A Cartography of Physiographic and Anthropogenic Factors influencing Vegetation in the Bamenda Mountain Region of Cameroon

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1. Introduction

Vegetal changes emerging from the colonial era and colonial activities in Africa have been a subject of geographic inquiry for years as interest in man-environment relationship or environmental determinism keeps rising. Changes in the vegetation date to ancient times far before colonialism. Archaeological and historical findings have revealed that ancient humans had influenced biodiversity and vice versa. Analysis of tree-ring data by dendrologists has shown human fingerprint upon climate variation across the world dating as far back as a century ago (Radford, 2019). During the colonial era up to the 1990s, there were speculations and scepticism about the threat of human-induced alterations to the environment, but this notion rapidly changed as scientists (e.g., Kasperson *et al*, 1995; Moran 2000, etc.) were able to show strong evidence of significant human disruption of global bio-geochemical cycles. This Nature–Society relationship has been a subject of research and it has given rise to many fields and subfields of research (TurnerII, 2015). With the advent of Geographic Information System (GIS), remote sensing and other technologies in the 1980s and 1990s, geographers were able to analyse complex human-environment relationship by documenting contemporary biodiversity, changes in vegetation, erosion patterns, human-historical disturbances, etc. at different scales (McConnell, 2001). Despite the advances made by different scientists to ascertain the causes or drivers of environmental (vegetation) dynamics, there hasn't been unity on the dominant driving factor. While some consider the characteristics of the physical milieu as the main driver of vegetal degradation, others (Zhou *et al*, 2014; Afungang, 2013) think human activities are the main driving forces. Others like Hagerman *et al*. (2010) think that it is a combination of physical and human factors plus land use policies. These changes are more quickly felt in mountain regions than in lowlands due to their exposure to climatic factors. The 19th century geographer Ellen Semple called mountainous areas "Museums of social antiquities" containing diverse resources important to humanity. This was at a period where colonial plantations and construction activities were booming in Africa. Most colonial land use policies just like the ones today failed to recognize the specificity of mountain regions and

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their production potentials in terms of crop and biodiversity (Ndenecho, 2006). As such, the vegetation degradation in mountain regions since colonial times has remained and still is high causing hydrogeomorphology crises and risks. For instance, small streams used for irrigation dried up while large rivers only flow intermittently. The deforestation of vast lands for plantation agriculture increased erosion and landslides events especially on steep slopes. The degrading human–environment relationship didn't end with colonialism and there isn't enough information that can be used to determine the exact impact of colonial activities on vegetation in The Bamenda Mountain region. As such, we believe that a detailed understanding of the environment and preconditioning factors that cause environmental dynamics is a step to resolving the problem. Thus, the objective of this paper is to examine the physiography and anthropogenic characteristics of the Bamenda Mountain from the colonial period (the 1900s) to 2019.

2. Methods and Materials

To access colonial vegetation, the physical characteristics (land cover) and the human activities (and use) in the study area were examined. Bas series of thematic maps were built and analysed. These thematic maps were developed using indirect and direct mapping methods. The topographic map was generated from a Digital Elevation Model (DEM) constructed from 10m interval contour lines extracted from a raster topographic image of the area. The DEM was then used to construct the slope map, relief unit graphs, hydrographic network, drainage and slope gradient map. The shaded relief generated from the DEM was used to interpret the surface by placing an artificial sun for illumination in the sky and altering the angle of the sun to see different angles of the surface. The Azimuth was moved at 90º interval (i.e., 315, 225, 135 and 45) representing the NW, SW, SE and NE directions respectively. This enabled a total view of the surface as the altitude was maintained at 30º at each point. The setting of the azimuth was set following the proposition of Smith and Wise (2007) that imagery with solar elevation angles <20º enhance the topographic "signal" through shadowing, making them easy to interpret. Major topographic features could be seen from the tilts and shadowing through the azimuth biasing. Although some authors argue that this method may not improve identification rates of landforms (Smith and Clark, 2005), it was useful in interpreting and analysing the topography, identifying relief features, drainage patterns, surface materials and direction of material flow. Furthermore, the DEM had X, Y and Z values from which the gradient was measured. Using satellite images with 5 m resolution in ArcMap, landforms were identified based on the size of the landform relative to the spatial resolution (relative size), the orientation of the landform with respect to the angle of solar reflection (azimuth biasing), the differentiation of the landforms through signal strength and texture and following controls of representation. Although digital maps have great information about the earth surface, visual perception in the field provides unprecedented details about an area (Otto and Smith, 2013). Thus, fieldwork was done from 2013-2015 to complement information seen on digital photos. For instance, the geomorphological unit map was constructed through direct visualization and interpretation of surface features and subsurface materials. Due to the large scale of the original geology map (1:50 000), small rock formations covering <50 m or with a resolution of <25 m wide were merged into one big

class. Anthropogenic features which are very often not visible on large scales could be identified by mapping at the scale of 1:3000. The field mapping exercise created a mental model that was later used in the analyses. For instance, a perspective on colonial vegetation change was accessed based on colonial artefacts such as the Bamenda government building constructed by the Germans as a military fort.

