Sustinere
Journal of Environment and Sustainability
Volume 6 Number 3 (2022) 251-270

Print ISSN: 2549-1245 Online ISSN: 2549-1253
Website: https://sustinerejes.com E-mail: sustinere.jes@uinsaid.ac.id

RESEARCH PAPER

Dynamics of land use/cover changes and plant diversity in Tubah Sub-Division, Cameroon

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Article history:
Received 24 April 2022 | Accepted 18 December 2022 | Available online 31 December 2022

Abstract. Land use change detection is often conducted to critically discern trends, causes, and their impacts on the landscape to enhance decision-making for conservation of biodiversity and ecological functions. The objectives of the study were to evaluate Land Use and Land cover changes in Tubah Sub-Division, Cameroon, from 1986 to 2017, and to determine plant diversity and abundance in areas with different land uses. Field surveys were carried out to determine the diversity of this area, eight 50x50m sample plots were established in four different sites and trees and shrubs with diameter at breast height (DBH≥10mm) were sampled. Primary data was obtained through field observations and ground truthing in order to confirm observations on satellite images. Land use maps were produced using GIS ArcGis 10.2. Images were extracted for the years 1986, 1996, 2006, and 2017. A total of 173 species were recorded in all the sites belonging to 63 families and 146 genera. The fallow land and secondary forest were the most diverse of all the sites with the highest Shannon index of H′= 3.09 and H′= 2.97 respectively. The least diverse were the agricultural and grazing lands, with H′= 1.39. Analysis of the GIS data revealed a decline in vegetation cover of 90.24 hectares from 1986-1996, 23.76 ha from 1996-,2006 and 86.70 ha from 2006-2017. Settlement areas increased by 63.64 ha from 1986-1996, 53.37 ha from 1996-2006 and 15.36 ha from 2006-2017. Water bodies reduced from 1986-1996 by 7.34 ha, 14.28 ha from 1996-2006 and 3.56 ha from 2006-2017. Bare ground increased by 135.88 ha from 1986-2017. Field observations revealed that agricultural intensification, construction of buildings, unsustainable logging and grazing were the major causes affecting plant diversity in Tubah Sub-Division. The study's outcomes are critical for future land-use planning exercises and the long-term conservation of the biodiversity and water sources for the communities. The population of Tubah should be educated on sustainable land use management and biodiversity conservation.

Keywords: land use and land cover changes; plant diversity; agricultural landscape; Cameroon.

1. Introduction

The degradation and conversion of forests to alternative land uses, such as agriculture, are leading causes of biodiversity loss (Haines-Young, 2009). Land use is a major cause of change in biodiversity, capable of altering ecosystem services and driving land degradation, habitat change,

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DOI: https://doi.org/10.22515/sustinerejes.v6i3.253

the spread of invasive species, and the loss and extinction of plants and animals (Chapin *et al*., 2000; Sala *et al*., 2000). The understanding of this fundamental link between land use and biodiversity is very vital for conservation (Goldman et al., 2008). For there to be sustainability in terms of habitat quality and biodiversity, management becomes a very important tool.

Rural landscapes are characterized by high biodiversity; usually as a result of the low socio-economic activities carried out in these areas (Musetsho et al., 2021). Indeed, much global biodiversity is concentrated in rural landscapes and one can even find wild species and natural habitats directly or indirectly associated with these landscapes (Chen and Zhang, 2021). A vital aspect of rural landscapes involves their agricultural production, which can also be linked to biodiversity. Essentially, landscape transformations are due to socioeconomic changes and the current spatial pattern of the landscape results from changes in land uses and management practices along time.

Biological diversity can have many different interpretations; it is most commonly used to replace the long-established terms, species diversity and species richness (Khera et al., 2001). It has been agreed upon by the United Nation Environment Programme (UNEP, 2002) and other international organizations that biodiversity can be defined as "the variety of life in all its forms, levels and combinations." Biodiversity encompasses three main levels of life's organization (genetic diversity, species diversity, and ecosystem diversity), but among these three, species diversity appears to be the easiest to visualize and is most commonly used. Cameroon, one of the most biologically rich countries known to date on the African continent, encompasses a mosaic of diverse habitats, including moist tropical forests, mountain forests, grassland, savannah and sub-Sahelian savannah, and near desert areas (Sunderland et al., 2003). Having a scientific understanding of the rate of Land Use and Land Cover (LULC) changes is critical, for sustainable development (Dhlamini, 2019). Anthropogenic factors are mainly responsible for affecting the structure and functioning of ecosystems and human well-being (Awo et al., 2021). The physical environment of the Tubah Sub-Division and its environs has been subjected to rapid population growth. The rapid increase in population (from 29,192 in 1976 to 65,250 in 2015), stands as the main driving force behind LULC dynamics. Agriculture is the main economic activity within this area, usually with major clashes between farmers and grazers (Nguh & Maluh, 2017). There is a high demand for land to meet the dire residential needs, commercial needs, social amenities, and socio-economic infrastructures. This has exerted pressure on the lean resources and created a variety of complex land cover and land use dilemmas and if not controlled, can lead to an environmental crisis.

It has been noted that LULC changes are considered one of the main causes that influence changes throughout the world. This view is supported by the assertions of other researchers (Pandit et al., 2007; Karki et al., 2018;. Both natural and human-induced changes modify the ecosystem, but these disturbances, in most cases, are poorly quantified and, as a result, their ecological states are poorly understood (Walters et al., 2006).

Several authors have documented the unprecedented loss in biodiversity as a result of deforestation in Cameroon using LULC remote sensing techniques. Temgoua et al. (2018) analyzed using LULC change and remote sensing techniques and showed ongoing deforestation with forest cover loss of about 240 ha in 30 years in Ajei Upland Watershed Community forest of North West Region, Cameroon. Mahmoud et al. (2020) investigated historical land-cover dynamics in unprotected forested areas of the Littoral Region in south-western Cameroon between 1975 and 2017, to detect changes that may influence this important biodiversity and wildlife area and found that the area of high-value forest landscapes decreased by c. 420000 ha, and increasing forest fragmentation caused a decline of c. 12% in the largest patch index. Fonge et al. (2018) investigated land-use changes in a peri-urban forest reserve of Barombi Mbo subject to anthropogenic influence and assessed the extant plant community structure through various indices and found that there is active forest conversion into farmland, and this conversion affected surrounding water bodies, with new guilds of species dominating under anthropogenic activities. A plethora of other researchers have employed approaches other than remote sensing to elucidate changes in biodiversity, especially around the Mount Cameroon region (Cheek et al., 1996; Sunderland et al., 2003; Check et al., 2004; Tchouto, 2004; Focho *et al.,* 2009a; Focho et al., 2010; Nkwatoh et al., 2010), but relatively little work has been conducted on biodiversity of Tubah Sub-Division, Northwest region of Cameroon, which embodies a wide variety of plant and animal taxa with ecological and socioeconomic importance. This area is rich in biodiversity, but suffers from high human pressure, expressed via anthropogenic activities. Land use change detection is often conducted to critically discern trends, causes, and their impacts on the landscape to enhance decision-making for conservation of biodiversity and ecological functions (Cheung et al., 2014). Adequate research on LULC is necessary without which policies related to land use and ecosystem services may not be aligned with practical realities on the ground. There Is limited knowledge on the rate of LULC changes together with the implications on biodiversity. The objectives of the study were to evaluate LULC changes in Tubah Sub-Division from 1986 to 2017 and to determine plant diversity and abundance in areas with different land uses.

2. Methods

2.1. Study site

Tubah Sub-Division is found in the North West Region of Cameroon, located about 15 km from Bamenda which is the regional capital. It is located between latitude 4°50′ - 5°20′N and longitude 10°35′ - 11°59′E. The altitude ranges between 950-1500 m above sea level, with flat woody lowlands in some areas (Figure 1). Its forested area is located in the northern part of the sub-division. Tubah has a surface area of 365 km^2, giving a population density of 145 persons/km^2 (United Councils and Cities of Cameroon National Office Website, 2015). It consists of four main villages Bambili, Bambui, Kedjom-keku, and Kedjom-ketingoh, with a total population of about 52,635 inhabitants (Helvetas, 2001). Tubah has a surface area of 365 km^2, giving a population density of 145 persons/km^2 (Nguh & Maluh, 2017).

