Land use/land cover dynamics and implications for landscape restoration in Cameroon's western highlands

Abstract

Land use – the way human beings employ the land and its resources is at the centre of scientific and policy interests in rapidly evolving landscapes of sub-Saharan Africa. An example par excellence of such landscapes is the Western Highland Region of Cameroon. This paper analyses the implications of land use changes in seven communities of the Western Highland Region of Cameroon. In doing so, it specifically: (i) examines the pattern of land use/land cover change between 1984 and 2021, and (ii) analyses their environmental implications. A mixed-methods approach involving the use of qualitative and quantitative data collection and analysis methods was employed. This specifically involved the survey of 300 households using semi-structured questionnaires, the conduct of nine (9) group discussions and twenty-two (22) key informant interviews. Secondary data were obtained through Municipal Council Reports. The data were analysed descriptively (using tables and charts) and spatially using maps. The study used archived satellite images to map land use dynamics over the study area from 1970's to present. In this light, NASA's Landsat satellite images from USGS earth explorer was acquired for the periods of 1979, 1984, 2000, 2013 and 2021 for diachronic analysis of land cover/use in the study area. The results revealed that land use/land cover changes were rapid, involving a significant reduction in grassland (72%), forests (48%) and bare areas (19%) between 1984 and 2021. This was followed by a correspondent increase (211%) in the built-up area, and in agricultural space (22%). Additionally, land use/land cover changes have led to a change in local climatic conditions, a decline in crop and livestock output, and rising food costs. The study recommends that international NGOs operating in this area should engage with communities on aspects of sustainable land management. Relevant government ministerial departments and municipal agents should emphasise the need to respect land use plans, to limit the uncoordinated colonisation of slopes for farming and settlement. Besides establishing the pattern of land use transformation in this landscape, this paper provides new insights on the environmental effects of land use/land cover dynamics in Cameroon's Western Highlands. The results demonstrate novelty through its further identification of food security issues linked to land use/land cover dynamics.

Key words: land use, land cover, planning, food insecurity, environment

1. Introduction

Population growth and the corresponding increasing demand for natural resources continue to threaten the survival of humanity in the 21st Century. With close to 8 billion inhabitants (WEF, 2022), the earth has the herculean task of providing the natural resources needed to cater for humanity. Natural ecosystems have been subjected to significant pressures, despite the clarion call from national and international stakeholders on the need to adhere to the Brundtland Report on Sustainable Development and the present-day Sustainable Development Goals (SDGs). Although several global challenges are a cause for concern, land use/land cover change has received unrivalled attention due to its significant environmental consequences (Erbaugh & Oldekop, 2018; Palmer *et al.* 2022). While most parts of the globe are exposed to this issue, land use/land cover change is identified as a significant environmental problem in sub-Saharan Africa (FAO, 2010).

The concomitants of rapid land use/land cover change are telling: besides the destruction of terrestrial and aquatic habitats, there has been a rise in the prevalence of communicable diseases (Agbozo & Jahn, 2021; Bates *et al.*, 2021). Crop failures especially in many parts of the developing world have been accompanied by rising famine, starvation and death. These environmental issues do not only destroy livelihoods, but aggravate resource-related conflicts in some parts of sub-Saharan Africa. It is therefore not uncommon today to learn of conflicts related to environmental despoliation (Koning, 2007; Kimengsi, 2015; Nkonya *et al.,* 2016). Such issues are evident in many parts of sub-Saharan Africa, including Cameroon.

Cameroon represents a useful epistemological option to understand land use/land cover change processes, given its ecological diversity (Fogwe, 1997; Molua & Lambi, 2007; Fogwe, 2014; Kimengsi & Andin, 2017; Fogwe, *et al.* 2019). In addition to this, significant deforestation and land degradation in Cameroon, driven by unsustainable agricultural practices and rising fuelwood demands have led to an 18.1% loss of vegetal cover between 1990 and 2010 (Dongmo, 1984; Ndobe & Mantzel, 2014). Hence, the problem of landscape degradation persists. For example; soil degradation in the northern regions of Cameroon (Jean & Stefan, 2011), wetlands degradation around the coastal low lands of Cameroon (Chebo, 2009; Orock & Kometa, 2015) and land degradation in the Sahel region of Cameroon (Jamin, 2007) have been recurrent. The trend is increasing in the Western Highlands, where significant population growth and unsustainable land use practices prevail (Lambi, 2001; Fogwe, *et al.,* 2019). The Western Highlands of Cameroon is amongst the most densely populated regions of Cameron (128.5 inhabitants per km^2), with a key socio-economic activity being peasant farming (Jiotsa, *et al.*, 2015). Its predominantly difficult terrain makes agricultural activities somewhat burdensome, as land use/land cover change continues seemingly unperturbed (Lambi & Ndenecho, 2009; Jiotsa *et al.*, 2015; Gwan *et al.*, 2021). All these affect the livelihoods of the local people who are considered the key actors in the landscape restoration process (Gwan *et al.*, 2021). As an agro-ecological zone, the Western Highlands has witnessed significant changes in its land uses, thus warranting an investigation.

In the study zone, the south eastern part of the Western Highlands of Cameroon, natural forests, gallery forests and grazing lands appear to have been subjected to a progressive de-vegetation process. Additionally, soil fertility seems to have witnessed a decline in the study site, as mirrored through a reduction in food crop output and a corresponding rise in the prices of food crops. Using land use/land cover maps, the study maps signatures of land, grasslands, and forest degradation over time. With growing concerns on sustainability, it would seem that there is an unanswered question with regards to the extent to which land use/ land cover change is effectively managed in the Western Highlands. These issues led to the central question: what are the patterns and environmental implications of land use/land cover dynamics in Cameroon's Western Highlands? This paper does not only contribute by establishing the pattern of land use/land cover transformation in Cameroon's Western Highlands, it also provides new insights on its environmental effects. Its novelty is further demonstrated by the further identification of food security issues linked to land use/land cover dynamics.

2. Study area

The spatial scope of this study covers the south eastern part of the Western Highlands. It stretches across the Santa-Babadjou-Mbouda axis, that is, Santa, Mbouda and Babadjou (Figure 1). The study area lies between longitude 10°10′00″E to 10°16′30″E and latitude 5°46′00″N to 5°56′30″N. This work is spatially delimited to the south eastern part of the Western Highlands. This specifically includes Mbouda, Babadjou, and Santa Sub-divisions. From these selected Sub-divisions (Mbouda, Babadjou, and Santa), we further enlisted two communities/villages in Santa sub-division: Santa village and Akum; two villages in Babadjou Sub-division: Matazem and Toumaka; and three villages in Mbouda Sub-division: Bafounda, Bamesso and Bamendou. These communities form part of the Western Highlands agro-ecological zone, with striking similarities in their economic activities and socio-cultural life. Figure 1 shows the location of the study communities. This area shows great ecological variations and consequently climatic variations. The relief, settlement patterns and agricultural activities shape such variations.

Situated in the Sudan Savannah Zone, this highland is endowed with varied vegetation. The predominant landscape unit consists of polyculture zones characterized by market gardening, food crops, forests, fruit trees and cash crops such as Arabica coffee and also raffia palm trees especially in the valleys. Within the mountainous formations, the most common species are *Ficus dracaena*, *Eucalyptus grandis* and *Loudetia simplex.* A sub montane forest, which has been greatly degraded as well as a montane forest exists in the Santa region. This zone also hosted the Bafut-Ngemba forest which has been exposed to significant degradation (Fogwe, 1997).