3. Physiography of Bamenda mountain region

3.1. Location of the study area

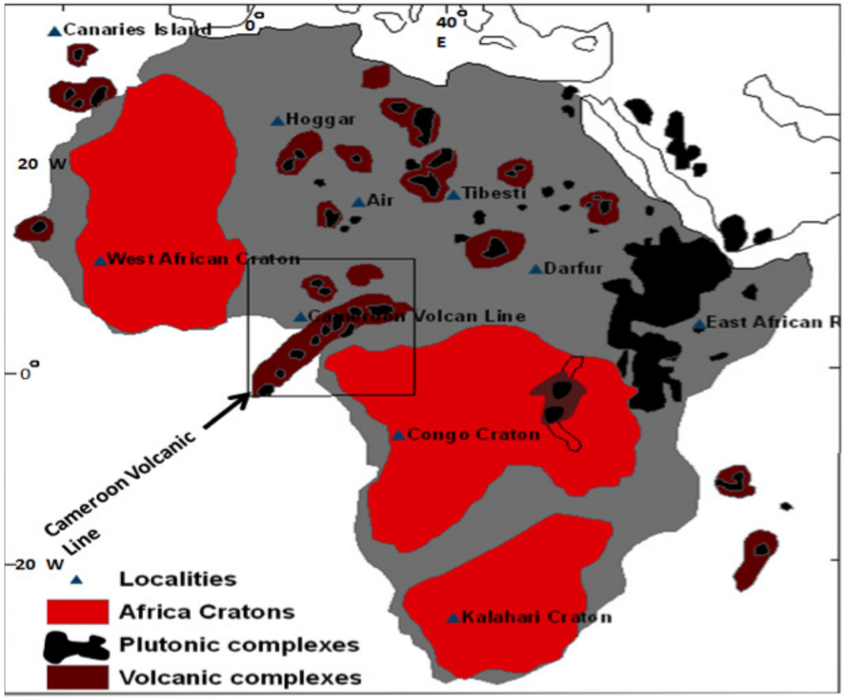


Ilustração 01 – Cameroon volcanic line in Africa. Afungang (2015).

Within a broad context of African geography, the study area (Ilustração 01) is in the Gulf of Guinea and forms part of the West African Volcanic complex in the African Craton. To be more specific, Bamenda Mountain is located on the northern edge of the Cameroon Volcanic Line (CVL) also known as Cameroon Hot Line (Kamgang *et al.*, 2007; Déruelle *et al.*, 2007). The CVL is a chain of 12 Cenozoic volcanic massifs running for approximately 1600 km extending from Pagalu Island in the Gulf of Guinea in the Atlantic Ocean to Lake Chad. This line is characterized by alignment of oceanic and continental volcanic massifs, and orogenic plutonic complexes. It's an alkaline volcanism related to a major fracture with a N30°E direction confined to a band of about 100 km wide and more than 1600 km long. It is segmented by N70°E Central Cameroon Shear Zone along the volcanism of Adamawa (Gountié *et al*., 2012). The volcanism along the Cameroon section of the Volcanic line seems to have started during the Eocene (44 My) and included 60 anoregenic plutons with the emplacement of the Bamoun plateau between 51.8 and 46.7 Ma (Moundi *et al*., 2007) and Mount Bangou between 44.7 and 43.1 Ma (Fosso *et al*., 2005). It is still active at Mount Cameroon which lastly erupted in 1999 and 2000. The continental sector of the CVL is marked by a trend of large massifs including Mount Manengouba, Mount Fako, Mount Bamboutos, Mount Bamenda and Mount Oko (Ilustração 02, 2a). The CVL ends around Ngoundere in the Admawa plateau (Ilustração 02). Within the geomorphological perspective, this area constitutes part of the Pan-African North-Equatorial fold belt (PANEFB). The PANEFB or Central African Orogen is a major Neoproterozoic Orogen linked to the Trans-Saharan Belt of Western Africa. The colonial masters had to consider these physical characteristics when making land-use decisions.

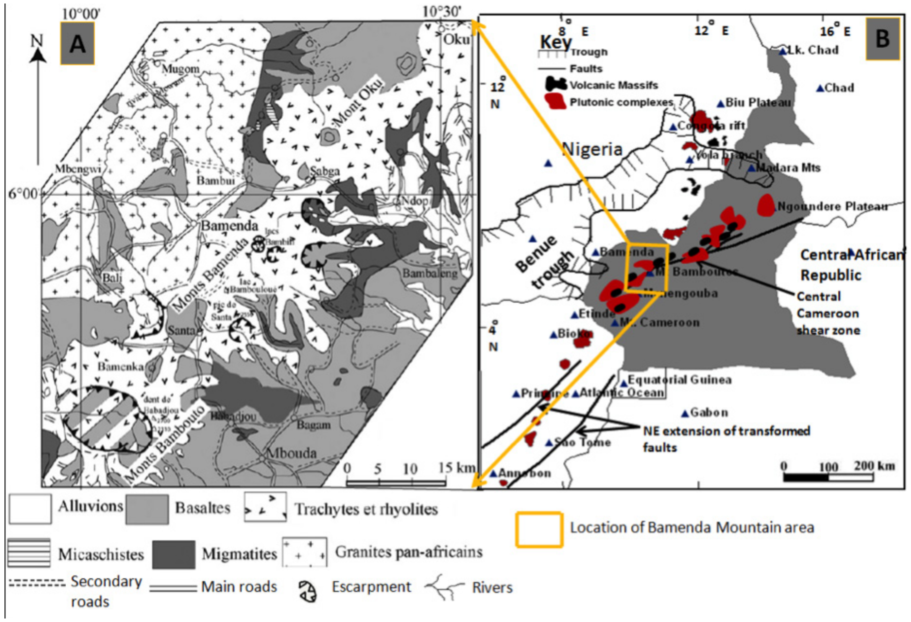


Ilustração 02 – Location map of Bamenda Mountain within the Western Highlands of Cameroon.

Source: Afungang 2015.

The study area belongs to the most important geomorphologic system in the region called West-Cameroon Highlands (Morin, 1988). Bamenda Mountain is the northern extension of the Bamboutos Mountain and it is the fourth largest volcano in the CVL (Gountié *et al*., 2012). The general massif lies between longitudes 10°00'E and 10°30'E and latitudes 05°45'N and 06°10'N. The area considered for this study lies between longitudes 10°3'54"E and 10°21'57" E, and latitudes 6°4'18" N and 5°46'15" N. It covers approximately 913.7 square kilometers. The area is bordered in the North by Bafut Mountains and Babanki hills, in the South by the Bamboutos Mountain and Bamenyam plains, in the West by Mbegwi lowlands, Ngembo and Bali hills, and in the East by the Ndop plain. The southern sector is dominated by the Santa plateau, the central part by Bamenda caldera and escarpment, the North Western slopes by the Bambili escarpment and the Bambili Sabga Mountain chain. Politically, the study area covers large parts of Mezam division including Santa sub-division. It habours three important economic hubs and includes Santa town in the extreme south west, Bamenda town in the center and Bambui-Bambili in the north west (Ilustração 03, Left).