Vegetation Cover and Distribution of the Tubah Community

Tubah is located in the belt where the environment is rich with grass as a result of the fairly rich soil in the area. A good portion of the area is covered with few forest patches (for example the Kedjom-keku forest) with lots of Eucalyptus trees. Eucalyptus lies mostly in the low-lying plains while woody valleys and natural forests exist in the watershed area (Helvetas, 2001). Unsustainable farming practices have largely destroyed the forest vegetation to an extent and depleted soil fertility. Similarly, years of overgrazing, burning of grasses, and increasing herd size, have severely degraded the remaining patches of grasslands. The present vegetation of Tubah consists mainly of the savannah ecosystem, with the Poaceae forming the main vegetation layer interspersed with a few other annuals, perennials, and trees (Ngwa & Fonjong, 2002a). The cultivated vegetation consists of planted trees like cola nut, eucalyptus, raffia palm, and other fruit trees. The dry and rainy seasons have a huge influence on agriculture and on vegetation as most plants dry up during the dry season and turn green during the rainy season.

Climate

The climate variation fits into two seasons; the dry and rainy seasons. In general, this area experiences a tropical highland climate. The rainy season stretches from March to October and is characterized by heavy rains brought in by the Southwest monsoon winds. The dry season begins in November and extends to February and is driven by the Northeast Trade winds and/or Harmattan. It is characterized by strong sunshine during the day and very cold nights. There is lots of dust during the dry season that covers the roads which in turn produces lots of mud in the rainy season (Helvetas, 2001).

The mean annual temperature is about 20.67°C with January and February having the highest temperatures and July, August, and September having the lowest (Yuninui, 1990). The mean minimum temperature ranges from 13^0C- 14^0C and the mean maximum temperature ranges from 20^0C- 22^0C. November records the lowest mean minimum temperature, while the highest mean maximum is recorded in December.

Rainfall varies from 1780mm to 2290mm per year. Heavy rainfall is usually experienced in the months of July to September. There is high humidity during the months of July and August, and low in January and February. Low clouds and mist occur during the rainy season (Kiteh, 2011).

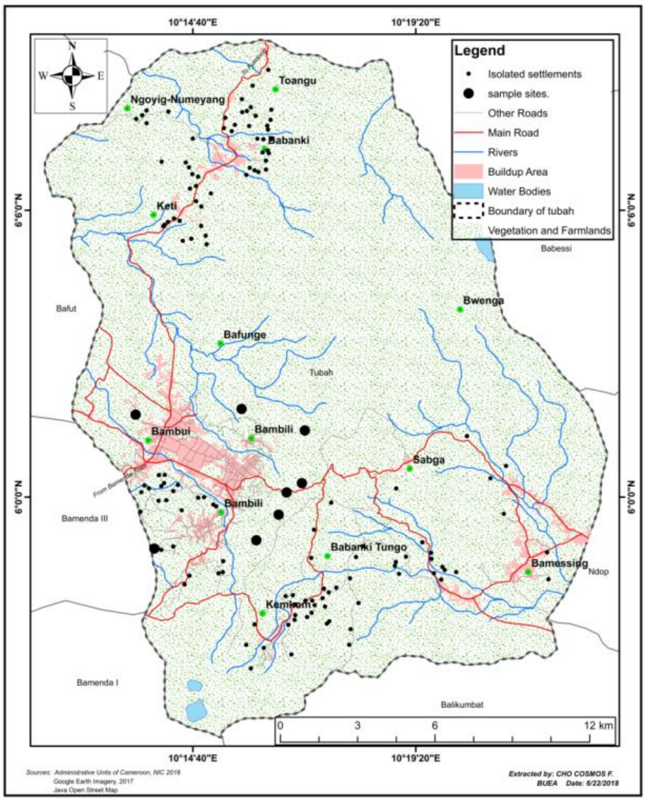

Figure 1. Map of Tubah Sub Division, Northwest Region, Cameroon

2.2. Methods

2.2.1 Ecological Sampling of the Different Sites

A reconnaissance survey was conducted in the study area in June 2017, and study sites were selected based on four different land use patterns. Surveys were conducted in the study area from July to December 2017. During the study, four semi-permanent plots with dimensions of 50 x 50 meters each were established in each of the study sites. The sample plots selected were a secondary forest, fallow land (a piece of land that was cultivated and then left for a period of time without cultivation, approximately 10 years and above), permanent grazing land, and agricultural land. Each semi-permanent plot has 25 sub-plots with dimensions of 10 x 10 meters.

For the secondary forest, fallow land, and permanent grazing land, all trees and shrubs in each sub-plot with DBH (diameter at breast height = 1.3 meters from the ground) ≥ 10 mm were measured for their DBH and height, and three sub-plots of 2 x 2 m were established for the herbs and grasses. Standard methods were used in plant material collection, drying, mounting, preparation, and preservation. Three specimens were collected for each species, and taxonomic identification was conducted using regional floras and matching specimens (Holmgren *et al.,* 1990), and later validated at the Cameroon National Herbarium (YA).

2.2.2 Land cover change in the study area

The different land cover changes and the anthropogenic activities associated with these changes were identified and their GPS points were recorded. Remotely-sensed Images TM, ETM of the years 1986, 1996, 2006 and 2017 were downloaded from the Global Land Cover Facility (GLCF) at 30 meters resolution. The images were geo-referenced and geo-coded. These were then classified using supervised maximum likelihood 7 parametric classifiers in ArcGIS image analysis software version 9.3. The GPS coordinates were collected from four land use categories; forest, settlement, water, and bare ground.

2.2.3 Data Analyses

Plant Diversity Analysis

Data on plant diversity was imported into Microsoft Excel 2007 and was grouped according to land use; secondary forest, fallow land, permanent grazing land, and agricultural land. Species diversity was determined using the Shannon-Weiner Diversity Index.

$$(H') : H = (Pi)(\text{logn } Pi) \quad (1)$$

Where $Pi = ni/N$; ni = number of individuals of species i; N = total number of individuals (Magaurran, 1988). Sorensen similarity matrix for plant species diversity was computed across sites.

Data on mean diameters for grazing land, fallow land, and secondary forest were subjected to bootstrap analysis with 200 re-samples at 95% CI in the XLSTAT package (Kovach Computing Service, 2018).

Existing land use and anthropogenic activities

Colour composites of bands 7-4-2 were used to display images in standard colour composites for land use and vegetation mapping (Trotter, 1998). The maps were compared on a pixel by pixel basis. Change detection of the various land cover categories was done by comparing land cover statistics (Boakye et al., 2008). Annual rates of change of land cover types were calculated by dividing the total change in cover type (in ha) within each period by the number of years between them.

3. Results

3.1. Plant diversity

A total of 173 species were recorded in all the sites belonging to 63 families and 146 genera (Table 1). Out of the 173 species identified, 48 species were trees, 28 species were shrubs, 10

Table 1. Species of the Tubah community and their vegetation abundance across sites