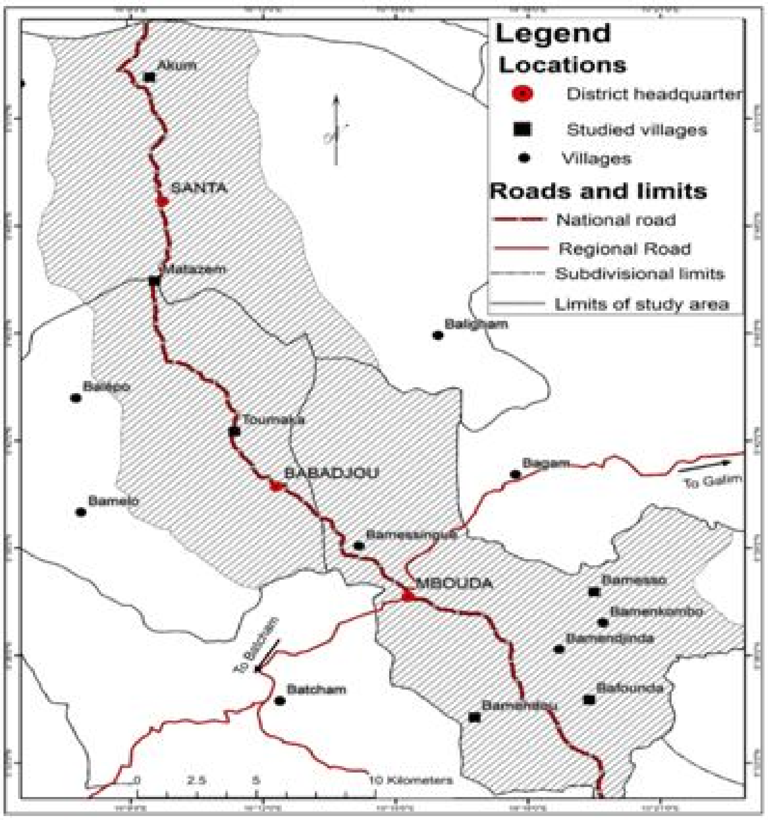

Figure 1: Location of the study communities (Santa, Akum, Bamesso, Bafounda, Bamendou Toumaka, Matazem) **in the Western Highlands**

Sources: Administrative limits of Cameroon (NIC, 2020), AW3D3O DEM (JAXA, 2019), Sentinel-2B 10m band 4 (ESA, 2020)

According to the results of the 2005 Population and Housing Census, the Municipalities of Babadjou, Santa and Mbouda have an estimated total population of over 268,351; being 44,198 inhabitants in Babadjou, 84,143 inhabitants in Santa and 140,000 inhabitants in Mbouda. Females dominate this population, estimated at about 55% females and 45% males. Both Mbororos and the Hausas constitute about 7% of the total population and constitute the minority group.

3. Research methods

Three communities (Santa, Babadjou and Mbouda) in the south eastern part of the Western Highlands of Cameroon were chosen for the study. These communities were chosen because over the years, they had exhibited strong evidence of land use change (Tchindjang *et al.*, 2003) which is not only due to increasing populations but also strongly because of the primary activity here which is farming.

The mixed-methods approach, involving a combination of qualitative (desktop reviews, focus group discussions as well as interviews) and quantitative data collection methods (survey of farming households) was employed for the selected communities to ensure data triangulation and to enhance the reliability of the results. Textural narratives were gotten in these communities through interviews and focus group discussions (qualitative). A semi-structured questionnaire was used to derive quantitative data.

The data collection instruments used for this study were; an interview and a focus group discussion guide, as well as a semi-structured questionnaire. They were designed to capture the indicators of land use change, the manifestations of land use change over time, and the options for sustainable land use management. Population statistics for the study sites were obtained from the Municipal Councils of Mbouda, Babadjou and Santa. Additionally, information on the activities that trigger land use change were provided by the Delegations of Agriculture and Rural Development, and Environment and Nature Protection. Climate data (rainfall and temperature) for the period 1961 to 2018 were collected from the Regional Delegation of Transport for the Northwest Region. Data on food crop production and the changes in the price of food crops from 2010 to 2021 was obtained from the Sub-Divisional Delegation of Agriculture and Rural Development. Additional data on livestock production for Santa was obtained at the Delegation of Livestock, Fisheries and Animal Industry.

To collect information from individuals and/or households, a set of semi-structured questions were designed and presented progressively to the respondents. Within each of these sub-divisions, two communities, each were selected with the exception of Mbouda where three communities were selected. In Santa sub-division, Akum and Santa communities were randomly selected. Santa has an estimated 1500 households from which a total of 100 households were sampled (50 in Santa and 50 in Akum). In Mbouda, Bamesso, Bafounda, and Bamendou communities were also randomly selected. With a total population of about 45000 inhabitants, they represent about ¼ of the total population of Mbouda. In Mbouda, a total of 130 questionnaires were administered, 44 in Bafounda, and 43 each in Bamesso and Bamendou. 70 out of the 300 households were sampled in Babadjou Sub-division in Toumaka (35) and Matazem (35). The total population in Babadjou is about 44198 inhabitants. The total number of questionnaires issued in all communities were 300. In the selected study communities, a more than 5% sampling fraction was assured. According to Alreck and Settle (1995), a sampling fraction of between 5 and 10% of the study population in such cases is considered appropriate.

The simple random sampling technique was used to reach out to most of the respondents; say about 70% of all those who received the questionnaire. Within the study communities, an ad-hoc household numbering process was performed for the households. Having derived the total number of households, raffle draws were repeatedly conducted to select household numbers randomly. The assigned house numbers guided the candidate to locate the exact house for the questionnaire to be administered. This approach guarantees that every households has an equal chance of being selected. It has been applied in recent studies around the Western Highlands (see Kimengsi *et al.,* 2022, Kimengsi & Mukong, 2022). The rest of the 30% was gotten using the snow-ball method. The latter method was preferred around Santa and Akum, considering the sensitive socio-political climate linked to an on-going social crisis at the time of data collection.

Both content analysis and thematic analysis were used to treat and analyse qualitative data. The purpose of the content analysis was to describe and analyse the characteristics of the document's content by examining who said what, to whom, and with what effect. The results for the first objective reflects both qualitative and quantitative analysis (narratives and thematic analysis) where maps and other existing literature are analysed together with perspectives from experts and the community. Quantitative data gotten from the structured questionnaires were treated and analysed using the SPSS. Descriptive analyses centred on the presentation of data using tables, frequencies and charts. This approach enabled the description of the data obtained including their spatial presentation. Climatic data were imputed into Microsoft Excel 2013 for descriptive statistical analysis. The main descriptive statistics computed were bar charts displaying linear regression and R-square values as well as trend lines. The bar charts showed the degree of fluctuation and anomalies in climate parameters (rainfall and temperature) and predicted future trends through the trend lines. Line graphs were also used to analyse the trend of food crop production and the prices of food crops over the years.