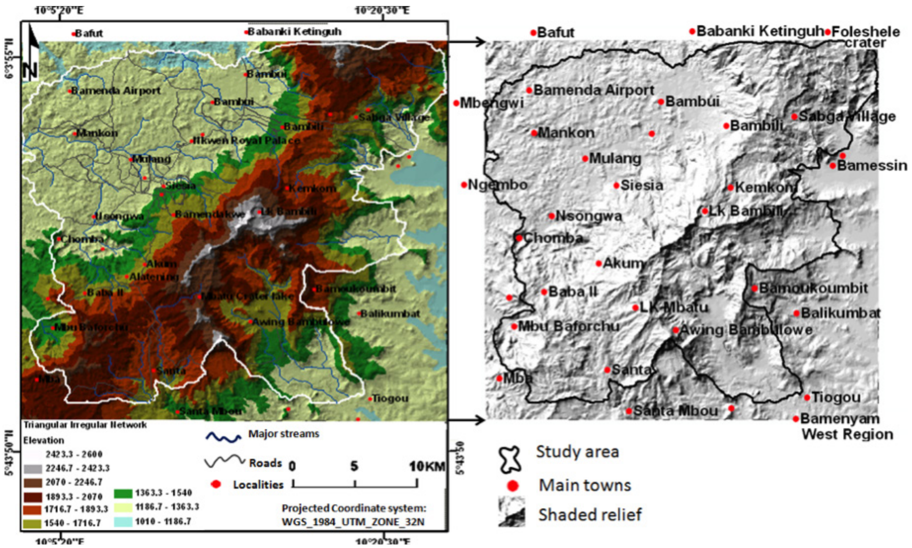


Ilustração 03 – Hypsometry map of the study area showing important localities.

The main physical properties of the area considered to have influenced colonial vegetation includes the relief, lithology, superficial formation, drainage system, vegetation and climate. Detail composition of each of these elements was examined to help explain the influence each factor has on the rapidly changing landscape.

3.2. Relief and Morphology

The hypsometry map of the study area (Ilustração 03) has altitudes ranging from 1010 m – – 2600 m. The relief structure of the study area is attributed to endogenic forces portrayed by volcanic envision as identified through volcanic ejecta (Hawkins and Brunt, 1965). It is a rugged Mountainous terrain, bearing the characteristic scars of Pleistocene formation believed to constitute part of ancient rock formation mostly common with landforms of humid tropics (Tricart, 1972). It is made up of mountain terraces (Ilustração 04), vertically rising volcanic plugs with steep slopes (Ilustração 04b), straight and rectilinear crest of multiple forms, broad bottom valleys, straights, elongated and round hills (Ilustração 04f), a few lowlands and minor plains. The SW part is made up of Santa-Mbu caldera measuring 6 x 4 km and the Lefo caldera measuring 4 x 3 km (Gountié *et al.*, 2012). The northwestern part is the lowland harbouring the main city Bamenda. In the east, chains of Mountains interlock the undulating landscape (Ilustração 04c). The volcanic spine that divides the area into two halves gives rise to many rivers and waterfalls that flow northwards and eastwards. The multi-step Sabga escarpment (Ilustração 04e) and the Along-Banjah mountain range (Ilustração 04d) have the most rugged relief in the entire study area.

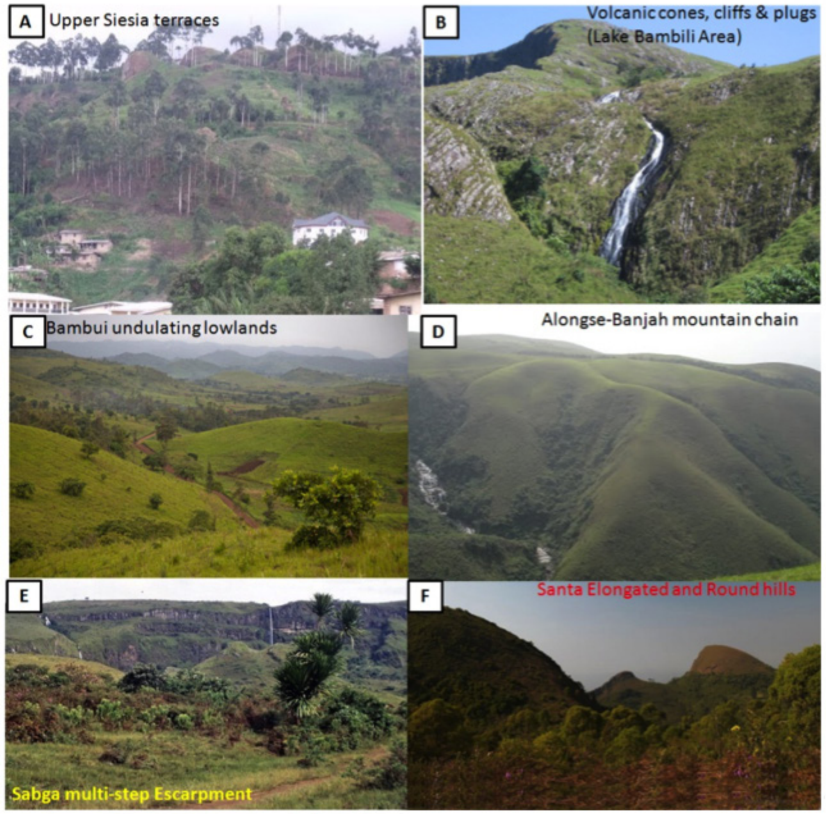


Ilustração 04 – Morphology of the Bamenda Mountain region.