Code	Family	Species	Author(s)	Secondary Forest	Fallow Land	Grazing Land	Agricultural Land	Total	Rel. abun.
AALC	Campanulaceae	*Lobelia columnaris*	Hook.f.	2	1	3	-	6	0.31
AAPG	Lamiaceae	*Plectranthus glandulosus*	Hook.f.	-	1	2	-	3	0.16
AATG	Combretaceae	*Terminalia glaucescens*	Planch. ex. Benth.	-	5	3	-	8	0.41
AARM	Phyllanthaceae	*Bridellia micrantha*	(Hochst.) Baill	21	3	-	-	24	1.24
ABAB	Sapindaceae	*Allophylus bullatus*	Radlk.	24	-	-	-	24	1.24
ABFM	Moraceae	*Ficus mucosus*	Welw. Ex. Ficalho	-	2	-	-	2	0.10
ABGG	Thymelaeaceae	*Gnidia glauca*	(Fres.) Gilg.	8	-	-	-	8	0.41
ABJI	Acanthaceae	*Justicia insularis*	T. Anders.	1	-	-	-	1	0.05
BAGL	Rhamnaceae	*Gouania longipetala*	Hemsl.	2	-	-	-	2	0.10
BAPF	Araliaceae	*Polyscias fulva*	(Hiern) Harms	3	10	-	-	13	0.67
BBVA	Asteraceae	*Vernonia amygdalina*	Del. Cent.	8	5	-	2	15	0.78
BCSN	Solanaceae	*Solanum nigrum*	(L.) Rouy.	-	-	-	23	23	1.19
BEAA	Fabaceae	*Albizia adianthifolia*	(Schumach.) W. F. Wight	5	-	-	-	5	0.26
BEAZ	Fabaceae	*Albizia zygia*	(DC.) J.F.Macbr.	6	10	19	-	35	1.81
BEDA	Dracaenaceae	*Dracaena arborea*	(Willd.) Link.	-	-	-	-	-	-
BEEG	Myrtaceae	*Eucalyptus grandis*	W. Hill ex Maiden.	-	17	-	-	17	0.88
BEVD	Verbenaceae	*Vitex doniana*	Sweet.	-	5	-	-	5	0.26
BRMI	Anacardiaceae	*Mangifera indica*	L.	-	-	-	-	-	-
BSML	Myrsinaceae	*Maesa lancoelata*	Mez.	34	3	-	-	37	1.92
CBPA	Lauraceae	*Persea Americana*	Mill.	-	-	10	-	10	0.52
CBPT	Pittosporaceae	*Pittosporum tenuifolium*	(Hook.f.) Kirk,	-	-	4	-	4	0.21
CDBE	Melianthaceae	*Bersama engleriana*	(Guerke) Verdc.	2	-	-	-	2	0.10
CDPV	Pittosporaceae	*Pittosporum viridis*	Banks ex sol.	35	-	4	-	39	2.02
CDVI	Myrtaceae	*Callistemon viminalis*	(Gaertn.)	-	-	-	-	-	-
CEFS	Moraceae	*Ficus sur*	Forsk.	-	8	-	-	8	0.41
CEAV	Asphodeaceae	*Aloe vera*	(L.) Burm.	-	-	-	-	-	-
DFCL	Rutaceae	*Citrus limon*	(L.) Burm. f.	-	-	-	-	-	-
DGSR	Malvaceae	*Sida rhombifolia*	(L.) Ugbor.	2	3	-	-	5	0.26
DJCA	Rutaceae	*Clausena anisata*	(Willd.) Hook.f. ex Benth.	19	6	-	-	25	1.29

Table 1. Species of the Tubah community and their vegetation abundance across sites (cont'd)

Code	Family	Species	Author(s)	Secondary Forest	Fallow Land	Grazing Land	Agricultu ral Land	Total	Rel. abun.
DIPG	Guttifereae	*Psorospermum guineense*	(L.) Hochr.	-	1	1	-	2	0.10
DMLE	Solanaceae	*Lycopersicon esculentum*	(L.) Mill.	-	-	-	297	297	15.37
DMTG	Ulmaceae	*Trema guineensis*	(Schum.& Thonn.) Ficalho	6	-	-	-	6	0.31
DNHR	Guttifereae	*Hypericum riparium*	A.Chev.	-	-	43	-	43	2.22
DPAC	Alangiaceae	*Alangium chinense*	Lour. Harms.	-	9	-	-	9	0.47
DPCM	Euphorbiaceae	*Croton macrostachyus*	Hochst. ex Delile	17	38	46	-	101	5.23
FBCG	Meliaceae	*Carapa grandiflora*	Sprague.	3	-	-	-	3	0.16
FIPM	Anacardiaceae	*Pseudospondias microcarpa*	Rich.) Engl.	-	2	-	-	2	0.10
FJEA	Fabaceae	*Entada Africana*	Guill. & Perr.	-	13	-	-	13	0.67
FJHL	Guttiferae	*Hypericum lanceolatum*	Lam.	8	-	-	-	8	0.41
GBZO	Zingiberaceae	*Zingiber officinale*	Roscoe.	-	-	-	4	4	0.21
GBAC	Bromeliaceae	*Ananas comosus*	(L.) Merr.	-	-	-	-	-	-
GUPA	Rubiaceae	*Psychotria angolensis*		9	-	-	-	9	0.47
GUPC	Piperaceae	*Piper capense*	Linn.	4	2	-	-	6	0.31
GVOB	Lamiaceae	*Oscimum basilicum*	(Willd.) Benth.	-	-	-	46	46	2.38
HBAV	Acanthaceae	*Asystacia vogeliana*	Benth.	1	-	-	-	1	0.05
HBAG	Acanthaceae	*Asystacia gangentica*	(L.) T. Anders.	1	-	-	-	1	0.05
HDOG	Lamiaceae	*Oscimum gratissimum*	Linn.	-	-	-	2	2	0.10
HFAA	Asteraceae	*Aspillia Africana*	(Pers.) C.D. Adams.	-	-	8	-	8	0.41
IAPP	Sapindaceae	*Paullinia pinnata*	L.	-	6	-	-	6	0.31
ICID	Balsaminaceae	*Impatiens disotis*	Hook.f.	1	5	-	-	6	0.31
IDMP	Musaceae	*Musa paradisiacal*	(L.) Kuntze.	-	-	-	1	1	0.05
IDMS	Musaceae	*Musa sapientum*	(L.) Kuntze.	-	-	-	1	1	0.05
IFCS	Rutaceae	*Citrus sinensis*	(L.) Osb.	-	-	-	-	-	-
IHDC	Apiaceae	*Daucus carota*	L.	-	-	-	89	89	4.61
IMLL	Fabaceae	*Leucaena leucocephala*	(Lam.) De Wit.	-	-	3	-	3	0.16
LAMP	Fabaceae	*Mimosa pudica*	L.	-	-	2	-	2	0.10
LBNC	Stilbaceae	*Nuxia congesta*	R.Br. ex. Fresen.	47	-	-	-	47	2.43

Table 1. Species of the Tubah community and their vegetation abundance across sites (cont'd)

Code	Family	Species	Author(s)	Secondary Forest	Fallow Land	Grazing Land	Agricultural Land	Total	Rel. abun.
LBOC	Oleaceae	*Olea capensis*	L.	39	-	-	-	39	2.02
LBPS	Rubiaceae	*Psychotriastrictistipula*		12	-	-	-	12	0.62
LCTM	Moraceae	*Trilepisium madagascariense*	DC.	71	-	-	-	71	3.67
LDTM	Combretaceae	*Terminalia mentali*	H. Perrier.	-	1	-	-	1	0.05
LDUP	Fabaceae	*Uraria picta*	(Jacq.) DC.	8	-	-	-	8	0.41
MAFT	Moraceae	*Ficus thonningii*	Blume.	1	9	-	-	10	0.52
MAPP	Rubiaceae	*Psychotria peduncularis*	(Salisb.) Steyerm.	14	9	13	-	36	1.86
MBAS	Agavaceae	*Agave sisalana*	Perrine.	-	1	-	-	1	0.05
MCMT	Bignonaceae	*Markhamia tomentosa*	K. Schum. Ex Engl	-	6	-	-	6	0.31
MDSE	Apiaceae	*Sanicula elata*	Buch.-Ham. ex D. Don	-	2	-	-	2	0.10
MFPA	Rosaceae	*Prunus Africana*	(Hook. f.) Kalkman.	4	4	-	-	8	0.41
MFRC	Euphorbiaceae	*Ricinus communis*	L.	-	-	-	-	-	-
MIST	Solanaceae	*Solanum tuberosum*	L.	-	-	-	32	32	1.66
MIVG	Lamiaceae	*Vitex glabrata*	R.Br.	1	-	-	-	1	0.05
NACS	Asteraceae	*Conyza sumatrensis*	(L.) Cronquist.	-	-	-	72	72	3.73
NAAC	Asteraceae	*Ageratum conyzoides*	L.	-	-	-	134	134	6.94
NACC	Poaceae	*Cymbopogon citratus*	(DC.) Stapf.	-	-	-	12	12	0.62
NCDS	Rubiaceae	*Diodia scandens*	Swart.	-	1	-	-	1	0.05
NDCC	Fabaceae	*Calliandra calothyrsus*	Meissner.	-	2	1	-	3	0.16
NDES	Acanthaceae	*Eremomastax speciosa*	(Hochst.) Cufod.	-	1	-	-	1	0.05
NDPB	Commelinaceae	*Palisota barteri*	Hook. f.	1	3	5	-	9	0.47
NIAV	Rosaceae	*Alchemilla vulgaris*	L.	-	5	3	-	8	0.41
NJTV	Fabaceae	*Tephrosia vogelii*	Hook. f.	-	9	1	-	10	0.52
NJBZ	Poaceae	*Brachiaria ruziziensis*	R.Germ.	-	-	48	-	48	2.48
NOPP	Poaceae	*Pennisetum purpureum*	Schumach.	-	-	17	-	17	0.88
NORI	Arecaceae	*Raphia indica*	G. Mann.	-	1	1	-	2	0.10
NPCD	Poaceae	*Cynodon dactylon*	(L.) Pers.	-	5	-	-	5	0.27
NPO	Lamiaceae	*Oscimum sp*		1	6	-	-	7	0.36
NPEH	Euphorbiaceae	*Euphorbia hirta*	L.	-	-	-	41	41	2.12
NPPC	Apiaceae	*Petroselinum crispum*	(Mill.) A. W. Hill.	-	-	-	11	11	0.57
PAAG	Apiaceae	*Apium graveolens*	L.	-	-	-	13	13	0.67
PACB	Lamiaceae	*Coleus blumei*	Viroid 1.	-	-	2	-	2	0.10
PAKA	Bignonaceae	*Kigelia Africana*	(Lam.) Benth.	-	8	-	3	11	0.57
PCME	Euphorbiaceae	*Manihot esculenta*	Crantz.	-	-	-	15	15	0.78