3.1 Geospatial Analysis

The study used archived satellite images to map land use dynamics over the study area from 1970's to present. To do this, NASA's Landsat satellite images from USGS earth explorer was acquired for the periods of 1979, 1984, 2000, 2013 and 2021 (Table 1) for diachronic analysis of land cover/use in the study area. The images were acquired for the dry season period to avoid the effects of atmospheric attenuations and/or cloud cover on imagery which could hinder effective classification to different land cover/uses. Image pre-processing and classification was done in ArcMap 10.3 with the help of remote sensing and GIS expert. Land cover/use classes were attributed based on field observations, real-time very high-resolution Google Earth images and ancillary maps like topographic maps of Bafoussam 3c. The study used archived satellite images to map land use dynamics over the study area from 1980's to present. To do this, NASA's Landsat satellite images from USGS earth explorer was acquired for the periods of 1984, 2002, and 2021 for diachronic analysis of land cover/use in the study area. The images were acquired for the dry season period to avoid the effects of atmospheric attenuations and/or cloud cover on imagery which would hinder effective classification to different land cover/uses. Image pre-processing and classification was done in ArcMap 10.5.

Table 1: Remote sensing data used for land cover/use change detection

Platform	**Sensor**	**Cell size (m)**	**Acquisition date**	**Satellite operator**	**Data source***
Landsat 5	TM	30	12/31/1984	NASA	USGS
Landsat 7	ETM+	30	12/13/2002	NASA	USGS
Landsat 8	OLI_TIRS	30	01/03/2021	NASA	USGS

MSS (Multispectral Sensor), TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper Plus), OLI_TIRS (Operational Land Imager_ Thermal Infrared Sensor), NASA (National Aeronautics and Space Agency), USGS (US Geological Survey) earth explorer*.

The land cover/use classification method was the supervised image classification based on pixels and training samples in Arc MAP 10.5. for the advantage of this method is its ability to obtain information at a more precise scale, a pixel as pointed out by Desclée and Mayaux (2014). The resultant land cover/use classes were attributed based on FAO land cover classification system by Di Gregorio and Jansen (2000), enhanced by field observations, real-time very high resolution Google Earth images and ancillary maps like topographic maps of Bafoussam 3c.

3.2 Image processing steps

After acquiring multi-sensor and multi-date Landsat images, further processing included image scene extraction and layer stacking to form image composite. Using 6 images bands for Landsat 5 and 7 for Landsat 7 and 8, we performed a layer stacking for colour composite. The composite image was then clipped to study area using ArcMAP 10.5 on the fly. Image enhancement color stretching were performed in ArcMap 10.5 for better visualization. The clipped composite Landsat images (false colour) were classified using ArcMap 10.5 based on supervised interactive classification. A supervised classification of colour composite for each image was performed by means of training areas and supervised pixel-based image classification. The advantage of the pixel approach is that information is obtained at a more precise spatial level (the scale of a pixel), (Desclée and Mayaux, 2014). Land cover classes were attributed based on field observations, topographic map of Bafoussam 3C, and real time very high resolution Google Earth imagery of the area. Field observations and very high resolution Google Earth imageries were used to assessed the accuracy of the attributed land cover/use classes.

4. Results

4.1 Land Use/ Land Cover situation in 1984

In 1984, the estimated total surface area covered by agricultural land was 20663.73 hectares, 1737.63 hectares for built-up areas, 2332.8 hectares covered by degraded forests, 10456.56 hectares covered by forests, 6811.65 hectares covered by grassland and 3331.54 hectares covered by burned/bare land. Therefore, out of the total surface area of 45333.91 hectares, 45.58% was covered by agricultural land, 3.83% covered by built-up areas, 5.15% covered by degraded forests and 23.07% was covered by grassland, while burned-bare areas covered 7.34% (Figure 2).

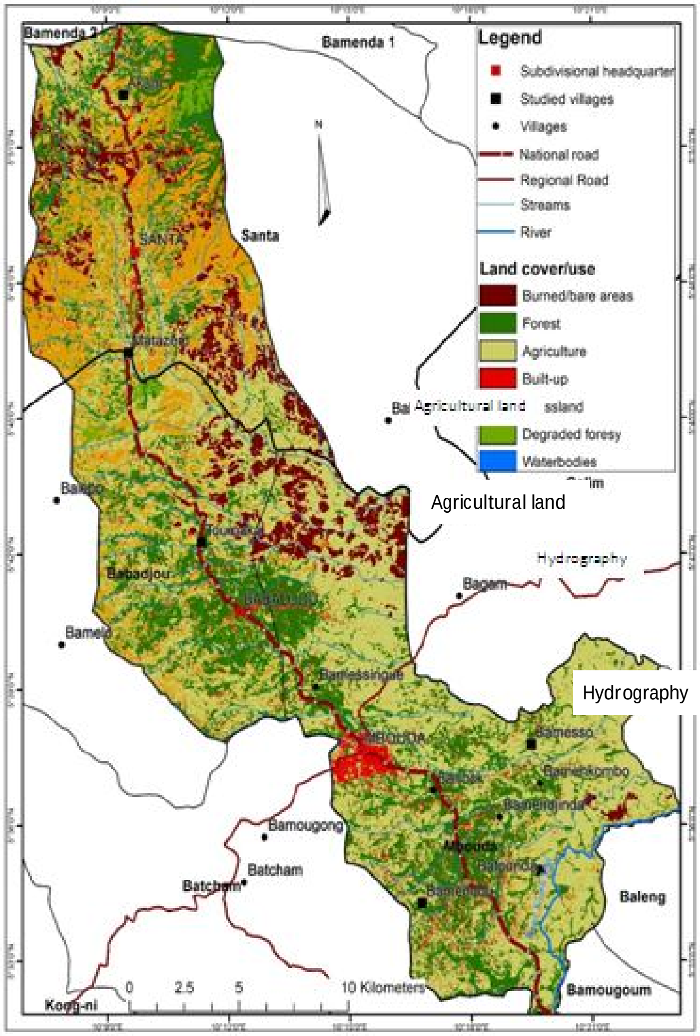

Figure 2: Land cover/use of the south eastern part of the Western Highlands in 1984
(Source: Developed based on the Topographic map of Bafoussam 3c)

4.2 Land Use/ Land Cover Pattern in 2002

In 2002, significant changes were observed based on the already mentioned indicators (agricultural and built-up areas, degraded forests, forests, grassland and burned/bare land). Agricultural land increased from 20663.73 hectares to 23927.81 hectares and by 3264.08 hectares within 18 years. The percentage of agricultural land increased by 7.2% from 45.58% to 52.78% (Figure 3).