The entire relief structure can be divided into four main units (Ilustração 05). This include: the Eastern valleys, the lowlands, the intermediate mountains or midlands and the volcanic mountains (escarpment and calderas). These units were classified following important relief defining components including altitude, shape and depth. The altitudes range from 1900 m to 2600 m in the Volcanic Mountains, 1400 to 1900 m in the intermediate plains, 1200-1400 m in the Lowlands and <1200 m in the Eastern valleys.

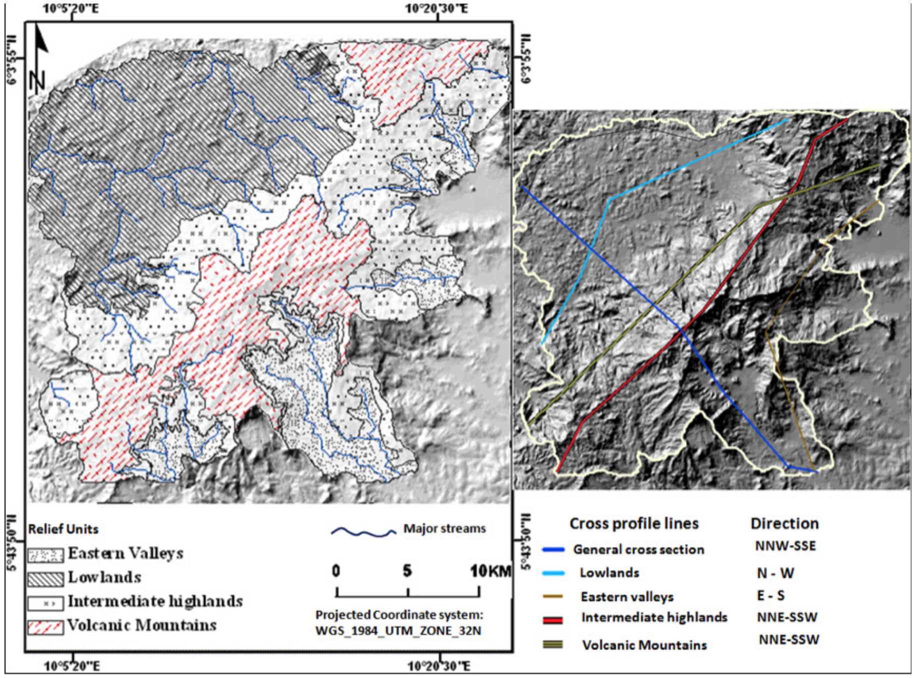


Ilustração 05 – Relief unites and cross section profile lines.

The general cross section map (Ilustração 05) shows an uplifted complex (volcanic mountains) in the centre with steep slopes stretching from the Santa highlands in the south to the Bamenda lowlands in the north (Ilustração 06). The lowland is marked by disjointed hills with small valleys in between them mostly marshy with seasonal streams. The volcanic structure made up of several mountains cuts across the central spin making the entire area visible from a single point around Bamenda Up Station escarpment peak.

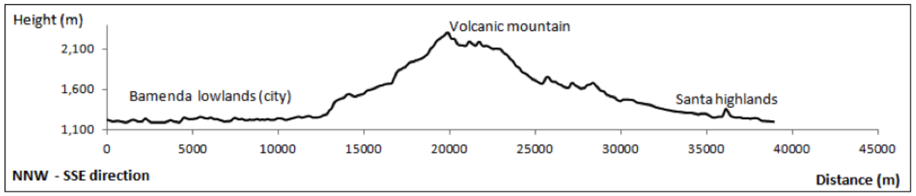


Ilustração 06 – General cross section of the study area.

The spatial extent of each relief unit (Table 01) was calculated from the topographic map. Though the volcanic structure is not very large in surface area (202.1 Km^2), it has an important influence on the climate of the area. The largest relief unit is the intermediate highland (306.4 km^2), followed by the lowlands (282.1 Km^2), and the smallest unit is the eastern valleys (123.1 Km^2) that extend to the Ndop plain. The colonial activities which were mainly coffee cultivation took place in the lowlands, intermediate highlands and the eastern valleys. However, the administrative headquarters of the Germans, as well as the British, was on the volcanic plateau. The mountain vegetation was cleared off to make way for the vast German fort and coffee farms.

Table 01 – Relief units by surface area

Nº	Relief Unit	Area (pixels)	Area (Km²)	Area (%)
1	Volcanic Mountain	2020956	202.1	22.12
2	Intermediate highlands	3064272	306.4	33.5
3	Lowlands	2820367	282.1	30.9
4	Eastern valleys	1231030	123.1	13.5

3.2.1. The Volcanic Mountains

The Volcanic Mountain also called the High Lava Plateau is part of the continental sector of the CVL eruptive chain which has been active from 52 Ma to present (Kamgang *et al.*, 2007). It is made up by a chain of large massifs (e.g. Bamenda escarpment, Santa-Akum hills, the Mendakwe, Njah and Alongse hills, Bambili and Sabga Mountain). These relief structures have identical characteristics with heights ranging from 2900 m in the NE to 2600 m in the central south and about 2000 m in the SW. It is composed of a series of individual anticlines (up fold) structures with U-shape and V-shaped valleys intersect, each uplifted compartment of the relief. The general relief is orientated northwards with NE facing slopes relatively gentle, mostly rectilinear, and highly exposed to weathering. The SW slopes are highly convex at the top and concave at the basement complex or talus. A few anticlinoria have abrupt ridges and the central cavity is the area with the highest elevation. The anticline and up fold structures have several volcanoes (e.g. Mbi crater, Bambili crater lake, Mbatu crater lake) spread along the spin of the Foleshele crater lake found within a few kilometres northeast of the study area. The "Mbi" crater is an important relief unit in the area because of its quasi perpendicular structure know for rock falls at its convex edges while its concave slopes have experienced spectacular debris flows in years. The volcanic Mountains (Ilustração 07) can be grouped into two principal units disconnected from each other by the intermediate plateau separating the caldera spin into two blocks. It has contrasting morphology marked by peak crest lines and hills, knolls and ridges that juxtapose V-shape and U-shaped valleys with Cols and saddles that dissect the landscape.

