery forest landscape in Ajei community forest were identified and grouped into; economic, socio cultural, governance and communication drivers.

- **Economic driver**

This driver's indirect influence on the forest results the need to step up household income from high and frequent demand for agriculture and wood

Table 3. Values of overall accuracies and Kappa index.

Landsat imagery	Overall errors (%)	Overall accuracies (%)	Kappa index
5TM of 1988	13	87	0.82
7ETM+ of 2003	12.3	87.7	0.83
8OLI of 2018	9.2	90.8	0.88

products. This high and frequent demand comes from an increase in the number of markets and market days set out for the buying and selling of wood and agricultural products within a week around Ajei. These markets include the Ajei mixed market, Andek, Mbengwi bone, Nyen-bo, batibo, Bamenda food markets. There is also the Tugi cattle market situated within the heart of Ngie Subdivision purposely functioning for the buying and selling of cattle. Many carpentry workshops and buyers of wood also exist within the listed neighborhoods above. Respondents revealed the persistent arrival of many buyam-sellams from other areas notably those from Bamenda, Douala, Yaounde and Bafoussam who flood these markets and sometimes buy through command before the market days. Local inhabitants around having to look for end means to satisfy this high frequent demand for agricultural and wood products. To satisfy this demand it entails opening new farm areas and exploiting new forest areas still in possession of wood products. This explains why the local inhabitants in Ajei find themselves penetrating the different forest patches to exploit and ensure continues supplies of their products to meet up with demand.

- **Socio-Cultural driver**

This driver has to do with the beliefs and perception of the inhabitants seen and interviewed carrying out exploitation activities within the forest patches. Cattle grazers having established their grazing huts in the area have a high level of negligence vis-à-vis the welfare of the forest. To them the forest patches are potential farm areas and grazing areas which someday, will be cut down for farming and grazing activities. To some farmers it is the absence of the means to cut down the trees and to transport farm products from the forest patches that hinders them from farming in the area effectively. From such responses gotten, it becomes very clear that elites of the community are the most concerned and interested set of persons, advocating for the conservation of this forest and as a matter of inconvenience for the forest, they do not reside in Ajei. Respondents interviewed, expressed a high degree of unawares on the importance of a community forest to them, first as individuals and secondly as a community in charge of the forest.

- **Governance**

In addition to the above cultural driver, governance on the community forest is weak. Respondents expressed very limited actions being taken to scale up community participation and to ensure that legislation on the different manner of use of the community forest grows public and be respected by all who get into

the forest. Respondents talk of everything being permitted; the use of fires for more space to farm, to graze, harvesting of fuel wood for household needs and many others without any attention or consideration being given to the impacts of such activities on the state of the forest.

- **Developments in transport and communication sector**

Though highly mountainous, there is a motor able road network partially tarred at stiff bends. The road is usable throughout the year. Ajei can be accessed from two entry points; through Andek and through Etwii and equally through the hills where foot paths taking their rise from numerous directions get into the village and the forest in particular. Respondents highlighted an increasing use of bikes, Hilux and cargo vehicles at affordable displacements fares; fuel is readily available in supply with many vendors within and without the village thus easing movements of goods and persons in and out of Ajei. With the coming of Nexttle mobile telephone network, Ajei is one of the villages that benefitted from the tackled mobile telephone communication setbacks that affected most rural areas. Communication between the inhabitants and "buyam sellams" of their products has been made easy, they are now easily informed about changes in prices, demand and supply conditions of products, when to produce, what quantities, where to better sell, in what quantities and prices.

3.2.3. Pressures of Land Use Change

Field observations show that the forest is pressured from every front, which is from downhill to uphill and from uphill to downhill directions and inside the forest by both anthropogenic and natural pressures.

Agricultural expansion within this community forest is manifested through two mediums: farming and cattle rearing. An extraction of these farms and grazing lands from Google satellite images show that, pressure on the forest by agriculture stands at 867 ha representing more than 50% of the community forest. Grazing lands cover about 689 ha and farming 178 ha representing 40% and 10% occupancy on forest land respectively.

Lumbering activity was observed around the forest patch boundaries. 7 key sites of wood extraction were located in the forest with harvesting done at any period depending on demand and need, notably for energy, building and construction purposes.

Development in infrastructures within the forest patches is also recurrent and also pressurizes the forest space. Ground truths revealed in this forest, 5 built cattle fences and 12 farm and cattle houses; with many natural water outpour points harnessed into water drinking spots for cattle and irrigation farming. The forest is equally equipped with a built-up vaccination yard for cattle, a dense network of roads and tracks of about 25 km for ease of movement of goods, persons and cattle, in and out of the patches.