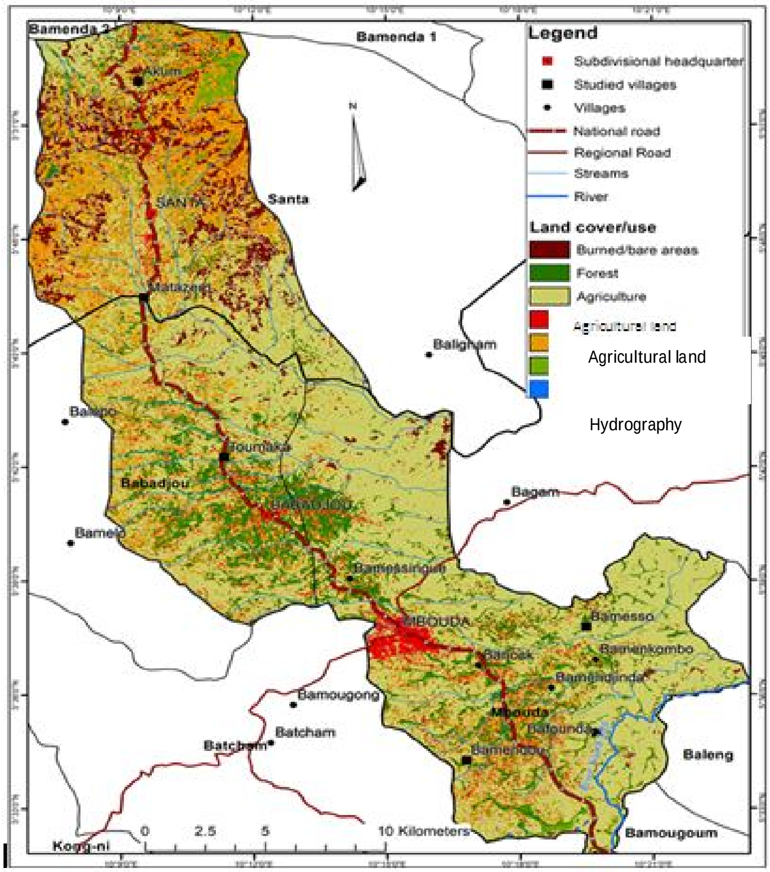

Figure 3: Land cover/use for the southern part of the Western Highlands in 2002

Built-up areas also significantly increased by 514.48 hectares (from 1737.63 to 2252.11 hectares), implying a percentage change of 1.14% (4.98-3.83%). Burned/bare areas also witnessed an increase from 6811.65 hectares to 6515.64 hectares (296.01 hectares). This indicates a percentage change by 1.38% from 7.34% in 1984 to 8.72% in 2002. On the other hand, degraded forests, forests and grasslands decreased by 1160.6 hectares, 2943.03 hectares, and 296.01 hectares respectively, with a respective decrease in the percentage of land occupied by these land uses of 2.56%, 6.5% and 0.66%. An increase in agricultural land, built-up area and burned/bare surfaces, and a counter loss of forests, grasslands and degraded forests as indicators of land degradation serve as pointers to the landscape degradation process within the 18-year period.

4.3 Land Use/ Land Cover in 2021

The acceleration in development intensified so much so that by 2021, the settlement areas drastically increased as seen on Figure 4. With the increase in settlement, forests (natural and secondary) continue to reduce; farmlands too decreased especially around the areas that are densely populated with buildings. Agricultural land for example increased to 25239.06 hectares from 23927.81 hectares in 2002, giving a difference of 1311.25 hectares and a percentage increase of 2.89%. Built-up areas equally drastically increased over the past 19 years (2002 to 2021) by 3167.69 hectares implying a more than double increase in percentage from 4.97% in 2002 to 11.97% in 2021. This represents a 7% increase in total built-up area. Both indicators (agricultural land and built-up areas) have kept increasing over the years, especially the built-up areas. The total surface area of degraded forests rather increased in 2021 contrary to the recorded decrease in 2002. It changed from 1172.2 hectares to 1673.89 hectares i.e. a change of 501.69 hectares. Though the total forestland has decreased between the year 1984 and 2002, there was an impressive improvement from 2002 to 2021. Total forestland increased from 7513.53 hectares in 2002 to 8378.43 hectares in 2021, that is, a change of 864.9 hectares. Therefore, 864.9 Ha of forest land was recovered from the 2943.03 hectares lost by 2002.

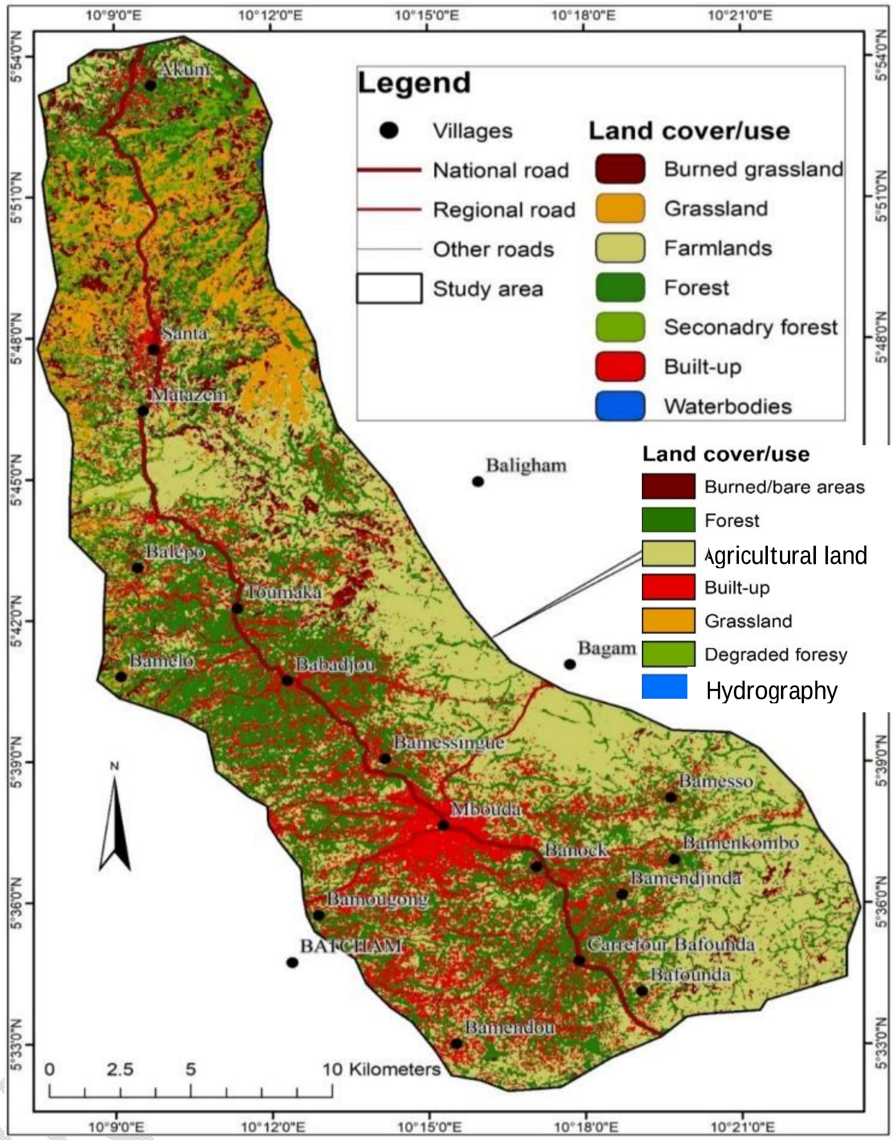

Figure 4: Land cover/use situation of the south eastern part of the Western Highlands in 2021

Meanwhile grassland further decreased by 4586.76 hectares from 6515.64 hectares to 1928.88 hectares. Just like the total built-up areas, this change was dramatic, from representing about 15% of the total surface area in 1984, to 14% in 2002 and to only 4.25% in 2021. Burned/bare areas equally decreased in 2021 by 1258.77 hectares, following an increase in 2002 by 296.01 hectares. Judging from the improvements or increase in forestlands, it is tempting to conclude that landscape degradation between 2002 and 2021 has not been significant. But the contrary is factual in the sense that built-up areas, agricultural land, and degraded forests increased while grassland and bare areas decreased. *Ceteris paribus*, it can be said that the dramatic change in built-up areas by the year 2021(caused by a continuous rise in the population), led to an increase in agriculture, forest degradation, and a decrease in grassland and burned/bare areas. In Akum, Santa, Matazem, and Bamendou, it is very glaring how farmlands have decreased especially around densely built-up areas.