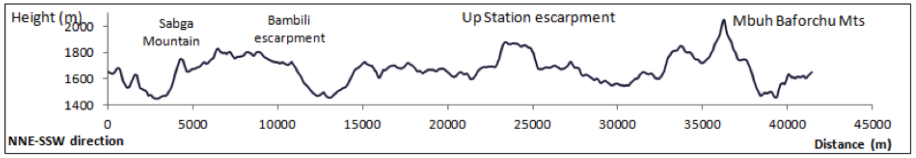


Ilustração 07 – The Volcanic Mountains.

The crest peaks have waxing, derivative and winning structures all through its profile forming bowl-like structures and cones at different heights. The northern slopes of the first plugs rise steeply upwards with a V-shape valley (Akum river) while the south-western peaks that rise after the short intermediate plain stretch inland into the enclaves of the Ngemba forest reserve with indented and broken escarpments in the mid axis. Mechanical and physical weathering processes are important here with angular rocks and large boulders dotted across the landscape. Isolated fragments of rocks are found within the limits of the escarpment suggesting past volcanic explosions in the area.

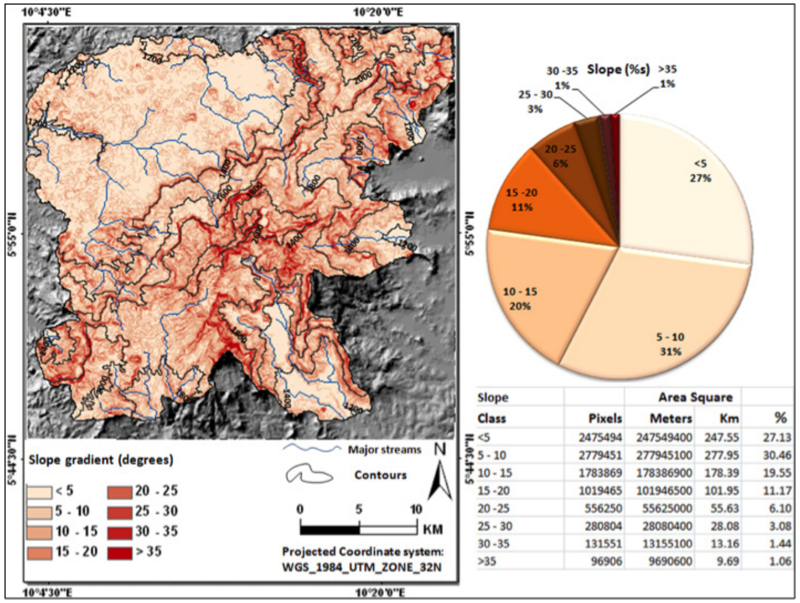


Ilustração 08 – Classified slope map of Bamenda Mountain.

The classified slope gradient map shows that 31 per cent of the study area is made up of 5 - 10-degree slopes while 35 degrees slopes make up just 1 per cent of the area. Most of the very steep slopes (>35°) are in the volcanic mountains while the gentle slopes (<5°) are in the Bamenda lowlands and the eastern valleys. The moderate slopes have scree deposits from fragmented rocks from the Mountain cliff, while the middle slopes are composed of deeply weathered mantle material.

3.2.2. Intermediate highlands

The intermediate highland (Ilustração 09) has Mountains with multiple derivatives, waxing hills and fast-rising volcanic plugs lying beneath the high volcanic Mountains. The mean height of these uplifts is about 1700 m at high altitudes. A common characteristic of the relief here are circular or rounded peaks, minor plateaus and several anticlinal (up fold) structures scattered across the landscape. At the centre is the chain of Mountain peaks with thrust fold borders. North of the thrust fault scarp are four uplifted compartments with multi-line ridges to the direction of the deep depression with a narrow outlet to the south. The depression is surrounded by high relief units with two sharp peaks reaching 2230 m and 2220 m tall separated from each other by a flat floor valley.

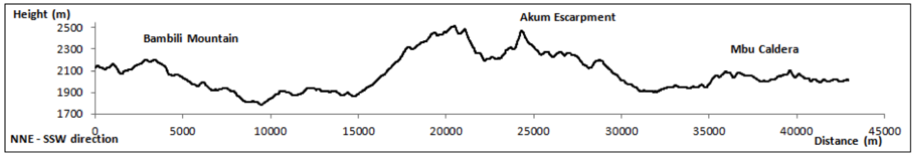


Ilustração 09 – Intermediate highlands.

At the edge of this karst depression are rock falls with boulders fragments deposited on the slope and at the bottom of the fluvial karst zone. Though many, the Bambili, Akum, and Mbu caldera mountains (Ilustração 09) are the major high relief features in the intermediate highlands. At the northeastern edge, two peaks between 1600 m-1700 m ASL stretch for close to 5 km to the west and the first peak abruptly ends at the edge of the Bambili twin volcanos. A series of anticlines and synclines succeed each other with a rift valley separating them. This inter-Mountain area has more concave slopes and is prone to erosion and landslides.

3.2.3. The Lowlands

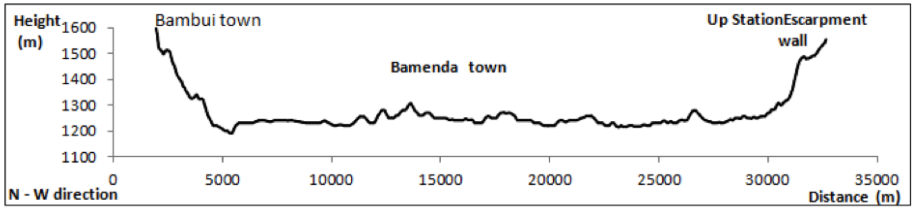


Ilustração 10 – The lowland (Bamenda town).

