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Analysis of land use land cover change dynamics in the Bali-Ngemba forest reserve, north west region of Cameroon

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Abstract
Understanding land use and land cover (LULC) changes within protected areas is key to appropriate decision making for their conservation. It is against this backdrop that this study examines LULC changes in and around the Bali-Ngemba Forest Reserve (BNFR) in Cameroon. Satellite imagery was collected from the US Geological Survey for the period 1984-2022, treated and analysed using ArcMap 10.5. From the findings, all (100%) the respondents affirm that forest cover in the BNFR has been decreasing in the past 10 years attributable to logging, agriculture expansion, fuelwood exploitation. The BNFR in 1984 had 82% (614.75ha) forest cover, 0% (0ha) shrubs and 17% (132.88ha) bare soils, rocks, and forest clearings. Between 1984 and 2003, forest cover declined by -10%, bare rocks and soil by -5.6% while shrubs gained 16.2% in coverage. Between 2003 to 2013, LULC types in the BNFR continued to change but at a gentler rate as forest and shrub cover both declined by -2% and -3% while bare rocks and soils gained 2.1% of coverage. Between 2013 and 2022, forest declined by -6.6%, bare soils and rocks by -2.3% while shrubs gained 8.8% of cover. Thus, between 1984 and 2022, the BNFR lost 142ha of forest cover to bare soils and shrubs at an annual rate of -4ha/yr., -0.8ha/yr., and -5ha/yr for the years 1984-2003, 2003-2013 and 2013-2022, respectively with the years 2003-2013 having the lowest rate of change (-0.8 ha/yr), while 2013-2022 had the highest rate of change (-5ha/yr). The results show that forest cover is decreasing with maximum annual decline rates of 1% in the BNFR attributable mainly to increased logging by the local population. A more favourable policy framework that provides alternative livelihood options to adjacent communities will help to reduce pressure on the reserve, thereby fostering conservation.

Keywords: Bali-Ngemba forest reserve, conservation, forest reserve, land use land cover change

Introduction

Species of the genus *Homo* are social mega faunal omnivorous predators and competitors whom since the Pleistocene have continued to manipulate and shape biota through the felling of trees to create space for agricultural land and infrastructural development, gather fuelwood and timber, produce charcoal and collect Non-Timber Forest Products (NTFPs) (Sandra and Yadvinder, 2022) [15]. These activities unfortunately, have fast-tracked the biodiversity decline and ecosystems loss globally, and left behind a trail of altered ecosystems and novel environmental niches resulting from land cover loss or land cover regeneration. The prime threat to biodiversity to date is man's quest for farmland and natural resources (Prakash and Verma, 2022) [13]. Anthropogenic activities have a huge effect on the physical environment (land cover) where these activities are carried out as new land is permanently created (land cover change) through the use of technology to transform the stock and flow of resources, forest clearance and the carving out of terraces on hilly terrain. With the increasing awareness on the impact of land use and land cover change (LULC) on the climate system, the study of LULC has gathered momentum within the global change research environment (Pielke *et al*., 2011; Mahmood *et al*., 2014; Houghton and Nassikas 2017) [12, 9, 6].

Tropical forest deforestation is an age-old issue (Fokeng *et al.*, 2020) [4]. Cameroon as a whole in the year 2020 lost 100,295ha of her primary forest and 202,796ha of tree cover to deforestation. At the sub national level, the North West region between 2001 and 2020 lost 25,136ha of her tree cover at a rate of 2.5%. While Mezam Division that harbors the Bali-Ngemba Forest Reserve (BNFR) amongst six (6) other reserves, within the aforementioned time frame lost 48ha of tree cover at a rate of 1.9% (Mongabay, 2019) [11].