Table 1. Species of the Tubah community and their vegetation abundance across sites (cont'd)

Code	Family	Species	Author(s)	Secondary Forest	Fallow Land	Grazing Land	Agricultural Land	Total	Rel. abun.
PCAD	Zingiberaceae	*Aframomum danielli*	K. Schum.	-	11	-	-	11	0.57
PGBA	Begoniaceae	*Begonia adpressa*	Sosef.	1	2	-	-	3	0.16
PGFE	Moraceae	*Ficus estrangulata*	.	1	17	-	-	18	0.93
PJDI	Fabaceae	*Desmodium incanum*	D.C.	-	1	3	-	4	0.21
RAC	Poaceae	*Calamagrostis sp*		-	1	-	-	1	0.05
RASA	Malvaceae	*Sida acuta*	Burm.f.	1	4	4	-	9	0.47
RASS	Loganiaceae	*Strychnos staudtii*	Gilg.	1	-	-	-	1	0.05
RCB	Poaceae	*Arundinaria alpina*	K. Schum.	-	2	-	-	2	0.10
RCCB	Commelinaceae	*Commelina benghalensis*	L.	-	-	-	6	6	0.31
RCPR	Arecaceae	*Phoenix reclinata*	Jacq.	-	-	2	-	2	0.10
RDBN	Arecaceae	*Bismarckia nobilis*	Hildebr. & H.Wendl.	-	3	-	-	3	0.16
RDPU	Piperaceae	*Piper umbellatum*	L.	-	1	-	-	1	0.05
RDCE	Araceae	*Colocasia esculenta*	(L.) Schott.	-	-	-	2	2	0.10
REXA	Annonaceae	*Xylopia africana*	(Benth.) Oliv.	-	2	-	-	2	0.10
SAAT	Amaranthaceae	*Amaranthus tricolor*	L.	-	-	-	6	6	0.31
SAAS	Amaranthaceae	*Achyranthes aspera*	Linn.	-	1	-	-	1	0.05
SAHM	Guttifereae	*Harungana madagascariensis*	Lam.ex Poir	-	-	22	-	22	1.14
SARV	Apocynaceae	*Rauvolvia vomitoria*	Afzel.	2	23	2	-	27	1.40
SCFF	Flacourtiaceae	*Flacourtia flavescens*	Willd.	-	11		-	11	0.57
SDEC	Asteraceae	*Emilia coccinea*	(Sims) G. Don.	-	-	6	13	19	0.98
SEBP	Asteraceae	*Bidens pilosa*	L.	-	-	-	8	8	0.41
SEPG	Myrtaceae	*Psidium guajava*	L.	-	-	37	-	37	1.92
SGEM	Asteraceae	*Elephantopus mollis*	Kunth.	-	-	2	-	2	0.10
STES	Fabaceae	*Erythrina senegalensis*	DC.	5	9	1	-	15	0.78
STFA	Moraceae	*Ficus asperifolia*	Miq.	-	8	-	-	8	0.41
STHA	Malvaceae	*Hibiscus acetosella*	Welw. ex Hiern.	-	-	4	-	4	0.21
TAPN	Polygonaceae	*Polygonum nepalense*	Meisn.	-	4	-	-	4	0.21
TBCM	Arecaceae	*Caryota mitis*	Lour.	-	6	2	-	10	0.52
TDCM	Asteraceae	Crassocephalum mannii	(Hook.f.) Milne-Redh.	3	3	-	-	6	0.31

Table 1. Species of the Tubah community and their vegetation abundance across sites (cont'd)

Code	Family	Species	Author(s)	Secondary Forest	Fallow Land	Grazing Land	Agricultural Land	Total	Rel. abun.
TDDE	Burseraceae	*Dacryodes edulis*	(G. Don) H.J Lam.	-	-	-	1	1	0.05
TGBC	Brassicaceae	*Brassica campestris*	Linn.	-	-	-	5	5	0.26
TGZM	Poaceae	*Zea mays*	L.	-	-	-	308	308	15.94
UBAT	Rutaceae	*Araliopsis tabouensis*	Aubrev. & Pellegr.	31	-	-	-	31	1.60
UBCS	Rubiaceae	*Canthium subcordatum*	DC.	9	-	-	-	9	0.47
UCBS	Sapindaceae	*Blighia sapida*	Koenig.	7	-	-	-	7	0.36
VACP	Caricaceae	*Carica papaya*	L.	-	-	-	1	1	0.05
VATF	Portulacaceae	*Talinum fruticosum*	(L.) Juss.	-	-	-	4	4	0.21
VBTO	Cucurbitaceae	*Telfairia occidentalis*	Hook.f.	-	-	-	6	6	0.31
VDBO	Brassicaceae	*Brassica oleracea*	Plenck.	-	-	-	2	2	0.10
VDGM	Fabaceae	*Glycine max*	(L.) Merr.	-	-	-	7	7	0.36
VGPV	Fabaceae	*Phaseolus vulgaris*	L.	-	-	-	120	120	6.21
WAOS	Salicaceae	*Oncoba spinosa*	Forssk.	1	-	-	-	1	0.05
WASC	Bignoniaceae	*Spathodea campanulata*	P. Beauv.	-	5	-	-	5	0.26
WBAH	Fabaceae	*Arachis hypogaea*	L.	-	-	-	11	11	0.57
WBCP	Cucurbitaceae	*Cucurbita pepo*	L.	-	-	-	4	4	0.21
WCPP	Piperaceae	*Peperomia pellucida*	L. Kunth.	1	-	-	-	1	0.05
WCSA	Araliaceae	*Schefflera abyssinica*	(Hochst. ex A.Rich.) Harms.	8	-	-	-	8	0.42
WCSP	Olacaceae	*Strombosia pustulata*	Oliv.	34	-	-	-	34	1.76
Total				435	337	324	834	1932	100

species were vines, and 74 species were herbs. Eight plant species were common on three sites (secondary forest, fallow land, and grazing land) these species include; *Lobelia columnaris* (Campanulaceae), *Albizia zygia* (Fabaceae), *Croton macrostachyus* (Euphorbiaceae), *Psychotria peduncularis* (Rubiaceae), *Palisota barteri* (Commelinaceae), *Sida acuta* (Malvaceae), *Rauvolvia vomitoria* (Apocynaceae), *Erythrina senegalensis* (Fabaceae) (Table 1).

The Shannon-Wiener diversity index (H'), Pielou's Evenness (J), and the species richness (S) of the different study sites is shown in Table 2. The fallow land and secondary forest were the most diverse of all the sites with the highest index of H'= 3.09 and H'= 2.97 respectively. The least diverse was the agricultural land with H'= 1.39. The fallow land was the most even with Pielou's Evenness value of 0.93.