The lowland is a bowl-like structure (Ilustração 10) found in the North West sector of the study area. The Bamenda lowland is found in the west flank of the Mbu caldera with an average altitude of about 1275 m stretching to the north and west in a semi-circle. It also has high altitude relief units, but lower than those compared to the intermediate highlands, the caldera host or volcanic Mountains. The steep slopes of the intermediate highlands to the east separate the caldera from the lowlands. The lowlands have altitudes ranging between 1200 m and 1350 with a rectilinear profile (facet) with the exception of a few uplifts with very steep slopes. Interwoven with a series of U-shaped valleys, the area extends for about 20 km with undulating slopes of low altitudes. The northern edge (Bambui town) is the highest point in the intermediate highland structure.

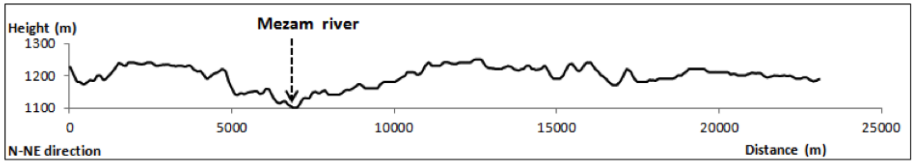


Ilustração 11 – Mezam river valley.

Further north of the lowland lays the northern valley also known as the Mezam river valley (Ilustração 11) which is a small depression that hosts River Mezam. This is the biggest river valley and lowest point (1070 m ASL) in the study area with its northern sector measuring about 1 km. However, at the NW edge of the valley is a diapiric depression lying adjacent to a fault scarp with very steep slopes probably developed from a volcano. This depression forms part of the Ngemba forest reserve. At the South-west edge of the reserve is a volcanic cavity with a fault scarp to the direction of the tectonic tilt with rectilinear slopes stretch over long distances to the west. The geomorphology of this environment is rapidly changing with the increase in population and climate change.

3.2.4. Eastern valleys

Another important relief unit in the study area is the eastern valleys found adjacent to the intermediate highland. It has the lowest altitude (1835 m ASL) in the study area with an average altitude of 1150 m. The eastern valleys that extend from the Ndop plain to the Tiogou plain (Ilustração 12) have a few seasonal streams. The structure of the relief is quite different from the rest of the region and it is the innermost or most enclaved part of the study area. The eastern valley is made up of the Awing lowlands which is a vast depression lying beneath the caldera to the east, home to the Santa coffee estate. The valleys have minor uplifted compartment where several springs flowing to the east take their rise. These valleys are more broad-based with significant width, less incised and waxing than those in the other relief units (Ilustrações 08, 09, 10). Weathering and erosion are very active processes here and some weathered materials here include volcanic ash and alluvium from polygenic erosion surfaces emanating from the uplands. With large fluvial incision inland, there are three alluvial fans which give rise to regolith deposits on the lowlands. The contact zone between the depressions and the highlands favour mass movements especially rock falls. Bush fires are rampant during the dry season giving the area a lofty scenery.

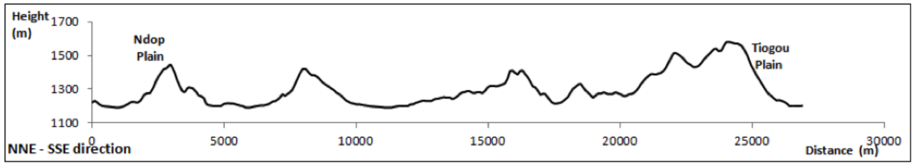
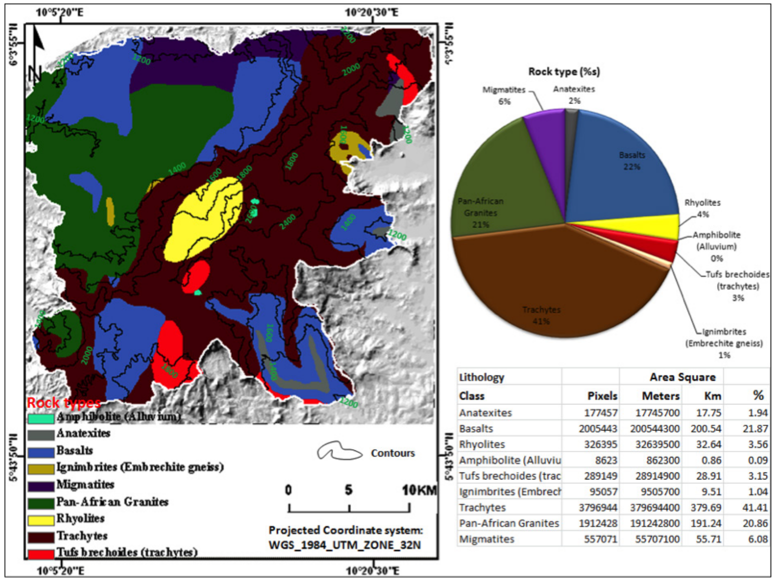


Ilustração 12 – Eastern valleys.