Natural factors also have an influence on the change in forest cover as cases of tree decay were observed. With probable causes being pest attacks or the over

aged nature of the tress in question, wild winds, rains and thunder storms equally affect the tree cover of the forest. In the face of these storms trees brought down while falling, do push down many other trees along to the ground.

4. Discussion

The Kappa indexes of 0.82, 0.84 and 0.88, respectively for the three images, prove that the classifications performed are reliable if we refer to the scale of [23]. Results on land cover status and overall forest cover change show an ongoing deforestation process within the community forest. Vegetation is experiencing an essentially regressive evolution. This regression is much more important in dense vegetation. This dense vegetation which was dominant in 1988, occupying 31.58% of the total forest surface area reduced to 17.76% in 2018, giving way to sparse vegetation (26.47% in 1988 and 30.66% in 2018) and bare soils (19.75% in 1988 and 31.03% in 2018). This trend is similar to those observed by many authors in Cameroon and in Africa [24] [25] [26] [27] [28] and in other African countries [29] [30] [31] [32].

Analysis of deforestation rates for the considered time periods 1988-2003 and 2003-2018 reveal deforestations rates of 1.83% per year and 1.49% per year respectively. This lower rate of deforestation for the second period is probably due to a decline in human activities in the community forest following its attribution in 2014 and a better sensitization of population. The rates of deforestation observed in our study area are higher than that of 0.65% reported by [33] for 1990-2000 period in Eastern Region of Cameroon and also greater than that of 0.13% found by [6] for the Congo basin for the same period. In Cameroon, [7] and [8] reported a deforestation rate of 0.2%. The rates found in our study area are higher.

In Ajei community forest, the conversion of the natural densevegetation into sparse vegetation and bare soils area is a consequence of the total sum of actions led by farmers and cattle headers leading farming and grazing activities on the forest. Wood extraction practices are limited and not in advanced state in this community forest. Similar drivers are found in other part of Cameroon by [26] [27] [28], respectively in Santchou, Koupa Matapit and Mount Cameroon caldera. [26] reported a Market-oriented agriculture based on cocoa and coffee as the main driving force of forest cover changein Santchou forest reserve. In Asia, an assessment on forest cover dynamics in the tropical deciduous forest in Kalrayan hills, in India highlighted illegal lumbering, forest fires and shifting cultivation as leading causes to land use and land cover change [34]. These findings do clearly reveal that agricultural expansion generally affects land cover conditions and status and is at the center of most forest lost registered in the world.

Development in areas of infrastructures and poor governance do also have a role to play. In Ajei community forest, a dense network of roads and tracks of about 25 km facilitate movement of goods, persons and cattle, in and out of the

forest patches and can further intensifies the state of fragmentation in this forest. Though there are now well-developed land use policies and practices to protect forest areas, the management board of the community forest still faces difficulties in the management of the forest. Difficulties to initiate and to scale up community participation notably on rational harvesting and exploitation of wood products, rational and intensive use of land still pose problems. These proximate and underlying drivers of deforestation have been reported by [10] for Congo Basin.

5. Conclusion

The trend of the change observed in Ajei community forest was a conversion of the natural dense forest into sparse vegetation and bare soils. The rate of deforestation is higher than that reported in the Congo basin and in Cameroon. The above lost in forest cover is a result of actions led by farmers, cattle grazers and wood extractors who through farming, grazing and lumbering activities in the forest convert the dense forest cover. Of all pressures, agricultural and infrastructural expansion notably cattle rearing, opening of roads and foot paths are at the center of forest cover lost. Economic motives notably the need to increase household incomes facilitated by frequent demand for agricultural and wood products in markets represent the main driver of forest change in the Ajei community forest. It is therefore important to control grazing activities within the forest notably in the dry season to check out the use of fires, to sensitize the community especially the cattle headmen on the importance of the community forest, the effects and damages of uncontrolled grazing, farming, and continues use of fires. Buffer zones around the remaining natural dense forest cover to preserve their status should be instituted alongside reforestation activities either through natural regeneration or tree planting campaigns.

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Conflicts of Interest

Authors declare no conflict of interest.

References

[1] Soni, S., Garg, P.K., Singh, A. and Maurya, A.K. (2015) Assessment of Land Use Land Cover Change in Chakrar Watershed Using Geospatial Technique. *Tropical Plant Research*, **2**, 101-107.

[2] de Wasseige, C., Devers, D., de Merken, P., Eba'a Atyi, R., Nasi, R. and Mayaux, P. (2009) Les forêts du Bassin du Congo: Etat des forêts 2008. Office des Publications

de l'Union Européenne, Bruxelles, Belgique.