Table 2. Species diversity, richness, and evenness across sites

Site	*S*	*H'*	*J*
Grazing land	9	1.4	0.90
Fallow land	28	3.09	0.93
Agricultural land	9	1.39	0.66
Secondary forest	35	2.97	0.82
p-value	0.01	0.03	0.01

3.2. Species similarity

Figure 2 shows a dendrogram of similarity between the four sites. The distance correlation (ward linkage) between the fallow land and the secondary forest was minimal, showing that there are some similar plant species present in the two sites. They had a similar percentage of 74.48. The agricultural land was less similar to all the other study sites.

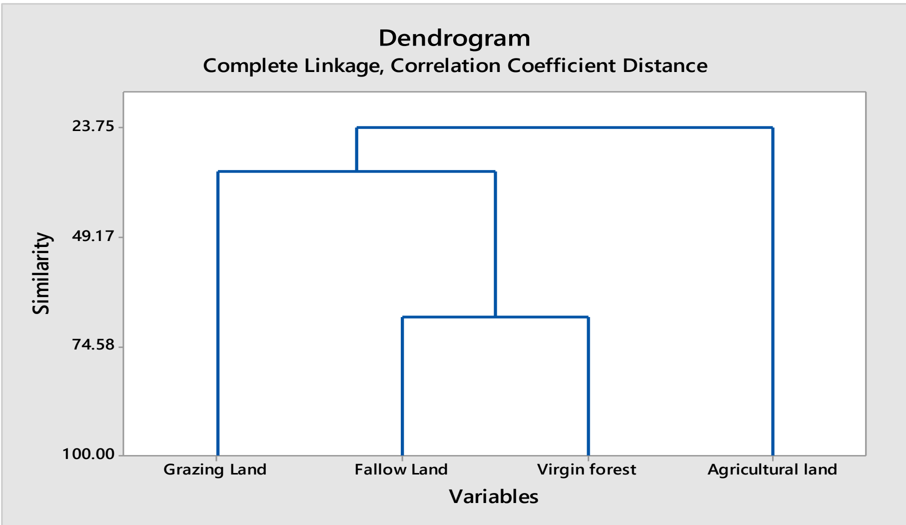

Figure 2. Dendrogram showing the similarities between the study sites

Figure 3 shows a pie chart representing the diameter class distribution between the fallow land, grazing land, and secondary forest. Trees were divided into three classes which include small trees (10-99 mm), medium trees (100-299 mm), and large trees (300 mm and above). The higher percentage of trees on the grazing land and secondary forest were found under the class of small trees, while on the fallow land, medium trees had the higher percentage. There were no large trees on the grazing land and no trees with DBH ≥ 10 mm were found on the agricultural land.

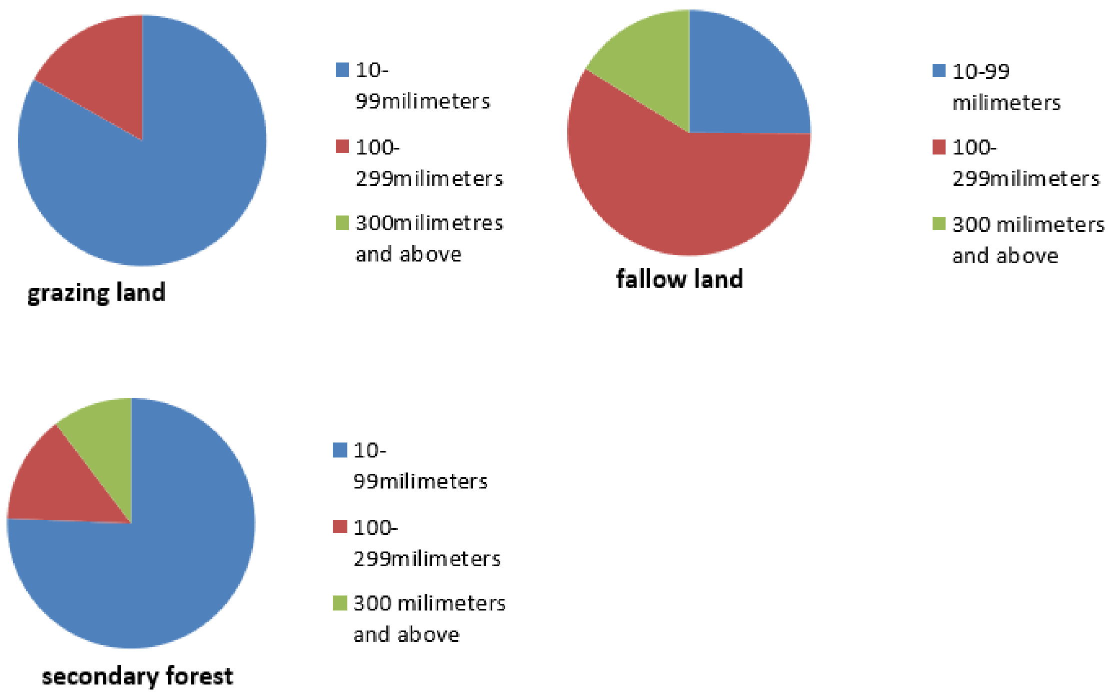

Figure 3. Diameter class distribution between grazing land, fallow land, and secondary forest

A visual appreciation of the bootstrap distribution of the mean and standard deviations is presented in Figure 4. For grazing land, the mean diameters are uniformly distributed on the normal curve and include the actual mean of the original sample. For fallow land and secondary forest, the distributions are negatively (fallow land) and positively (secondary forest) skewed.

3.3. Existing land use and anthropogenic activities

This study found that land was used in the Tubah Sub-Division villages for farming, building construction, grazing, road establishment, fallow plots, and secondary forest. The most common land use identified was building construction, followed by farming and grazing. This could be as a result of the rapidly increasing population as reported by Nguh and Maluh (2017). During the study, many activities were seen in the field, which undermine biodiversity and drive changes in LULC (Figure 5). The different anthropogenic activities observed at the time of the study included excessive logging, road construction which has resulted in deforestation and habitat fragmentation, building construction which has resulted in a total change of land use and complete loss of vegetation cover, agricultural activities which resulted firstly in the complete removal of vegetation cover followed by replacement with a monocrop, the application of agrochemicals, and grazing activity.

3.4. Trends of land cover change

From the classified maps, five classifications were identified based on the inability to clearly separate green vegetation from the forest with that of agricultural land and other vegetation types as a result of the cloud cover. The five classification types include vegetation, bare ground, settlement, water, and crater (Table 3).