5. Environmental Implications of land use dynamics in the Western Highlands

The effects of land use/land cover change can equally be short-term or long-term. Some of these effects include decreased biodiversity, decreased ecosystem services, food insecurity and an increase in the cost of living, a decrease in crop and livestock production, and climate change. Owing to land degradation, farmers now resort to the intensive application of soil additives (reported by 89% of the population). While this assures short term productivity, it has long term effects on the soil and also degrades the water systems. Food insecurity and rise in food costs and changes in local climate were also other effects related to land use/land cover change (Table 2).

Table 2. Effects of land use/land cover change in the Western Highlands.

Effects / Evidence/ Aspects of Degradation	Zero response (%)	<25% (less severe)	25-50% (fairly severe)	51-75% (severe)	>75% (very severe)
Changes in local climate	2	20.6	29.8	33.8	13.8
Decline in crop production	0	1.6	21.6	54.1	22.6
Decline in livestock production	12.8	80.3	6.2	0.7	0
Food insecurity and rise in food costs	2.6	20	47.2	24.3	5.9
Expensive use of soil additives	0	5.2	5.6	28.5	60.7
Soil erosion and soil loss	0	12.7	33.8	31.5	22
Loss of soil fertility	0	4.7	23.9	27.5	43.9
Decline in water spots	0	18.7	14.4	40.3	26.6
Loss of grassland	0	62.3	20.7	13.8	3.3
Loss of forests	0	20.7	37	17.7	24.6

Source: Field work, 2020

From Table 2, the effects/evidences of land use/land cover change were classified into 5 percentage brackets including those who did not respond, those who did not notice any changes and those who were indifferent about the changes. Specific aspects of land use/land cover change at 0%, those who perceived that the degree of each effect of land use/land cover change was rated either less than 25%, between 25-50%, 51-75% and above 75%. Soil erosion, soil loss and soil infertility are some of the highlighted evidences or aftermaths of land use/land cover change. These could happen when poor soil management and poor farming methods expose the soil to agents of erosion like wind and running water. When erosion takes place and the soil is lost, it loses its fertility.

The population perceived a decline in soil fertility over the years in the study sites. This is mirrored in the decline in productivity levels. Productivity over the years has been dropping and soil fertility decline is one of the causes. The total population noticed that there is some level of soil fertility loss, soil erosion and loss of soil. A scale of measurement was adopted to rank how the population rated the degree of these effects. Some 22% of the total population experienced soil erosion and soil loss (rated above 75%), 31.5% held that it is rated between 51%-75%, 33.8% were of the opinion that it is between 25-50% and only 12.7% of the populated rate it below 25%. Analyses for the loss of soil fertility show that out of the 100% who responded, only 4.7% think the percentage of soil fertility loss is below 25%, and 23.9% noted that it stands at 25-50%. Some 27.5% held that it is between 51-75% and 43.9% noted that this was above 75%. Though low soil fertility is not the sole effect of the loss of vegetation cover, its role in land use/land cover change needs to be emphasized. The loss of vegetation cover here includes forest and grassland. Apparently, there is not much evidence of grassland loss as more than half (62.3%) of the population think it rates below 25%, 20.7% rate it between 25-50%, 13.8% rate it at 51-75% and only 3.3% rate the loss of grassland at above 75%. For forest land, 20.7% rate its loss at below 25%, 37% at between 25-50%, 17.7% at 51-75% and 24.6% at above 75%.

As global climate has been changing, there has also been changes in local climates. The aggregate changes in local climates, make up for the global change. Local climates here have been taking a turn in an unfavourable direction because of land degradation. Land use/land cover change owing to the loss of vegetation especially forests and increased population density, always spells bad news for the climatic condition of the area. Hence, with a degrading or declining vegetation in these communities, besides other factors, temperatures generally increase, and normal rainfall and sunshine schedules are altered (that is, the period for rainy and dry seasons). There is less rainfall now than before in terms of frequency and amount, with longer periods of sunshine and general dryness. Out of the total population, 2% did not respond to this while 20.6% think the evidence or effects is rated at less than 25%, 29.8% rate the effects between 25-50%, 33.8% at between 51-75% and 13.8% above 75%. Climatic data was analysed to depict variations in temperature and rainfall over the years. Figure 5 shows **v**ariations in temperature in the south eastern part of the Western Highlands between 1961 and 2018.

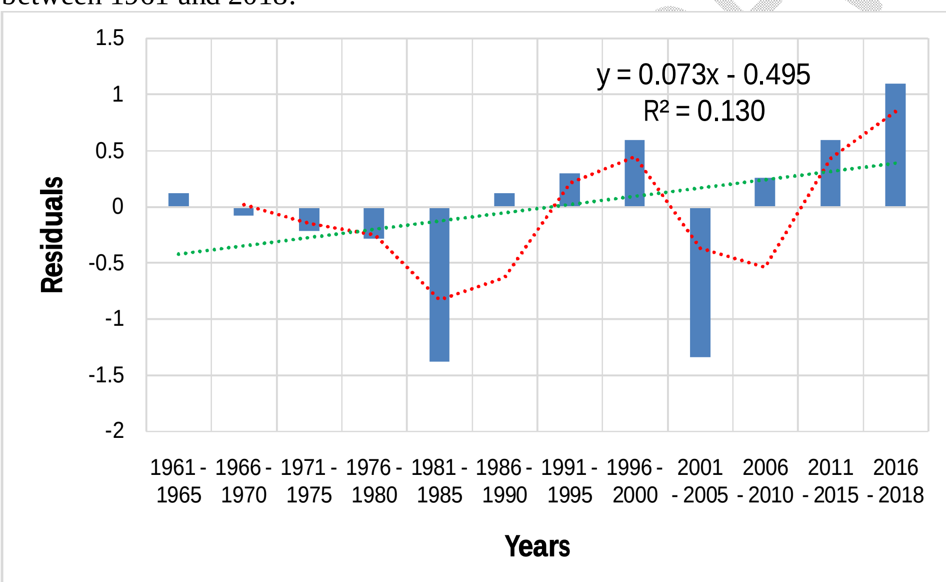

Figure 5: Variations in temperature in the Western Highlands between 1961 and 2018.

From Figure 5, it is evident that there was a significant variation in temperature between 1961 and 2018. The computation of temperature anomalies showed an increasing trend in temperature between 1961 and 2018 with most years experiencing positive temperature anomalies. The years 1996-2000, 2011-2015 and 2016-2018 experienced the highest positive temperature anomalies (exceeding 0.5^{o}C) while the years 1981-1985 and 2001-2005 experienced the highest negative temperature anomalies (-1^{o}C and beyond). The trend line predicts an increasing temperature trend in the coming years.