[3] Djeukam, R. (2008) Forestry and Communities in Cameroon. CED. http://www.ceecec.net/wp-content/uploads/2008/10/Forestry_in_Cameroon_19-05.pdf

[4] Fru, D.N. (2015) The Contribution of Community-Based Natural Resources Management to Livelihood, Conservation and Governance in Cameroon. A Comparative Assessment of Three Community Forest in Fako Division. Post Graduate Diploma Thesis, Pan African Institute for Development, West Africa.

[5] FAO (2016) Global Forest Resource Assessment 2015. How Are the World's Forests Changing? 2nd Edition, Food and Agricultural Organization of the United Nations, Rome.

[6] Ernst, C., Mayaux, P., Verhegghen, A., Bodart, C., Musampa, C. and Defourny, P. (2013) National Forest Cover Change in Congo Basin: Deforestation, Reforestation, Degradation and Regeneration for the Years 1990, 2000 and 2005. *Global Change Biology*, **19**, 1173-1189. https://doi.org/10.1111/gcb.12092

[7] Duveiller, G., Defourny, P., Desclee, B. and Mayaux, P. (2008) Deforestation in Central Africa: Estimate at Regional, National and Landscapes Levels by Advanced Processing of Systematically Distributed Landsat Extracts. *Remote Sensing of Environment*, **112**, 1969-1981. https://doi.org/10.1016/j.rse.2007.07.026

[8] FAO (2006) Évaluation des ressources forestières mondiales 2005. Progrès vers la gestion forestière durable. Food and Agricultural Organization of the United Nations, Rome.

[9] Montellano, A.R. and Eric, A. (2011) Detecting Forest Degradation Patterns in Southeast Cameroon. *Proceedings of the* 15*th Annual Brazilian Symposium of Remote Sensing SBSR*, Curitiba, Brazil, 30 April-5 May 2011, 1606-1613.

[10] Geist, H.J. and Lambin, E.F. (2002) Proximate Causes and Underlying Driving Forces of Tropical Deforestation. *BioScience*, **52**, 143-150. https://doi.org/10.1641/0006-3568(2002)052[0143:PCAUDF]2.0.CO;2

[11] Defourny, P., Delhage, C. and Kibambe Lubamba, J.P. (2011) Analyse quantitative des causes de la déforestation et de la dégradation des forêts en République Démocratique du Congo. UCL/FAO/CN REDD, Kinshasa.

[12] Gessesse, D. (2007) Forest Decline in South Central Ethiopia: Extent, History and Process. Ph.D. Thesis, Stockholm University, Stocholm.

[13] Muttitanon, W. and Tripathi, N.K. (2005) Land Use/Land Cover Changes in the Coastal Zone of Ban Don Bay, Thailand Using Landsat 5 TM Data. *International Journal of Remote Sensing*, **26**, 2311-2323. https://doi.org/10.1080/01431160512331326666

[14] de Wasseige, C., Flynn, J., Louppe, D., Hiol Hiol, F. and Mayaux, P. (2014) Congo Basin Forest: State of the Forests 2013. Weyrich, Belgium. https://www.observatoire-comifac.net/docs/edf2013/FR/EDF2013_FR_INTRO.pdf

[15] Loveland, T.R. and Dwyer, J.L. (2012) Landsat: Building a Strong Future. *Remote Sensing of Environmen*t, **122**, 22-29. https://doi.org/10.1016/j.rse.2011.09.022

[16] Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A. and Townshend, J.R.G. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science*, **342**, 850-853. https://doi.org/10.1126/science.1244693

[17] Nagendra, H., Lucas, R., Honrado, J.P., Jongman, R.H.G., Tarantino, C., Adamo, M. and Mairota, P. (2013) Remote Sensing for Conservation Monitoring: Assessing

Protected Areas, Habitat Extent, Habitat Condition, Species Diversity, and Threats. *Ecological Indicators*, **33**, 45-59. https://doi.org/10.1016/j.ecolind.2012.09.014

[18] Wani, A.A., Joshi, P.K., Singh, O. and Shafi, S. (2016) Multitemporal Forest Cover Dynamics in Kashmir Himalayan Region for Assessing Deforestation and Forest Degradation in the Context of REDD+ Policy. *Journal of Mountain Science*, **13**, 1431-1441. https://doi.org/10.1007/s11629-015-3545-3

[19] Mukete, B., Sun, Y., Baninla, Y., Achem Baye, J., Bakia, M., Sajjad, S., Tamungang, R., Jaba, W. and Chalwe P. (2017) Perspectives of Remote Sensing and GIS Applications in Tropical Forest Management. *American Journal of Agriculture and Forestry*, **5**, 33-39. https://doi.org/10.11648/j.ajaf.20170503.11

[20] Cheung, L., Kemen, A., Utami, A. and Bangoura, J. (2014) Building National Forest and Land-Use Information Systems: Lessons from Cameroon, Indonesia, and Peru. World Resource Institute Working Paper.