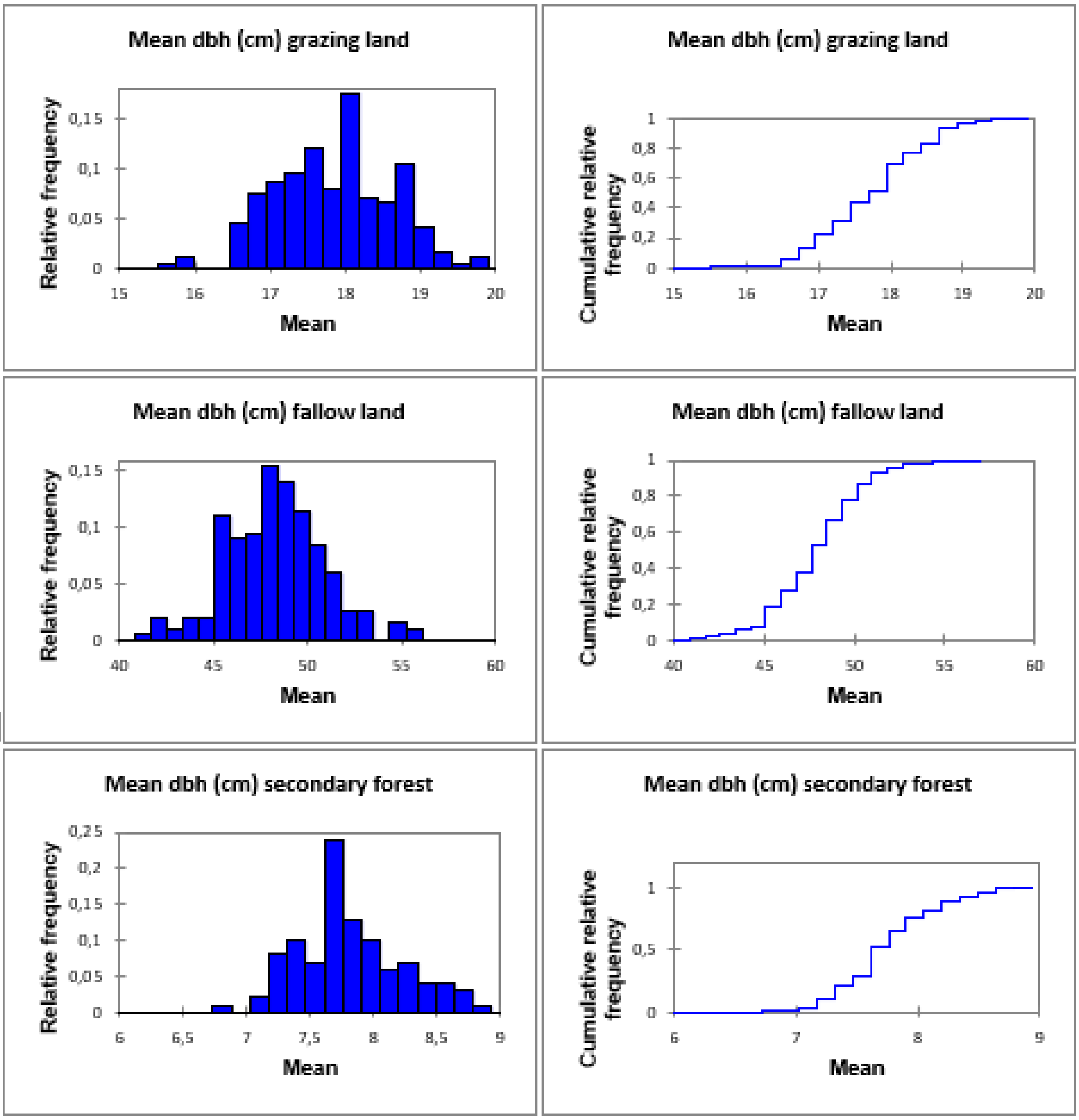

Figure 4. Graphical representation of the bootstrap distribution of the sample mean

The raster images in in 1986, 1996, 2006, and 2017 are presented in Figure 6 and Figure 7. Vegetation cover loss recorded was 90.24 ha from 1986-1996, 23.76 ha from 1996-2006, and 86.70 ha from 2006-2017. Settlement areas increased by 63.64 ha from 1986-1996, 53.37 ha from 1996-2006, and 15.36 ha from 2006-2017. Water was reduced from 1986-1996 by 7.34 ha, 14.28 ha from 1996-2006, and 3.56 ha from 2006-2017. Bare ground increased by 135.88 ha from 1986-2017 (Table 4).

Figure 5. Anthropogenic Activities in Tubah (a) Logging (b) Road Construction (c) Building Construction (d) Farming € Grazing

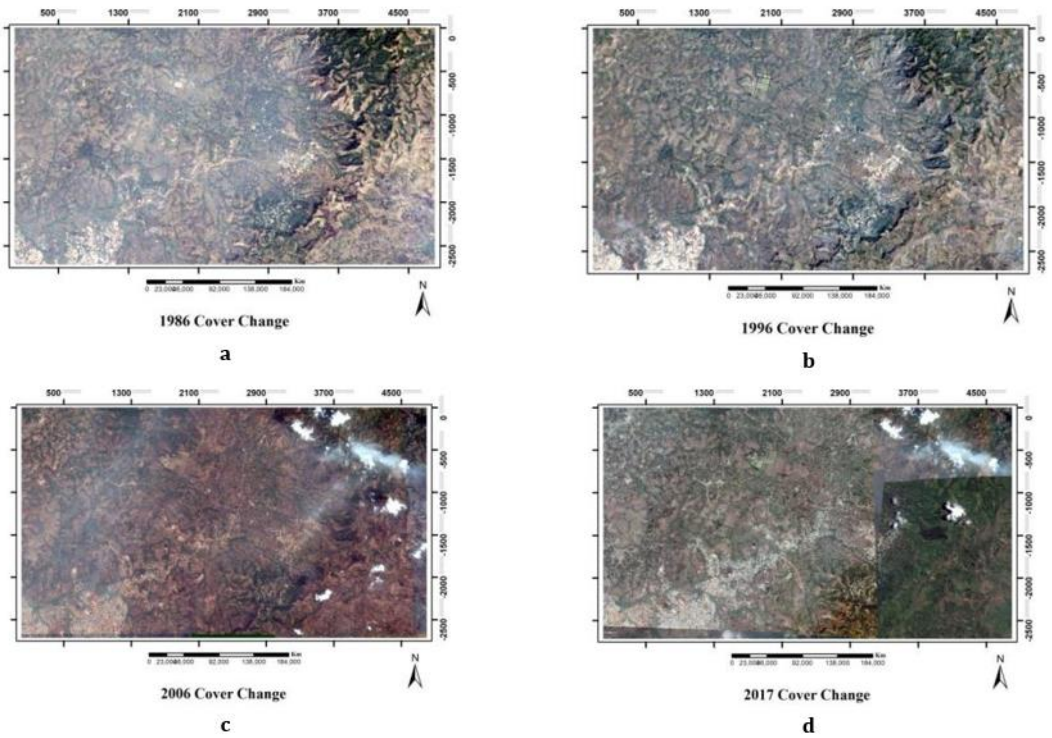

Figure 6. Unclassified raster images (a) 1986 (b) 1996 (c) 2006 (d) 2017

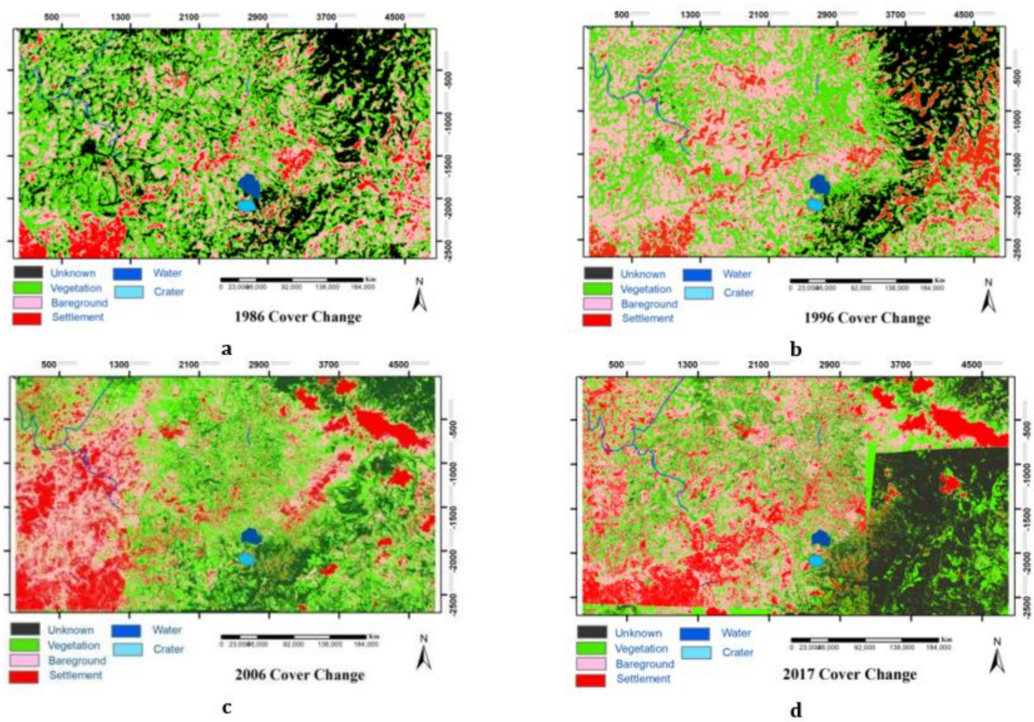

Figure 7. Classified maps of raster images (a) 1986 (b) 1996 (c) 2006 (d) 2017

Table 3. Surface cover areas of different land uses of the tubah Sub-Division for the years 1986, 1996, 2006 and 2017, with cover changes and percentage change from 1986-1996 (10 yrs.), 1996-2006 (10 yrs.), 2006-2017 (11 yrs.) and 1986-2017 (31 yrs)