Rainfall equally experienced significant fluctuations around the Western Highlands between 1961 and 2018 (Figure 6). The trend analysis performed reveals a declining trend in the amount of rainfall. Years with negative rainfall anomalies outnumbered those with positive rainfall anomalies. The years 1991-1995 and 2016-2018 experienced the highest negative rainfall anomalies (over -200mm of rainfall) while the years 1961-1965 and 1966-1970 experienced the highest positive rainfall anomalies (over 200mm of rainfall). The trend line predicts declining rainfall in the coming years.

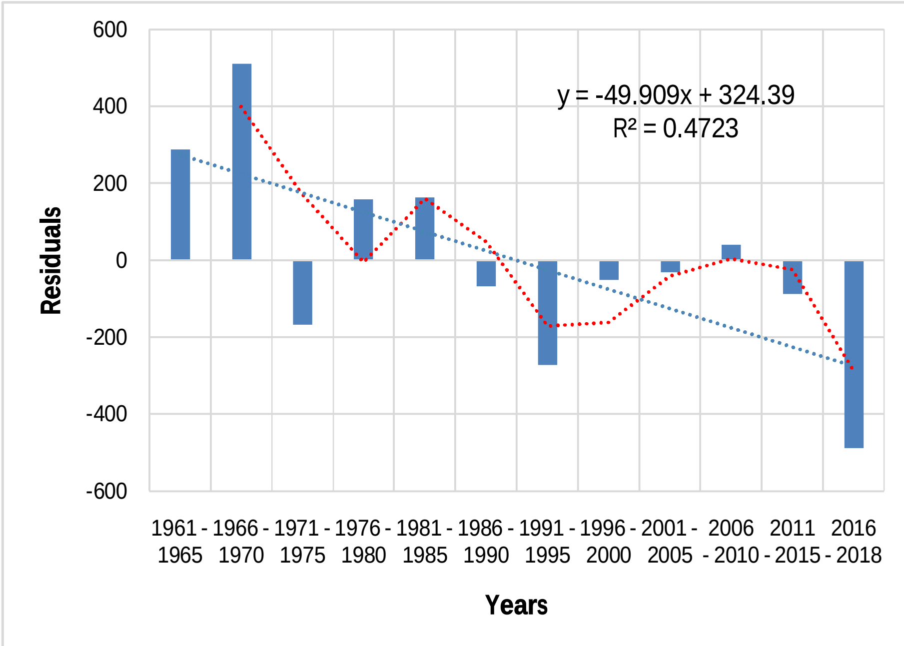

Figure 6: Variations in rainfall in the Western Highlands between 1961 and 2018.

For rainy days, the trend analysis showed that rainfall was scanty and erratic in the south eastern part of the Western Highlands between 1961 and 2018 (Figure 7). The number of rainy days fluctuated tremendously. Most of the years were characterized by negative rainy days anomalies with the years 1986-1990, 2011-2015 and 2016-2018 experiencing the highest negative rainy days anomalies. The trend line for rainy days predict a decrease in the number of rainy days in the coming years. The decline in the number of rainy days is a pointer to reduced rainfall input. This eventually distorts the hydrology as ground water recharge and streamflow is reduced. Moisture deficiency renders the landscape susceptible to degradation.

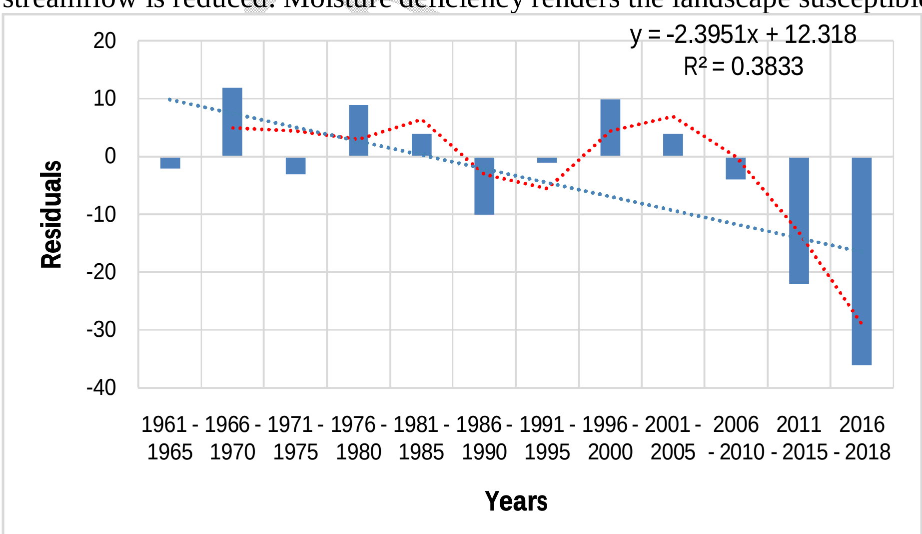

Figure 7: Variations in rainy days in the Western Highlands between 1961 and 2018

The above analyses signals increasing temperatures and a decline in rainfall and consequent increase in dryness. This increase in dryness or decrease in the input of water into the environmental system or cycle also results in a decline in water spots and the drying up of rivers and streams. All interviewees attest to this, irrespective of their ratings; 18.7% rate the degree below 25%, 14.4% of the population rate it between 25-50%, 40.3% stand at the 51-75% range, and 26.6%, above 75%. Table 3 shows the population's perception on the changes in the flow characteristics of some Streams from 1991 to 2021. From it, it can be observed that most of the streams have witnessed a reduction in their volume, while others have dried up.

Table 3: Population's perception on the changes in the flow characteristics of some streams from 1991 to 2021

Stream	Town	1991-2001	2001-2011	2011-2021
Big stream Matazem	Babadjou	Continuous (high volume)	Continuous (high volume)	Continuous (reduced volume)
Small stream Matazem	Babadjou	Continuous (high volume)	Continuous (reduced volume)	Seasonal flow
24 Escaliers	Mbouda	Continuous (high volume)	Continuous (moderate volume)	Seasonal flow
NNO stream	Mbouda	Continuous (high volume)	Continuous (reduced volume)	Continuous with drastic reduction in volume
Custom	Babadjou	Continuous (high volume)	Continuous (reduced volume)	Continuous with drastic reduction in volume
To'odzo	Mbouda	Continuous (high volume)	Continuous (moderate volume)	Seasonal flow
Nephew	Santa	Continuous (high volume)	Continuous (reduced volume)	Continuous with drastic reduction in volume
Njom	Santa	Continuous (high volume)	Continuous (moderate volume)	Seasonal flow
Saptsi	Santa	Continuous (high volume)	Continuous (moderate volume)	Seasonal flow

Source: Field Work 2020

Land use/land cover change also causes a decrease in crop production. This covers crop production and livestock production. A majority of the population acknowledged that livestock had reduced and is still reducing. Meanwhile, it was unanimously accepted that crop production has dropped due to other effects of degradation. To establish the severity of land use/land cover change, this study uses data on the decline in crop output to serve as proxy. In the case of Mbouda and Babadjou, crop production data for the period 2010 and 2021 was used. The data shows that on the whole, the output of maize and Irish potatoes witnessed a significant decline (Figure 8). In Mbouda, the annual output of maize witnessed a decline from 30400 tons in 2010 to 22200 tons in 2021, while that of Irish potatoes witnessed a decline from 22050 tons in 2010 to 12250 tons in 2021. Although maize output in Babadjou witnessed an increase in the period between 2010 and 2018, a further progressive decline in output is observed for the period between 2018 and 2021. This also applies to Irish potatoes whose production dropped from 4800 tons in 2018 to 3000 tons in 2021.