The northern edge of the eastern valleys has fault scarps dominated by late tertiary and quaternary rock formations. The southeast central axis is made up of a series of volcanic plugs covered by Trachyte and Rhyolite. This fault scarp culminates at the monocline ridge to the east. The edge of the diapiric depression in the east has undulating relief features with convex slopes at the fault line segment. Some fault lines intersect through the two major edges of the depression cavity. The south edge is made up of high mountains, chevrons and V-shape valleys (Ilustração 12). Meeting the thrust fault or caldera line, this contact segment gives rise to the steep slopes with 20 % on average. The lowlands and eastern valleys are largely composed of old fluvial terraces and flood plains which are often covered by water during periods of high discharge. Ditch bank erosion is very prominent here as flood waters moving downstream remove rock and soil materials on the riverbank. Unconsolidated sediments transported from the upslope have created a floor on the flood plain largely composed of sand, gravel, loam, silt, and clay. Along the Mengwe River, precisely at Njenefor where the river course was diverted for anthropic activities, we find geologically ancient floodplains (fluvial terraces) composed of old flood deposits ranging from coarse gravel, fine sand and fine silt forming very fertile soils good for farming. Swamp-grown crops such as cocoyam give this area a green-looking vegetation during the harsh harmattan season when most of the area is dry. The fertility of this area may have attracted the implantation of the Santa tea estate plantation on the Santa-Awing slopes during the colonial period. The new infrastructure changed the vegetation.

3.3. Lithology

The Bamenda Mountain is largely made up of eruptive bimodal lavas and minor intermediate lavas (Kamgang *et al.*, 2007). Metamorphic and igneous rocks of Late Precambrian and Early Paleozoic age outcrops in the northeast trending belts form the geological core of the area. Petrographic and geochemical studies by Gountié *et al.* (2012) and fieldwork by Afungang (2015) show that the area has Amphibolite of aluminium, Anatexites, Basalts, Ignimbrites, Migmatite, Pan African granite, rhyolite, trachyte and Tuff brechoides (Ilustração 13).



Lithology		Area Square		
Class	Pixels	Meters	Km	%
Anatexites	177457	17745700	17.75	1.94
Basalts	2005443	200544300	200.54	21.87
Rhyolites	326395	32639500	32.64	3.56
Amphibolite (Alluviu	8623	862300	0.86	0.09
Tufs brechoides (trac	289149	28914900	28.91	3.15
Ignimbrites (Embrech	95057	9505700	9.51	1.04
Trachytes	3796944	379694400	379.69	41.41
Pan-African Granites	1912428	191242800	191.24	20.86
Migmatites	557071	55707100	55.71	6.08

Ilustração 13 – Geological map of Bamenda Mountain.

Source: Afungang 2015.

The volcanic massifs are covered by felsic rocks (trachyte, ignimbrite, phonolite and rhyolite) and prismatic lavas found on the caldera rims and in the protrusion's caldera floor. The lowland surfaces are composed mainly of plutonic granite and gneiss rocks (Dumort, 1968) with patches of ignimbrite and phonolite. The eastern valleys are con-

tained remnants of quaternary volcanic deposits with Plutonic and Metamorphic rocks. The contact point between the lowlands and the highlands contains patches of Amphibolite and welded Ignimbrites and Migmatite. This has made this area unstable and exposed to landslide. Clay rocks formed through chemical weathering usually silicate-bearing, composed mostly of phyllosilicate minerals, have water trapped in their structure. Rocks of sedimentary origins mainly laterite and siltstone are found in most parts of the lowlands. There are pockets of laterite formations with reddish and unfertile soils rich in aluminium in the lowland. Laterites are highly exploited in the area for road and house construction. Siltstones are used as grinding stones in kitchens and for decoration. The thrust faults or Bamenda escarpment area and the shear zones placed as syntectonic and post-tectonic plutons are composed of strong peraluminous leucogranites commonly associated with regionally metamorphism and highly folded orogenic belts. The Mountain floor is mainly composed of trachytic domes, which are also abundant on the external slopes of the massif. Sedimentary rocks present in the area include sandstone, laterite and siltstone and some metamorphic rocks (quartzite) and plutonic formations (diolerite) are found in many areas.

The geological formations show great correlation with the relief. The Bamenda lowlands basement rock is predominantly garnet bearing leucougranites and Pan African granites, Laterite rocks and siltstone. The intermediate highland is predominantly occupied by basalt and ignimbrite and the volcanic Mountains are dominated by trachyte, rhyolite and phenolate. The eastern valleys and plains are made of migmatite and alluvium. The alignment of the rocks is important in understanding their behaviour during heavy rainfall and earthquake events. Geology influences erosion and human activities, which are important driving forces of vegetal dynamics.

Ilustração 14 (a) – Rock samples found on Bamenda Mountain area.

Some rock types are more liable to change than others. Basalts, for instance, are common dark-colour volcanic rocks (Ilustração 14 a) involved in most slides in the area. Basalts belong to the quaternary and tertiary volcanic formations. The tertiary basalts are denser than those of the quaternary and are found underneath the relatively quaternary overlying basalts. The light quaternary basalts easily slide over the denser tertiary type along bedding plains especially when water percolates and forms a sliding layer (shear zone) in between the layers. Ignimbrite, a pyroclastic rock formed by volcanic ash and rich in petrochemicals, is found in the area, although it makes just 1 % of all rock formations.

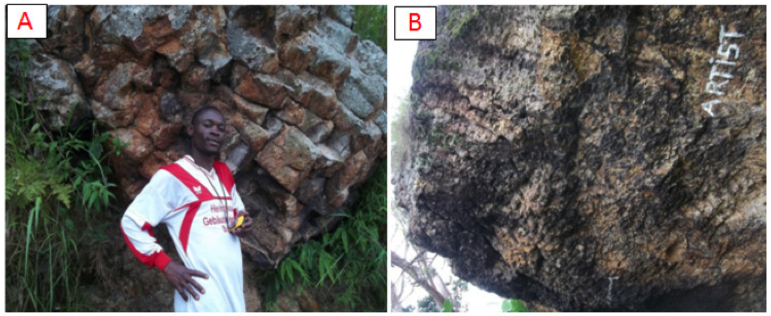


Ilustração 14 (b) – Rhyolite (A) and Trachyte (B) boulders at Siesia quarter Nkwen.