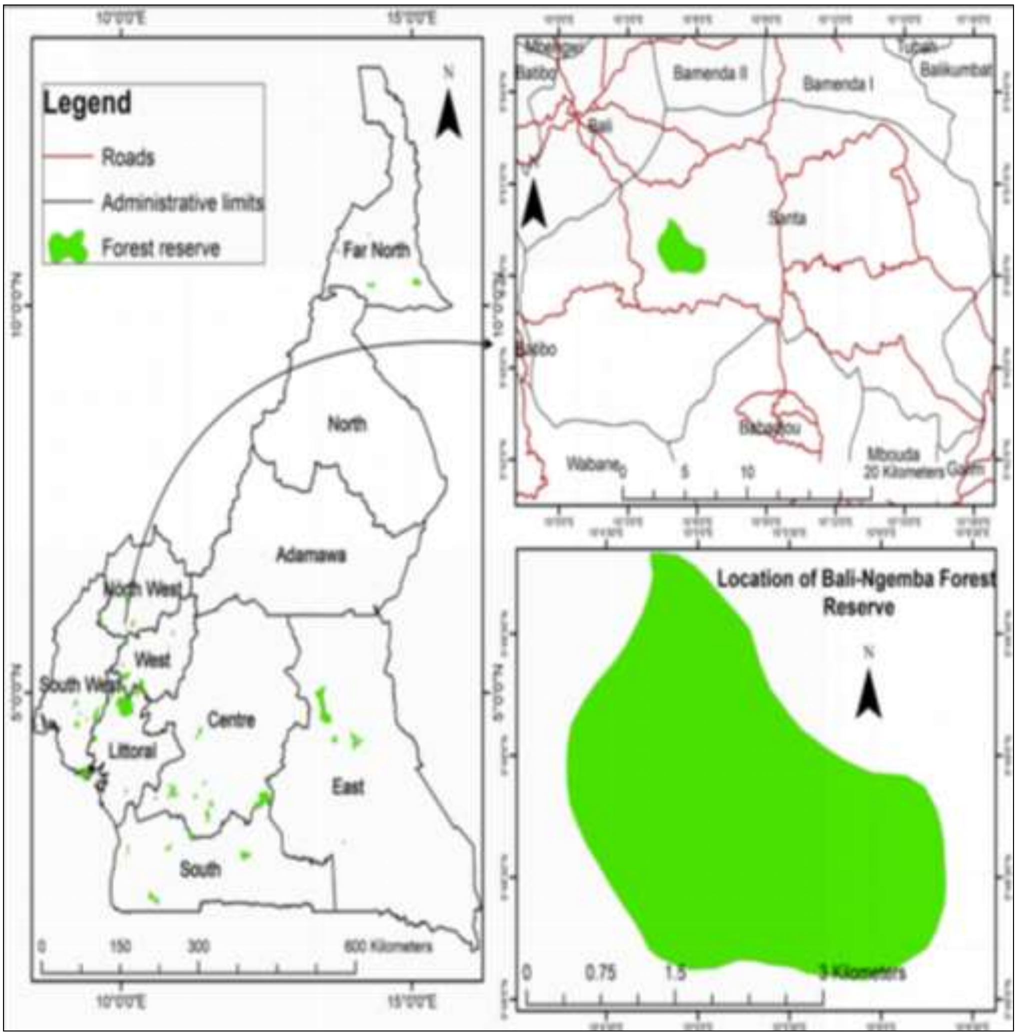
Found along the chain of volcanic mountains making up the Western Cameroon Highlands is the Bamenda Highlands which has the largest remnants of Afromontane Forest in Central Africa (Ambebe *et al.*, 2021) [1]. This region, after Cameroon's New Forest Policy (NFP) has seen the creation of seven (07) reserves including the Bali-Ngemba Forest reserve, Mendankwe communal forest reserve, Kilum-Ijim forest reserve, Bafut-Ngemba forest reserve, Mbessa Forest Reserve, the Kimbi Game Reserve, and the Mbei and Mbiame forest reserve (Samba *et al*., 2020) [14]. Of these, the Bali Ngemba is a plantation forest. Despite Cameroon's biodiversity wealth and the multitude of Protected Areas (PAs) and reserves, the populations of threatened species within Cameroon's PAs and reserves are dwindling rapidly owing to human-induced perturbations such as grazing, poaching, deforestation, encroaching farmlands, bush fires, habitat destruction and migration of species (Reeves and Meli, 2015). This assertion holds valid for the Bali Ngemba Forest Reserve that was Classified on the 21st of July 1934 as a Native Authority reserve. Since the creation, of the BNFR, fringe populations like the Mantum, Baba II, Pinyin, Mbu Baforchu and Beissen have always depended on the reserve for diverse livelihood purposes like agriculture and infrastructural development thus have gradually and steadily converted the region which was previously covered with montane forest to degraded patches of its old self. This reserve is one of the state's created reserves that is threatened by population pressure. This study therefore defines the pattern of LULC in the BNFR in the past 38 years and outlines the conservation implications of this trend.