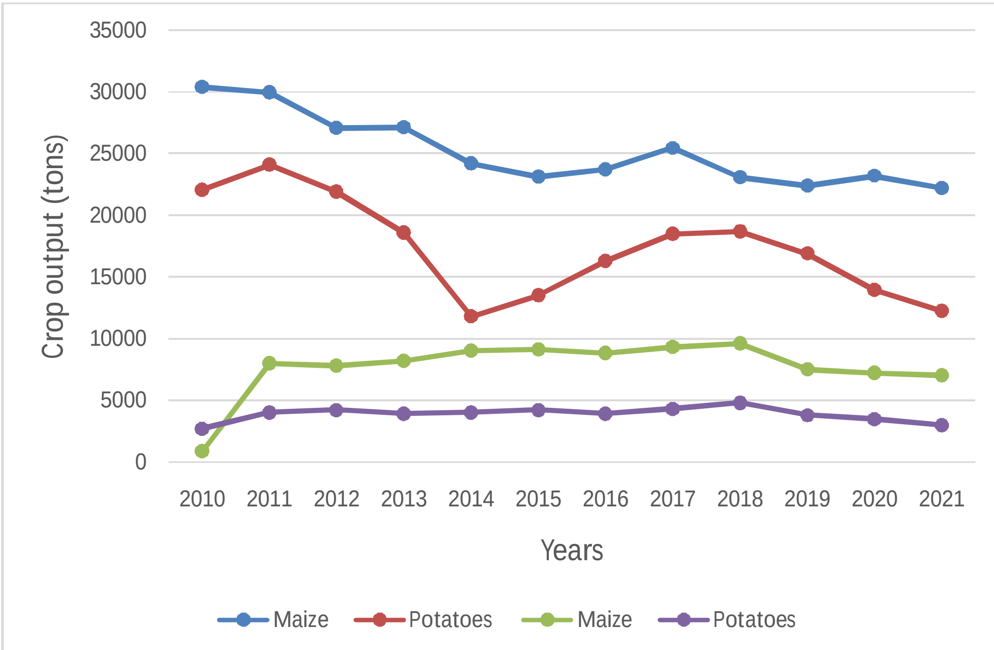

Figure 8. Declining trends in maize and Irish potatoes output in Mbouda and Babadjou.
Source: Drawn based on data from the Sub-Divisional Delegations of Agriculture and Rural Development, Mbouda and Babadjou

In the case of Santa, but for cabbage and Irish potatoes, all other crops witnessed a decline in output in the period between 2010 and 2021 (Figure 9). It is established that cocoyams, tomatoes and cassava have witnessed the most significant decline in output. On the whole, there is an overall decline in crop output for the five selected crops. This decline is attributable to the degradation of the landscape which renders the soil less productive.

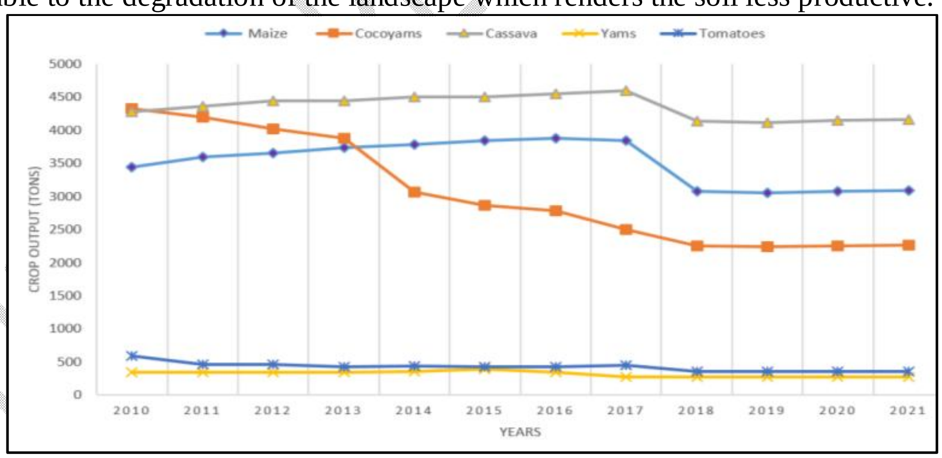

Figure 9. Decline in crop output in Santa between 2010 and 2021
Source: Drawn based on data from the Sub-Divisional Delegation of Agriculture and Rural Development, Santa

One of the expected results of a decline in crop production is food insecurity (scarcity). Given that the population is growing, and crop production is declining with decreasing farmlands, the population becomes food insecure because they depend mostly on crop production for their wellbeing and livelihood. This effect is not felt only in these communities (study sites), but other communities or areas that consume their produce. It can be established that this has contributed to the rise in prices of farm produce across the North West and West regions as well as beyond to other regions that consume agricultural products from here. From Figure 10, it is established that the prices of the selected crops have witnessed a significant increase between 2009 and 2021.

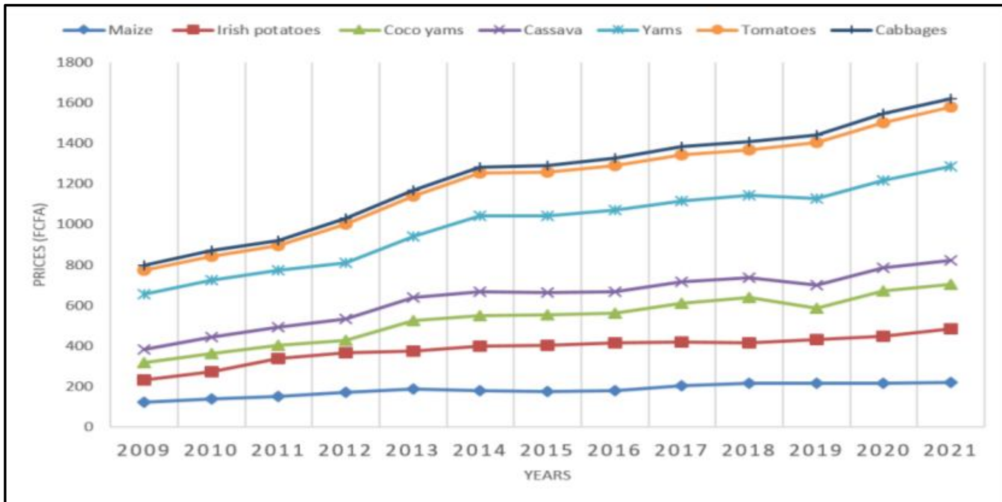

Figure 10. Evolution in the prices of selected crops in Santa (2009 to 2021)

Source: Drawn based on records from the Sub-Divisional Delegation of Agriculture and Rural Development, Santa

6. Discussion

On the whole, a significant reduction of grassland (72%), forests (48%) and bare areas (19%) was reported between 1984 and 2021. This was followed by a correspondent increase (211%) in the built-up area, and in agricultural space (22%). The south eastern part of the Western Highlands is predominantly a grassland area. It is therefore understandable that this land cover type witnessed significant encroachment and consequent degradation in these last decades. Furthermore, patches of natural and degraded forest could be found in several communities of the south eastern part of the Western Highlands, including gallery forests. Key degrading activities on grasslands include overgrazing of pasture areas. This is very common around the Bamboutos Mountain, and in parts of Santa and Akum. Besides overgrazing, the search for agricultural and settlement space is a perennial challenge in these study sites. This has caused households that rely on farming and real estate developers to explore opportunities to further utilize grassland areas, and to further encroach into forested landscapes. Some of the gallery forests have given way to diverse farming practices. The practice of Ankara and slash and burn essentially involves the removal of the vegetal covers, including the burning of grass to enhance temporal crop productivity. While these land cover/land use categories are prone to degradation, an increase in agricultural space, especially with the intensification of chemical fertilizer use does not only reduce soil quality but also degrades water bodies.