Cover Type	**Land Cover For Different Years**				**Changes in Surface Area, Annual Changes, and Changes Percentage**											
					1986-1996			**1996-2006**			**2006-2017**			**1986-2017**		
	1986	**1996**	**2006**	**2017**	**Total change in (Ha)**	**Annual change (Ha/Yr)**	**%**	**Total chang e in (Ha)**	**Annual change (Ha/Yr)**	**%**	**Total change in (Ha)**	**Annual change (Ha/Yr)**	**%**	**Total change in (Ha)**	**Annual change (Ha/Yr)**	**%**
Unknown	278.09	168.81	223.45	335.58	-109.28	-10.93	-3.93	54.63	5.46	3.24	112.14	10.19	4.56	57.49	5.75	2.07
Vegetation	552.43	462.19	438.44	351.73	-90.24	-9.02	-1.63	-23.76	-2.38	-0.51	-86.70	-7.88	-1.80	-200.70	-20.07	-3.63
Bare Ground	379.57	405.77	415.84	515.45	26.20	2.62	0.69	10.07	1.01	0.25	99.61	9.06	2.18	135.88	13.59	3.58
Settlement	94.55	158.19	211.56	226.92	63.64	6.36	6.73	53.37	5.34	3.37	15.36	1.40	0.66	132.37	13.24	14.00
Water	74.73	67.39	53.11	49.55	-7.34	-0.73	-0.98	-14.28	-1.43	-2.12	-3.56	-0.32	-0.61	-25.18	-2.52	-3.37
Crater	32.00	28.89	19.34	14.00	-3.11	-0.31	-0.97	-9.55	-0.95	-3.30	-5.34	-0.49	-2.51	-18.00	-1.80	-5.63

Table 4. Accuracy classified confusion matrix for 1986, 1996, 2006, and 2017 images

Classes Type	**1986**		**1996**		**2006**		**2017**	
	Prod. acc. (%)	**User acc. (%)**	**Prod. acc. (%)**	**User acc (%)**	**Prod. acc. (%)**	**User acc (%)**	**Prod. acc. (%)**	**User acc (%)**
Vegetation	100.00	77.09	76.43	100.00	100.00	97.33	98.21	90.00
Bare Ground	97.29	100.00	88.99	92.13	78.41	100.00	100.00	89.24
Settlement	69.73	92.81	74.12	86.36	89.02	93.62	100.00	100.00
Water	83.01	100.00	100.00	92.31	100.00	86.90	91.94	97.85
Crater	77.90	87.32	100.00	94.22	98.88	100.00	83.10	99.98
Overall Accuracy	98.4361		88.9532		96.3671		98.1925	
Kappa Coefficient	0.9722		0.8748		0.9473		0.9699	

4. Discussion

4.1. Species diversity in the study area

The tropical regions are known to contain more than half of the global species diversity, and this vegetation is often subjected to rapidly increasing anthropogenic pressure which leads to biodiversity loss (Barlow et al, 2018). The North Western region of Cameroon is generally known to be covered by grassland vegetation, even though it also consists of a series of secondary forests. In the study area, a majority of the representative species were herbaceous plants and the most dominant family was the Fabaceae and Asteraceae. This result was similar to the findings of Simbo (2010) who reported that the Asteraceae was the most dominant plant family in Babungo, Northwest region of Cameroon. Focho et al. (2010) also reported that there was a scarcity of natural forests in the Northwest region of Cameroon. The secondary forest had more species represented than the rest of the other sites; this could be due to the reduced effect of anthropogenic influences as compared to the other sites, resulting in the conservation of biodiversity.

A plant community is said to be rich if it has a Shannon diversity value of ≥3.5, (Kent & Coker, 1992). In this study, all our sites reported a Shannon-Weiner diversity indices value of below 3.5, making the community relatively poor in diversity. The fallow land was the most diverse community in the area followed by the secondary forest. This could be due to the presence of emergent and successional species reappearing on a previously disturbed area (fallow land), i.e. reconstitution of vegetation and also the reduced disturbance on the secondary forest. The agricultural land was the most even of all study sites. This could be due to the manual and uniform arrangement of crop species during cultivation.

From the bootstrap analysis, the grazing land was evenly distributed, while the fallow land was negatively skewed and the secondary forest positively skewed. This could be a result of reduced anthropogenic influences on the fallow land and secondary forest as compared to the grazing land. Thus, this is an indication that there are significant differences in the diversity and distribution of species between the sites.

4.2. Land use and land cover changes (LULC)

Tubah Sub-Division has undergone remarkable changes in its LULC situation over time and space from 1986 to 2017. The LULC statistics in Tubah Sub-Division indicate that there has been a steady growth in settlement and bare ground at the expense of vegetation cover.

The rate of change of these land cover classes based on GIS shows that vegetation cover declined or reduced drastically over a period of 20 years. Vast hectares of vegetation was lost between 1986-1996 (90.24ha), this decreased between 1996-2006 (23.76 ha), and 86.7 ha decrease between 2006- 2017. This could be attributed to deforestation, agricultural projects, and unplanned development as illustrated on Plates 1 and 2. Agricultural intensification, land conversion for roads, and building or settlement were observed during the reconnaissance survey.

With respect to water, a downward trend was observed. Water bodies were found to decrease or decline by 7.34ha, 14.28 ha and 3.56 ha between the periods of 1986-1996, 1996-2006, and 2006-2017 respectively. Similar findings were made by Musetsho et al. (2021) who identified wetlands as the most affected ecosystems affected by deforestation, agricultural activities, and other developmental projects, including environmental changes. This could be attributed to high evaporation rates associated with climatic change, causing water bodies to dry up.

Results on GIS also revealed an increase in settlement. These results are similar to the findings of Nguh and Maluh (2017) who reported a steady increase in settlement and farmland in the Tubah Sub-Division from 1983-2013. According to Balgah (2007), these changes can be accounted for by human activities to meet up with their ever-increasing needs, the yearning for food crops, and social, economic, political, or financial prosperity. Residential development potentially undermines the integrity of ecosystems, especially those carried out within fragile ecosystems, bringing about a reduction in biodiversity, pollution, and habitat fragmentation.

The steady increase in the bare ground could be a result of road construction, clearing forests to create space for new agricultural fields, or even as a result of bush burning for new grazing lands. These activities have implications for the resource development in Tubah Sub-Division and result in the loss of natural biodiversity in this area, which urges planners to put forward strategies for sustainable land use planning and biodiversity conservation.

5. Conclusion

The study's outcomes are critical for future land-use planning exercises in Tubah Sub-Division, an area rich in biodiversity. LULC analysis using GIS techniques revealed significant decline in vegetation and water bodies, and an increase in settlement and bareland in the study area between 1986 and 2017. Agricultural intensification, land conversion for construction, roads, grazing, and logging were some of the main anthropogenic activities recorded during the study.

Significant differences were recorded in the plant diversity index (Shannon diversity) of the different use categories. Grazing and agricultural lands supported the lowest plant diversity ($H' < 1.4$), while fallow lands and secondary forests sustained higher plant diversities of 3.09 and 2.97 respectively.

Based on the findings of this research, it is recommended that the population of Tubah should be educated on sustainable land use planning and biodiversity conservation, thus, protecting the natural environment. The agricultural sectors should practice more sustainable agriculture so as to be able to reverse the increasing trends in biodiversity loss.

Acknowledgement

The authors gratefully acknowledge the collaboration of the villagers in the Tubah villages in this study as well as the botanists of the Cameroon National Herbarium for their help in validating the identities of specimens.

References

Awo, M.E., Fonge, B.A. and Tabot, P.T. (2019) *Ecosystem Services and Perception of Water Quality of Lake Barombi Kotto, Cameroon.* International Journal of Trends in Scientific Research & Development, 3, 1739-1746.https://doi.org/10.31142/ijtsrd23529

Balgah, S. (2007). *Population growth and land use dynamics in Buea Urban area*. Loyola of Social Science, p: 1.

Barlow, J., França, F., Gardner, T.A. *et al.* The future of hyperdiverse tropical ecosystems. *Nature* **559**, 517–526 (2018). https://doi.org/10.1038/s41586-018-0301-1

Boakye, E., Odai, S. N., Adjei, K. A., & Annor, F. O. (2008). Landsat images for assessment of the impact of land use and land cover changes on the Barekese catchment in Ghana. *European Journal of Scientific Research*, *22*(2), 269–278.