Materials and Methods

1. Study area

The study was carried out in the Bali-Ngemba Forest Reserve (BNFR). The BNFR is located in Santa sub-division, Mezam Division, North West Region of Cameroon. Santa Subdivision is found between latitudes 5°42′and 5°53′ north of the equator and longitudes 9°58′ and 10°18′ east of the Greenwich Meridian and covers 532.67 km² *(*Konje *et al*.,2019) [8]. The BNFR (Fig 1) is one of the over 07 reserves found in the North West Region of Cameroon and was Classified on 21st of July 1934 as a Native Authority reserve. Like most forest reserves in the North West Region, it is located on a highland at an altitude ranging from 1350 to 2100m (Cheek, *et al.*, 2018; Key Biodiversity Areas Partnership, 2022) [2]. This reserve with a surface area of 905ha (Key Biodiversity Areas Partnership, 2022) is a key biodiversity area located in the valley of the Alatening stream and it is a catchment from where several streams take their rise and provide water that is used by local communities in Pinyin, Mantum, Baforchu and Baba II.

The BNFR belongs to Cameroonian type climatic zone with two main seasons i.e., long rainy season and short dry season. There is an overabundance of rains which fall during the rainy season stretching from the months of March to November. The total annual rainfall is between 2,000-3,000 mm. The dry season runs from late November to late March with temperatures oscillating between 12°C and 23°C. The very temperate climate is both humid and cool (Cheek *et al* 2018; Cheek *et al*., 2022) [2, 3].



Source: Authors' conception, 2023

Fig 1: Location of Bali-Ngemba Forest Reserve

2. Acquisition and processing of Satellite Images

The pattern of LULC was studied from 1984-2022. Multi-sensor satellite data for change detection of forest cover change dynamics in the study area was used (Table 1). The accuracy of attributed LULC classes was checked with archived and real-time Google Earth Images as well as the topo sheet of Bamenda and Bafoussam. The raw satellite data was freely obtained from the website of the US Geological Survey (https://earthexplorer.usgs.gov/). These acquired satellite images have been widely used for land change science over decades now since its coming to existence in 1972. The raw data was further processed for radiometric adjustment, band extraction and layer stacking in ArcMap 10.5. In the same direction, using the service of a remote sensing analyst, land cover/use change detection was done for different time periods of the acquired images using a supervised interactive classification technique in ArcMap 10.5. This technique classifies images based on pixel information. The pixel approach has an advantage in that, the information is obtained at the scale of a pixel which is a more precise spatial level (Desclée and Mayaux, 2014). This technique is amongst the common techniques for forest cover detection as shown by Takem-Mbi (2013) [16], Fokeng and Meli (2015) [5], Fogwe *et al* (2019) [11], Fokeng *et al* (2020) [4], Akenji and Fokeng (2021). LULC classes were attributed on the basis of field observations, and very high-resolution Google Earth Images.

Table 1: Multi-sensor satellite data

S/N	Platform	Sensor*	Resolution (m)	Acquisition date	Satellite operator	Source
1	Landsat 5	TM	30	1984/12/31	NASA	USGS
2	Landsat 7	ETM+	15~	2003/01/10	NASA	USGS
3	Landsat 8	OLI/TIRS	15	2013/12/23	NASA	USGS
4	Landsat 8	OLI/TIRS	15	2022/12/17	NASA	USGS

*TM: Thematic Mapper; ETM+: Enhanced Thematic Mapper Plus; MSI: Multispectral Imager; NASA: National Aeronautics and Space Administration; OLI/TIRS: Operational Land Imager Thermal Infrared Sensor; USGS: US Geological Survey; ~15m Pansharpened composite image