[21] MINFOF (2009) Manual of Procedure for the Attribution and Norms for the Management of Community Forest. 2nd Edition, Ministry of Forestry and Wildlife, Yaoundé Cameroun.

[22] Ajei Highlands Watershed Community Forest Managing Board (2016) Participatory Socio-Economic, Zoological and Botanical Inventory of Ajei Highlands Watershed Community Forest. Unpublished Report, AHWaCoFoMb.

[23] Landis, J.R. and Koch, G.G. (1977) The Measurement of Observer Agreement for Categorical Data. *Biometrics*, **33**, 159-174. https://www.jstor.org/stable/2529310 https://doi.org/10.2307/2529310

[24] Wafo, T.G., Tsayem Demaze, M. and Fotsing, J.M. (2006) L'information spatialisée comme support d'aide à la gestion des aires protégées au Cameroun: Application à la réserve forestière de Laf-Madjam. Interactions Nature-Société, Analyse et Modèles. UNR6554 LETG, La Baule.

[25] Momo Solefack, M.C., Chabrerie, O., Gallet-Moron, E., Nkongmeneck, B.A., Leumbe Leumbe, O.N. and Decocq, G. (2012) Analyse de la dynamique de déforestation par télédétection couplée aux modèles d'équations structurales: Exemple de la forêt néphéliphile du mont Oku (Cameroun). *Acta Botanica Gallica*, **159**, 451-466. https://doi.org/10.1080/12538078.2012.750583

[26] Meli Fokeng, R. and Meli Meli, V. (2015) Modeling Drivers of Forest Cover Change in the Santchou Wildlife Reserve, West Cameroon using Remote Sensing and Land Use Dynamics Degree Indexes. *Canadian Journal of Tropical Geography*, **2**, 29-42.

[27] Momo Solefack, M.C., Njouonkouo, A.L., Temgoua, L.F., Djouda Zangmene R., Wouokoue Taffo, J.B. and Ntoukpa, M. (2018) Land Use/Land Cover Change and Anthropogenic Causes around Koupa-Matapit Gallery Forest, West-Cameroon. *Journal of Geography and Geology*, **10**, 56-65. https://doi.org/10.5539/jgg.v10n2p56

[28] Toh, F.A., Angwafo, T., Ndam, L.M. and Antoine, M.Z. (2018) The Socio-Economic Impact of Land Use and Land Cover Change on the Inhabitants of Mount Bambouto Caldera of the Western Highlands of Cameroon. *Advances in Remote Sensing*, **7**, 25-45. https://doi.org/10.4236/ars.2018.71003

[29] Avakoudjo, J., Mama, A., Toko, I., Kindomihou, V. and Sinsin, B. (2014) Dynamique de l'occupation du sol dans le Parc National du W et sa périphérie au nord-ouest du Bénin. *International Journal of Biological and Chemical Sciences*, **8**, 2608-2625. https://doi.org/10.4314/ijbcs.v8i6.22

[30] Benoudjita, N. and Djinet, I.A. (2017) Comment les aires protégées structurent les écosystèmes des périphéries. *International Journal of Biological and Chemical*

Sciences, **11**, 2225-2242. https://doi.org/10.4314/ijbcs.v11i5.22

[31] Zakari, S., Toko, I., Thomas, O.A.B., Djaouga, M. and Arouna O. (2018) Application de la télédétection et du SIG au suivi des formations végétales de la forêt classée des trois rivières au Nord-Est du Bénin. *European Scientific Journal*, **14**, 450-469. https://doi.org/10.19044/esj.2018.v14n15p450

[32] Temgoua, L.F., Allaissem, B., Tchamba, M., Saradoum, G., Osée, M.M. and Solefack, M.C.M. (2018) Spatio-Temporal Dynamic of Land Use and Land Cover in the Classified Forest of Djo-li-Kera, South-Eastern, Chad. *Open Journal of Forestry*, **8**, 283-296. https://doi.org/10.4236/ojf.2018.83019

[33] De Wasseige, C., Flynn, J., Louppe, D., Hiol Hiol, F. and Mayaux, P. (2014) Congo Basin Forest: State of the Forests 2013. Weyrich, Belgium.

[34] Sakthivel, R., Manivel, M., Jawaharraj, N., Pugalanthi, V., Ravichandran, N. and Vijay, D.A. (2010) Remote Sensing and GIS Based Forest Cover Change Detection Study in Kalrayan Hills, Tamil Nadu. *Journal of Environmental Biology*, **31,** 737-747.