Chapin III, F., Zavaleta, E., Eviner, V. *et al.* 2000. *Consequences of changing biodiversity*. *Nature* **405**, 234–242. https://doi.org/10.1038/35012241

Chen, S., Zhang, Y. Research progress on biodiversity in the rural landscape[J]. Biodiv Sci, 2021, 29(10): 1411-1424.

Check, M., Polland, B. ., Darlyshire, I., Onana, J. ., & Wild, C. (2004). *The plants of Kupemanenguba and the BakossiMts, Cameroon: A conservation checklist*. Royal Botanic Gardens, Kew, UK.

Cheek, M., Cable, S., Hepper, F. N., Ndam, N., & Watts, J. (1996). *Mapping plant biodiversity on Mount Cameroon*. The biodiversity of African plants (pp. 110-120). Springer, Dordrecht.

Cheung, L., Austin, K., Utami, A., Bangoura, J., & Stolle, F. (2014). *Building national forest and land-use information systems: Lessons from Cameroon, Indonesia, and Peru*. *February*, 16. https://www.wri.org/sites/default/files/land-use-infomation-systems_working_paper.pdf

Dhlamini, L. (2019). *Integrating Agenda 2030 for Sustainable Development Goals (SDGs) into Regional and National Development Plans and Strategies; United Nations Development Programme*.

Focho, D.A., Newu, M.C., Anjah, M.G. Fongod A.N. and Fonge B. A. (2009). *Ethnobotanical survey of trees in Fundong, Northwest Region, Cameroon. J Ethnobiology Ethnomedicine* **5**, 17. https://doi.org/10.1186/1746-4269-5-17

Focho, D. A., Fonge, B. A., Fongod, A. G. N., & Essomo, S. E. (2010). A study of the distribution and diversity of the Family Orchidaceae on some selected lava flows of Mount Cameroon. *African Journal of Environmental Science and Technology*, *4*(March 2015), 263–273.

Fonge, B. A., Tabot, P. T., Bakia, M.-A., & Awah, C. C. (2018). Patterns of land-use change and current vegetation status in peri-urban forest reserves: the case of the Barombi Mbo Forest Reserve, Cameroon. *Geology, Ecology, and Landscapes*, *3*(2), 104–113. https://doi.org/10.1080/24749508.2018.1508981

Goldman, R. L., Pejchar Goldstein, L., & Daily, G. C. (2008). Assessing the conservation value of a human-dominated island landscape: Plant diversity in Hawaii. *Biodiversity and Conservation*, *17*(7), 1765–1781. https://doi.org/10.1007/s10531-008-9383-7

Haines-Young, Roy. (2009). Haines-Young R. Land use and biodiversity relationships. Land Use Policy. Land Use Policy. 26. 10.1016/j.landusepol.2009.08.009.

Helvetas, C. (2001). *Tubah rural council monographic study*.

Holmgren, P.K., Holmgren, N.H., and Barnett L.C.(1990). Index Herbariorum 1: The Herbaria of the World, 8th Edition. International Association for Plant Taxonomy and New York Botanical Garden, New York.

Karki, S., Thandar, A. M., Uddin, K., Tun, S., Aye, W. M., Aryal, K., Kandel, P., & Chettri, N. (2018). Impact of land use land cover change on ecosystem services: a comparative analysis on observed data and people's perception in Inle Lake, Myanmar. *Environmental Systems Research*, *7*(1). https://doi.org/10.1186/s40068-018-0128-7

Kent, M., & Coker, P. (1992). *Vegetation description and analysis*.

Khera, N., Kumar, A., Ram, J., & Tewari, A. (2001). Plant biodiversity assessment in relation to disturbances in mid-elevational forest of Central Himalaya, India. *Tropical Ecology*, *42*(1), 83–95.

Kiteh, C. C. (2011). *Stakeholder participation: Myth or reality? A case study of community water supply management in Bambui-Tubah village in Cameroon. Master thesis in Sustainable Development at the department of Earth science Uppsala University*.

Kovach, W.L. (1999) MVSP—*A Multivariate Statistical Package for Windows*, Version 3.1. Kovach Computing Services, Pentraeth.

Magaurran, A. E. (1988). *Ecological diversity and its measurement.* Princeton University Press, Princeton, New Jersey.179 pp.

Mahmoud, M. I., Campbell, M. J., Sloan, S., Alamgir, M., & Laurance, W. F. (2020). Land-cover change threatens tropical forests and biodiversity in the Littoral Region, Cameroon. *Oryx*, *54*(6), 882–891. https://doi.org/10.1017/S0030605318000881

Musetsho, K. D., Chitakira, M., & Nel, W. (2021). Mapping land-use/land-cover change in a critical biodiversity area of south africa. *International Journal of Environmental Research and Public Health*, *18*(19). https://doi.org/10.3390/ijerph181910164

Nguh, B. S., & Maluh, N. B. (2017). The implications of land use/cover dynamics on resources development in Tubah Sub-Division, Cameroon. *Journal of the Cameroon Academy of Sciences*, *14*(1), 71. https://doi.org/10.4314/jcas.v14i1.6

Nkwatoh, A. F., Labode, P., Iyassa, S. M., & Nkwatoh, F. W. (2010). Evaluation of Irvingia (I. gabonensis and I. wombulu .Bail) Trade; a major non-timber forest product in the Ejagham forest reserve of South West Cameroon. *Ethiopian Journal of Environmental Studies and Management*, *3*(1), 70–77.

Ngwa, N. S. E., & Fonjong, L. N. (2002). Actors, options and the challenges of forest management in Anglophone Cameroon. *GeoJournal*, 57, 95-111. https://doi.org/10.1023/A:1026042621101

Pandit, M. K., Sodhi, N. S., Koh, L. P., Bhaskar, A., & Brook, B. W. (2007). Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. *Biodiversity and Conservation*, *16*(1), 153–163. https://doi.org/10.1007/s10531-006-9038-5

Sala, Osvaldo & Chapin III, F Stuart & Armesto, J.J. & Berlow, Eric & Bloomfield, J. & RH, Dirzo & Huber-Sannwald, Elisabeth & Huenneke, Laura & Jackson, Robert & Kinzig, A.P. & Leemans, Rik & Lodge, David & Mooney, Harold & Oesterheld, Martín & Poff, N. & Sykes, Martin & Walker, Brian & Walker, Marilyn & Wall, Diana. (2000). Biodiversity - Global biodiversity scenarios for the year 2100. Science (New York, N.Y.). 287. 1770-4. 10.1126/science.287.5459.1770.

Simbo, David. (2010). An ethnobotanical survey of medicinal plants in Babungo, Northwest Region,

Cameroon. Journal of ethnobiology and ethnomedicine. 6. 8. 10.1186/1746-4269-6-8.
Sunderland, T. C. H., Comiskey, J. A., Besong, S., Mboh, H., Fonwebon, J., & Dione, M. A. (2003). *Vegetation assessment of Takamanda Forest Reserve, Cameroon*. Smithsonian institution, SV, pp 19-53.
Tchouto, M. G. P. (2004). *Plant diversity in a central African rainforest. Implications for biodiversity conservation in Cameroon*. PhD thesis, University of Edinburgh/Royal Botanic Garden of Edinburgh.
Temgoua, L. F., Ajonina, G., & Woyu, H. B. (2018). Land use and land cover change analysis in Ajei Upland Watershed Community Forest, North West Region, Cameroon. *Journal of Geoscience and Environment Protection*, *06*(09), 83–99. https://doi.org/10.4236/gep.2018.69007
Trotter, C. M. (1998). Characterizing the topographical effects at red wavelengths using juvenile conifer canopies. *International Journal of Remote Sensing*, *19*(11), 2215–2221.
UNEP. (2002). *Global environment outlook 3. United Nations Environment Programme, Nairobi*. http://www.unep.org/geo/geo3/
Walters, D. J. J., Kotze, D. C., & O'Connor, T. G. (2006). Impact of land use on vegetation composition, diversity, and selected soil properties of wetlands in the southern Drakensberg mountains, South Africa. *Wetlands Ecology and Management*, *14*(4), 329–348. https://doi.org/10.1007/s11273-005-4990-5
Yuninui, N. M. (1990). *Initiation practical report on Bambili Village. A research report,* Regional College of Agriculture, Bambili. Cameroon. p. 45.