3. Land use land cover change detection analysis

Different formulae were employed to estimate the annual rate of change per hectare (equation 1), percentage share of each land use type in the studied time periods (equation 2) and the land use dynamic degree index (equation 3). The rate of change in LULC type (Equation 1) was calculated using the formula proposed by Fokeng *et al* (2020) [4] as follows:

$$R\Delta = \left(\frac{ha}{year}\right)\frac{Z - X}{W} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: RD = Rate of Change; Z = recent area of LULC type in ha; X = previous area of LULC type in ha; W = time interval between Z and X in years.

In order to determine the percentage change in the various land covers per annum, a formula for assessing percentage change of the target LULC types was employed for change detection for the periods 1984-2003, 2003-2013 and 2013-2022 (Eq. 2) in line with Fokeng *et al* (2020) [4].

$$\%\Delta l = \frac{a2 - a1}{A} \times 100 \ldots\ldots\ldots\ldots\ldots (2)$$

Where: $\%\Delta l$ = change in the targeted LULC; $a1$ and $a2$ = the areas (image-based estimated areas) of the targeted LULC at the start and end of the change detection analysis; and A= the sum total area of the targeted LULC at start and end of the change detection analysis.

In order to measure the rate of change of the target LULC type, the land use dynamic degree index (Equation 3) was established based on Jian *et al*., (2008) cited in (Fokeng *et al*., 2020) [4].

$$K1 = \frac{Ua - Ub}{Ua} \times \frac{1}{T} \times 100\% \ldots\ldots\ldots\ldots\ldots (3)$$

Where: K1 = land use dynamic degree index; Ua = area of the target land use type at the start of the study period; Ub = area of the target land use type at the end of the study period; T = study period (unit of year).

Results

1. Local Population perspective on the pattern of land use land cover change in the Bali-Ngemba Forest Reserve

All the respondents affirmed that forest cover in the BNFR has been decreasing in the past 10yrs. Likewise, 97% of the population also confirmed that the previous land cover of their farms was forest (Table 2).

Table 2: Previous use of farm lands in the Bali Ngemba Forest Reserve

Previous land cover	Frequency	Percent
Forest	100	97.0
Farm land	3	3.0
Total	100	100.0

This trend could partly be attributed to the "Anglophone crisis" that began in 2016 causing government control /management of the reserve through ANAFOR to be withdrawn. The absence of a management body at the reserve for the past 7yrs has encouraged more encroachment as 64% of the population has been exploiting the reserve for less than 10yrs (Table 3).

Table 3: Duration of exploitation of the Bali Ngemba Forest Reserve

Duration of exploitation	Frequency	Percent
Less than 10yrs	64	64.0
More than 10yrs	36	36.0
Total	100	100.0

In this population, 62% of the people own between 3-4 farms in the reserve (Table 4) with 68% of the farms ranging between 1-6ha (Fig 2) while 22% of the population have no clue as to the size of their farms.

Table 4: Number of farms owned by each person in the Bali-Ngemba Reserve

Number of farms	Frequency	Percent
1-2	38	38.0
3-4	62	62.0
Total	100	100.0

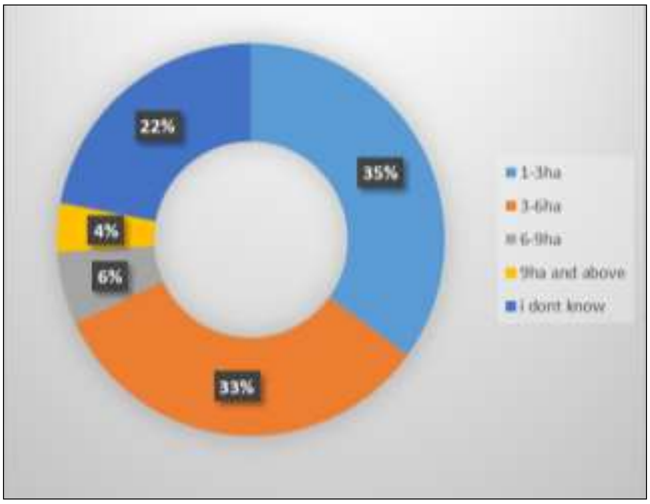


Fig 2: Average farm sizes in the Bali-Ngemba Forest Reserve

Also, 45% of the population believe that, as a result of logging, fuel wood exploitation forest cover is rapidly giving way to bare lands (Fig 3)