Land use/land cover change is very significant in the south eastern part of Cameroon's Western Highlands. In parts of sub-Saharan Africa (Ethiopia, Kenya, Malawi and Tanzania), Kirui *et al.* (2021) explored the state, extent and patterns of land use change. After complementing remote sensing with ground-level assessments, they reported that land degradation was estimated at about 51%, 41%, 23% and 22% between 1982 and 2016, in Tanzania, Malawi, Ethiopia and Kenya, respectively. Furthermore, through ground-truthing with the aid of Focus Group Discussions (FGDs), their claim was validated. The results of this study therefore tie with Kirui *et al.* (2021) who reported a decline in biomass involving the loss of degraded and natural forests, shrub land and grassland degradation. The Tanzanian case is quite similar to the south eastern part of the Western Highlands, as a significant proportion of the degradation manifest through the decline in grasslands – 76% in Tanzania. However, the results contradict evidence gathered from Puerto Rico, Denmark and South Korea, where the underlying causes of land use/land cover change were linked more to governance and market failures, unclear land tenure and lack of policy coordination (Mansourian, 2017; Stanturf *et al.,* 2019).

In the south eastern part of the Western Highlands, land use/land cover change is triggered by poor farming methods (79%), population growth (37%) and expansion of settlement (34%). Primarily, poor farming methods such as slash and burn, "*Ankara*" and the excessive use of chemical fertilizers. Besides this, more than 80% of the households studied have settled in hilly environments, while 16% have settled in valleys. Topographic site occupation is an unperturbed phenomenon in the south eastern part of the Western Highlands, especially as poor farming households cannot afford the cost of settling around more undulating terrains. It is noteworthy that such occupational decisions are not exclusive rooted in poverty; even wealthy households prefer to identify hilly environments for the construction of imposing structures. In East Africa, Wynants *et al.* (2019) reported that increase in soil erosion is a key trigger. The authors noted that this lethargy is rooted in historic disruptions to co-adapted agro-pastoral systems. Furthermore, systemic lapses linked to fragmented agricultural growth policies has precipitated land management mismatches in temporal and spatial scale. The consequence has been soil exhaustion, declining fertility and increased soil erosion. While the current issues might hold true for the south eastern part of the Western Highlands, the extent to which agricultural growth policies has shaped landscape degradation represents a useful research avenue to be further explored. The results clearly resonate with the findings of Msangi (2007) who studied landscape degradation triggers and manifestations in the Southern Africa region. The author reported that landscape degradation occurs mostly through soil erosion, loss of nutrients, and the depletion of organic biological matter. Other factors he noted include overgrazing of rangelands, uncontrolled burning and the improper cultivation of steep slopes. Drought cycles of 2-3 and sometimes 5-6 years were reported as outcomes of the landscape degradation process. However, in other parts of the global south (e.g. Myanmar), landscape degradation is significantly explained by forest loss - with a decline in forest cover from 58% in 1990 to 44% in 2015. Here, Naing Tun *et al.* (2021) showed that landscape degradation is driven more by logging than forest clearing. These issues are linked to corruption in the logging sector which has insignificant local-based small and medium enterprises.

Ken *et al.* (2020), in their mixed-methods analysis of drivers of land use change in Cambodia reported nine direct drivers to include illegal logging, commercial wood production, the clearance of land for commercial and subsistence agriculture, charcoal production, new settlement and land migration, natural disasters, human-made forest fires, and fuelwood for household consumption. In the Tsitsa Landscape of Southern Africa, Itzkin *et al.* (2021) rather observed that natural and climatic variables, land use and land cover changes and overgrazing were key landscape degradation triggers. These were also linked to poverty and disempowerment. However, in parts of West Africa (e.g. Cote d'Ivoire), Kouassi *et al.* (2021) observed drastic changes in land use and land cover, including the rapid conversion of forest landscapes into agricultural space at an annual rate of up to 3.44%. Furthermore, and contrary to the findings of this study, the authors equally reported migration (54.2%) and logging (47.7%) as key drivers of landscape degradation. However, their findings related to the evolution of land degradation to incorporate shorter fallow periods (46.7%) and the inappropriate application of inputs (31.4%) concur with the case of the south eastern part of the Western Highlands of Cameroon.

7. Conclusion

Based on the analysis, the following conclusions are drawn: First, land use/land cover change is significant in the south eastern part of the Western Highlands, albeit in varying proportions. This is mirrored through the significant reduction in grasslands, forest and bare areas within a close to four-decade time period. Such changes are linked to the corresponding expansion of settlements and unsustainable agricultural space. Key degrading activities on grassland include overgrazing of pasture areas, an increase in agricultural space, especially with the intensification of chemical fertilizer use. Besides these, topographic site occupation - an unperturbed phenomenon in the south eastern part of the Western Highlands– precipitates land use/land cover change. Land use/land cover change in the south eastern part of the Western Highlands manifests through vegetal loss, increasing drought and desertification, the loss of biodiversity, decline in soil fertility and crop productivity, as well and pollution of water sources. In the south eastern part of the Western Highlands, some of the principal effects of land use/land cover change include decreased biodiversity, decreased ecosystem services, food insecurity and increase in the cost of living, decrease in crop and livestock production, climate change. This paper recommends that international NGOs operating in this area should engage with communities on aspects of sustainable land management. Relevant government ministerial departments and municipal agents should emphasise on the respect for land use plans, to limit the uncoordinated colonisation of slopes for farming and settlement.

FUTURE STUDIES

The findings from this study leave potential avenues for future studies. Firstly, this study covered the south eastern part of the Western Highlands of Cameroon and sought to explore land use/land cover dynamics. It is possible that the patterns and scale of land use/land cover change might differ in other yet-to-be-covered parts of the Western Highlands (e.g., the Bui plateau and the Kom Highlands). Therefore, a more enlarged study which covers the different parts of the Western Highlands could provide complementary empirical evidence. Secondly, the links between land use/land cover change and rural livelihoods requires future research attention, especially as it is globally recognised that the asset portfolio of households tend to shape their engagement with land uses. Thirdly, forces such as migration shape institutional change sometimes. With the significant waves of internally displaced persons (IDPs) now inhabiting the south eastern part of the Western Highlands, future studies should strive to explore the role of in-migrants (IDPs) in shaping land use/land cover change.

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