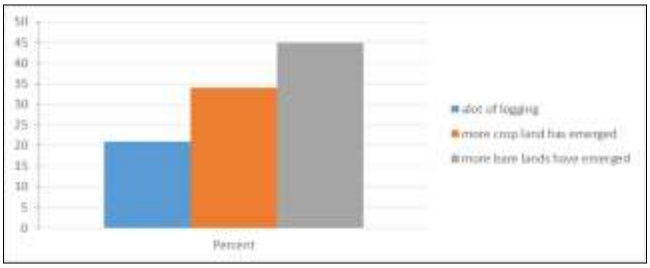


Fig 3: Pattern of land use land cover in the Bali-Ngemba Forest reserve

2. Land use land cover change dynamics from satellite data

Three (03) LULC classes resulted from the classification and processing of satellite images namely; forest, shrubs and bare soils/rocks (Figure 4). Their respective surface areas were quantified as displayed on Table 5.

Source**:** https://earthexplorer.usgs.gov/ (2023)

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Source: https://earthexplorer.usgs.gov/ (2023)

Fig 4: Real-time high-resolution satellite image of LULC in the BNFR

Table 5: Land cover/use change from 1984 - 2022 in the Bali-Ngemba Forest Reserve

Land cover/use		**Areal changes in hectares (ha) 1984 - 2022**						
	1984	**2003**	**2013**	**2022**	**1984-2003**	**2003- 2013**	**2013-2022**	**1984-2022**
Forest	614.75	536.0175	521.055	472.23	-78.2325	-14.963	-48.825	-142.02
Shrubs	0	121.2075	120.33	186.165	-	-0.876	65.835	64.9575
Bare soils, rocks and forest clearings	132.88	90.405	106.245	89.235	-42.435	15.84	-17.01	-43.605
Total	747.63	747.63	747.63	747.63	-		-	-

In 1984, the BNFR had above half (614.75 ha) of its surface area covered in forest. In the BNFR, forest still occupies the largest share of land cover types (82, 71, 69, and 63 % in 1984, 2003, 2013 and 2022, respectively).

Analyzing the satellite images by year, LULC from 1984 to 2022 was characterized by three land cover conversion systems. With the most prominent for the reserve in 1984 being forest cover. The BNFR in 1984 had 82% (614.75ha) forest cover, 0% (0ha) shrubs and 17% (132.88ha) bare soils and rocks, and forest clearings. (Fig 5, Table 5).

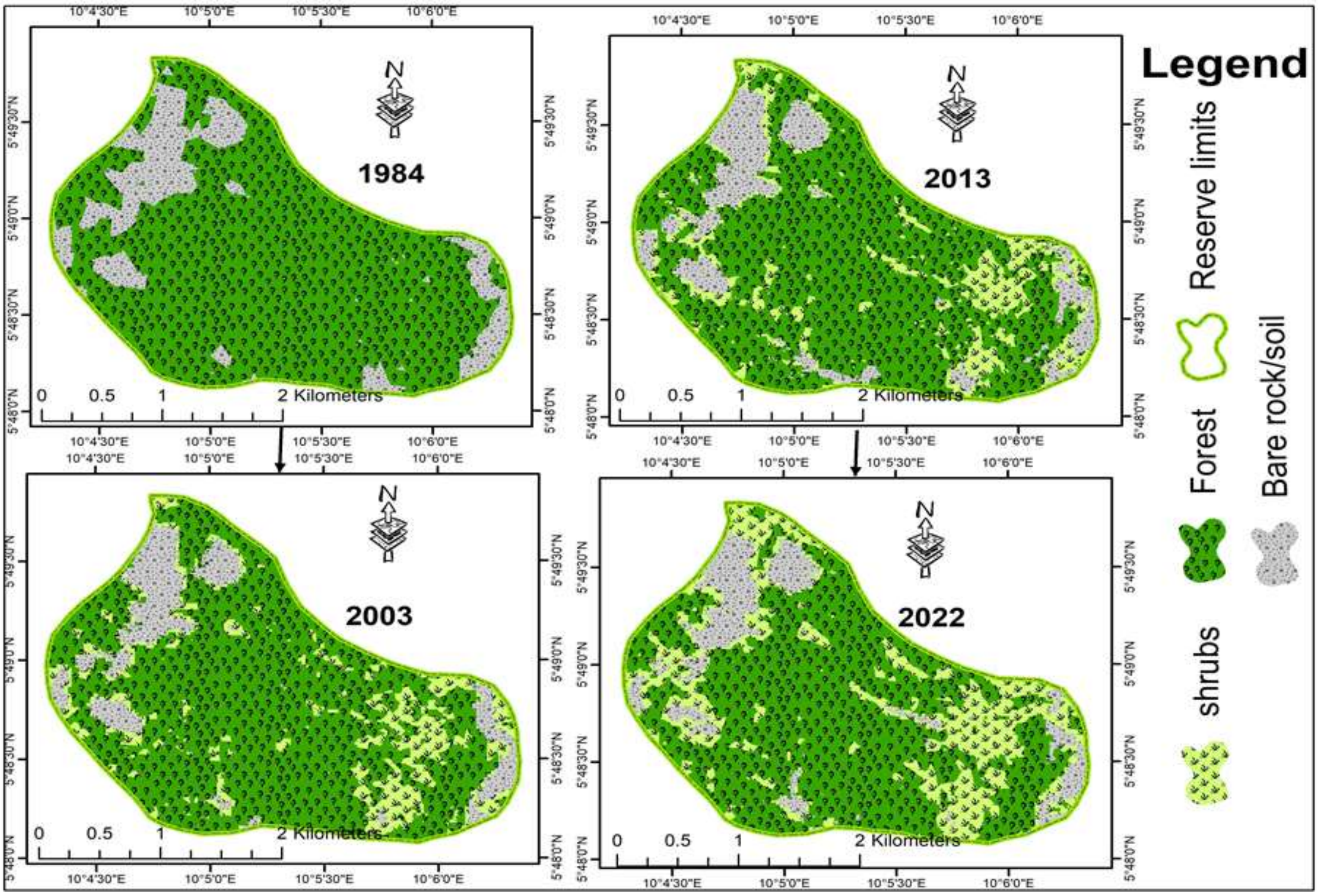

Fig 5: Land cover /landuse change dynamics (1984-2022)

The absence of shrubs (0 ha) is attributed to the thick canopy layer that hindered sunlight from reaching the forest floor in 1984 thus very little vegetation in the understory.

By 2003 Forest cover in the BNFR was on the decline as the reserve had lost 11% of her forest and could be estimated at 71% (536.0175 ha) forest cover (Fig 3). On the other hand, shrubs cover had increased to 16.2% (121.2075 ha) leading to a decline of 5% in areal cover of bare rocks and soil leaving it at 15.8 %(90.405 ha).As the years progressed and riparian populations grew, the forest was manipulated thus paving the way for more sunlight to reach the understory thus the increase in shrub population.

For the year 2013, forest cover was on a steady decline as forest cover in the BNFR accounted for 69% (521.055 ha) (Fig 5, Table 5). Shrub cover remained almost stagnant at 16.1% (120.33ha) while bare soils and rocks was at 14% (106.245ha) in areal cover. By 2022 forest cover was still on the decline the BNFR lost another 6% of forest cover between 2013 and 2022 placing forest cover at 63% (472.23 ha) (Fig 5) shrub cover pushed higher to 24% (186.165ha) and bare soils and rocks at 11%(89.235ha). This declining trend in forest cover was earlier documented by Cheek, *et al*, (2018) [2] when they observed that the canopy of the forest has become sparser and the clearance at the forest edges was continuing unchecked.

Apart from the analysis of satellite images by year, the images were also analyzed according to three time ranges (1984 -2003, 2003 -2013 and 2013 -2022). Between 1984 and 2003, forest cover declined by -10%, bare rocks and soil by -5.6% while shrubs gained 16.2% in coverage (Fig 6). This trend is attributed the increase in riparian populations pushing them to manipulate the forest through logging, search of fuel wood and food security through the creation of farms. Thus, reducing the canopy thickness allowing for more sunlight to reach the forest floor that enhances the gain in the shrub layer.

Further still, amid the years from 2003 to 2013, LULC types in the BNFR continued to change but at a gentler rate as forest and shrub cover both declined by -2% and -3% while bare rocks and soils gained 2.1% of coverage (Fig 6). The gain in overall cover for bare soils is due increase logging by the local population. Despite the reforestation works that were going on at the reserve during this period, weak regulations and follow up by ANAFOR in administering the reserve still left chances for -2% of forest to be lost.

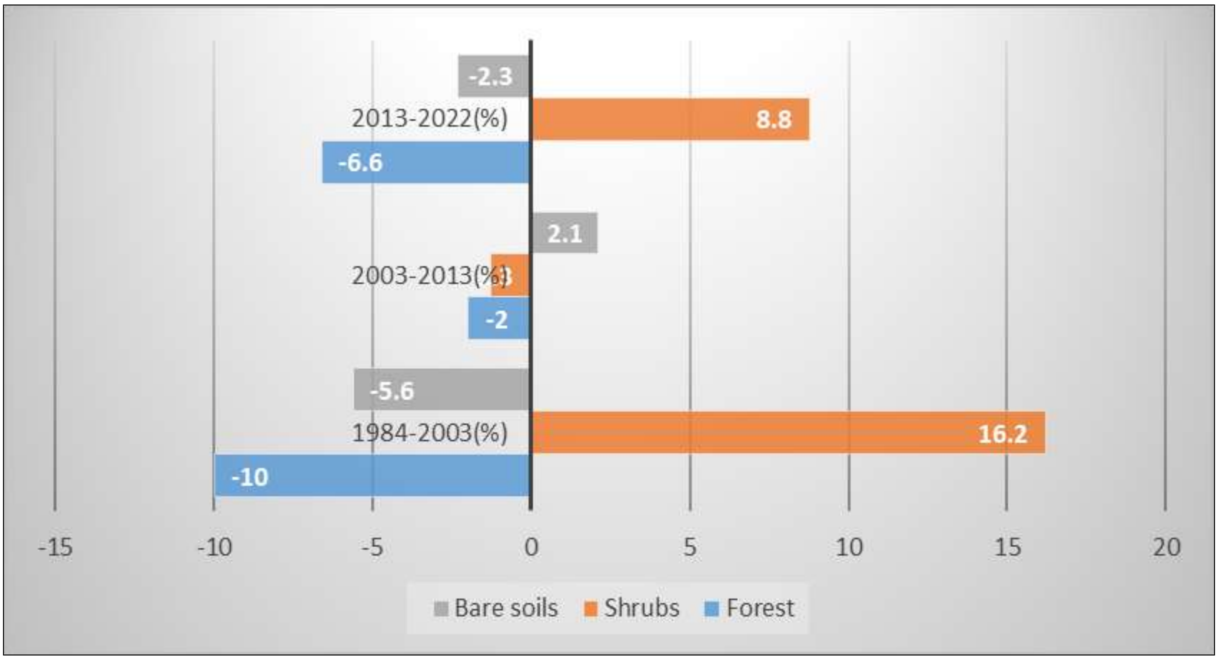

Fig 6: Percentage change in land cover

Finally, in the years between 2013 and 2022, forest declined by -6.6%, bare soils and rocks by -2.3% while shrubs gained 8.8% of cover. Seven years in this period was characterized by the 'Anglophone crisis" that further lessened control at the reserve thus the -6.6% forest loss. While the gain in shrub land is attributed to further manipulation of intact forest due to absence of the foresters during the crisis period.

Apart from the % change discussed above, the rate of change in LULC in the BNFR from 1984 to 2022 was evaluated. According to which, between 1984 and 2022, the BNFR has lost 142ha of forest cover (Table 6) to bare soils and shrubs at an annual rate of -4ha/yr., -0.8ha/yr., and -5ha/yr. For the years 1984-2003, 2003-2013 and 2013-2022 respectively (Table 6) with the years 2003 -2013 having the lowest rate of change -0.8 ha/yr. while 2013 -2022 has the highest rate of change -5ha/yr.

Shrub cover on the other hand, had a positive rate implying gains in surface area of 6.3ha/yr. and 7.3ha/yr. for the years 1984-2003 and 2013-2022 respectively but still registered a negative rate in the years 2003 – 2013 of -0.1ha/yr.

Table 6: Annual rate of land cover change in the Bali-Ngemba Forest Reserve

Land cover	1984-2003(ha/yr.)	2003-2013(ha/yr.)	2013-2022(ha/yr.)
Forest	-4	-0.8	-5
Shrubs	6.3	-0.1	7.3
Bare soils	-2.2	1.7	-1.8

Lastly bare soils and rocks between 1984 -2003 and 2013-2022 registered a negative rate implying loss in surface cover of -2.2 and -1.8 ha/yr. respectively. While these classes of land cover land use were the only one to gain surface area during the 2003-2013 period of 1.7ha/yr.

As indicated by the land use dynamic degree index (K1), the variation direction of forest cover is consistently negative for the three study periods with a maximum annual decline rate of 1% in 2013-2022.

Table 7: Land cover/use dynamics degree index for the Bali-Ngemba Forest Reserve

Land cover	1984-2003	2003-2013	2013-2022
Forest	-0.7	-0.3	-1
Shrubs	0	0.08	-5.5
Bare soils and rocks	1.6	-1.7	1.8

In contrast, the variation direction of shrubs was positive from 1984 -2013 implying an increase in shrub land cover but went negative between 2013-2022 indicating the reserve was losing shrub land cover as it moved from 0, 0.08 to -5.5. Bare soils gained total area within 1984-2003 but began losing in 2003-2013 with an index of -1.7.

Discussion

Considering the total area of the BNFR in 1984, the area of forest cover was 82 % and has continued to decrease over the various study periods implying that between 1984 and 2022 19% of forest cover in the BNFR has been lost indicating a moderate reduction in the area covered by the BNFR. These findings are in line with those of Cheek *et al* (2018; 2022) [2, 3] in which he warned that anthropogenic activities in the reserve were causing the decline of the forest cover and species like the *Vepris bali sp* which was already extinct at the time of his study. However contrary trends have been reported by other investigators ranging from an increase in forest cover to a more severe decline as reported by Ambebe *et al* (2021) [1] for the Bafut-Ngemba Forest Reserve. The discrepancy with the latter study is attributed for the most part to intense logging for charcoal which is absent in the BNFR.

Unlike Fokeng *et al*. (2020) [4] in the Metchie-Ngoum Protection Forest Reserve where six (06) LULC categories namely clearings / farms, build up areas, water bodies, secondary forest, forest, lowland shrubs, and cloud cover were derived from the classified satellite imagery, just three (03) categories were encountered in the BNFR namely forest, shrub and bare lands and rocks. In the same vein, anthropogenic interferences in the Metchie-Ngoum Protection Forest Reserve were the main drivers of forest cover changes and conversions to agricultural lands and built-up area, significantly degrading the original vegetation, which is the same trend observed in the BNFR.

Conclusion

These results for this study demonstrate the presence of modifications on the LULC types of the BNFR with forest cover decreasing faster than any other land cover type in the reserve as a result of the encroachment into the area and different types of livelihood activities including farming, logging and fuel wood exploitation. It is thus obvious that there would be a major decline in forest cover to meet human needs and also due to absence of the forest guards who have been absent from the reserve since the onset of the Anglophone crisis. A more favourable policy framework that provides alternative livelihood options to adjacent communities will help to reduce pressure on the reserve, thereby fostering conservation.

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