The rocks (Ilustração 14 b, B) are believed to have fallen off from the adjacent Up Station cliff under the influence of gravity. Some of these rock fragments were recently brought down by landslides. For instance, the 2009 Siesia landslide brought down huge boulders from the cliff face that destroyed eight houses (Ilustração 14 b, A e B). Laterite and siltstones are the most volumetrically present sedimentary rocks in the study area. These rocks are littered all-round the Siesia landscape and some believe they have been displaced during the construction of the Bamenda fort by the German colonial masters. Laterite is highly exploited for construction work creating big gullies and ravines on the slope. Sandstone is also used for construction; siltstone is used by carvers for craftwork like sculptures.

3.3.1. Superficial formations

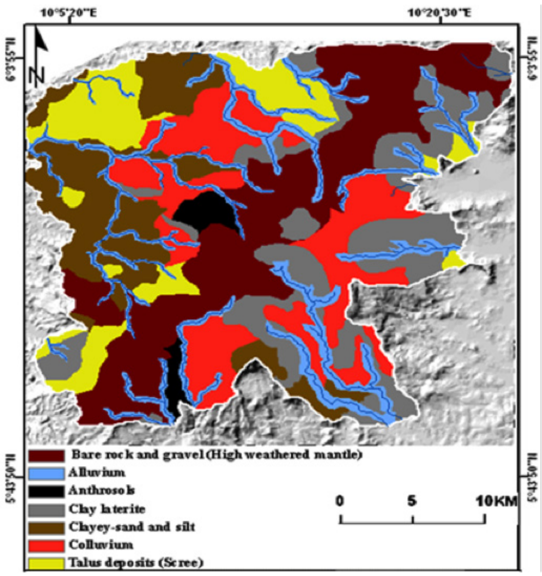


Ilustração 15 – Superficial formations map developed from the soil map of Bamenda area by ORSTOM (1984) and field cartography.

Ilustração 16 – Source of Weathered materials in the area. (A) Alongse rock pedestal; (B) Bambili rock pedestal; (C) Weathering of granites in upper Bambili; (D) Weathrting of rhyolitic rocks on Bamenda up station escarpment; (E) Rock pedestal at "Mesong me mabo'o; (F) Gravel along a newly graded road; (G) Laterite outcrop; (H) Laterite soils exposed by slope excavation.

Superficial formations are geological deposits composed of material originating from the physical transformation of rocks *in situ*. These formations can be divided into three main types; materials developed on the spot from weathering and erosion (scree, volcanic ash); transported and deposited materials through gravity (colluvium, alluvium, clay, silt sand, laterite); and anthrosols from cultivated areas. Geotechnical characteristics of these materials done by Guedjeo *et al.* (2013) show that they have a bulk density between 1.32 and 1.59, specific density between 2.20 and 2.58, porosity level between 47.92 and 64.28 %, water content of <35.2 %, cohesion 2.60-7.20 kPa and the angle of internal friction between 25.5 and 28. Changes in superficial formations reflect changes in vegetation cover. In areas where colonial farms were opened, physical and chemical weathering and erosion quickly modified the landscape (e.g. Santa tea estate area). Some of the weathered material (Ilustração 16) is from human activities (Ilustração 16 F, H) and others from the expansion and contraction of rocks due to an increase and decrease in temperatures. Talus deposits and armor make up 11 % of soil deposits in the area.

Anthrosols or soils that have been profoundly modified by the addition of organic materials or household wastes or modified through long-term human activities like irrigation or cultivation are found in extensive lands in some parts of the study area. The biological, chemical and physical properties of these Anthrosols show decades-old human activities that date back to the colonial days of plantation agriculture. Estimates made a decade ago show that over 40 % of the landscape is under agro-pastoral activities (Afungang, 2010; Nkwemo, 1999). The exact vegetation change engineered by colonial activities can really be ascertained because the topsoil has undergone significant modification since ancient times when the Bantus and Tikars settlers mostly agriculturalists occupied the Bamenda highlands (Boutrais, 1978).

3.4. The drainage system

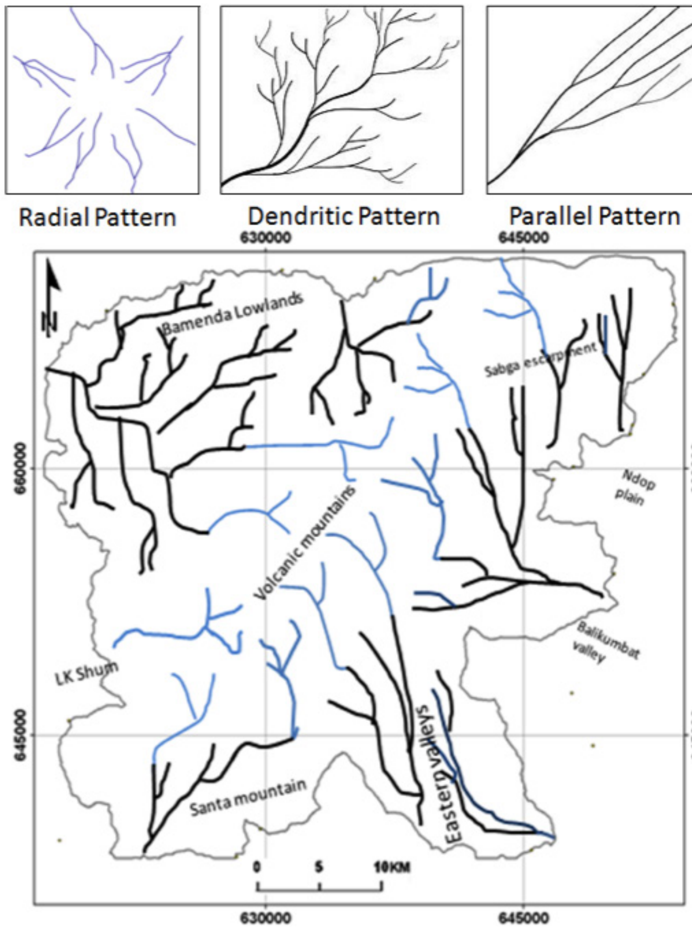


Ilustração 17 – Sketch map of the hydrographic network.

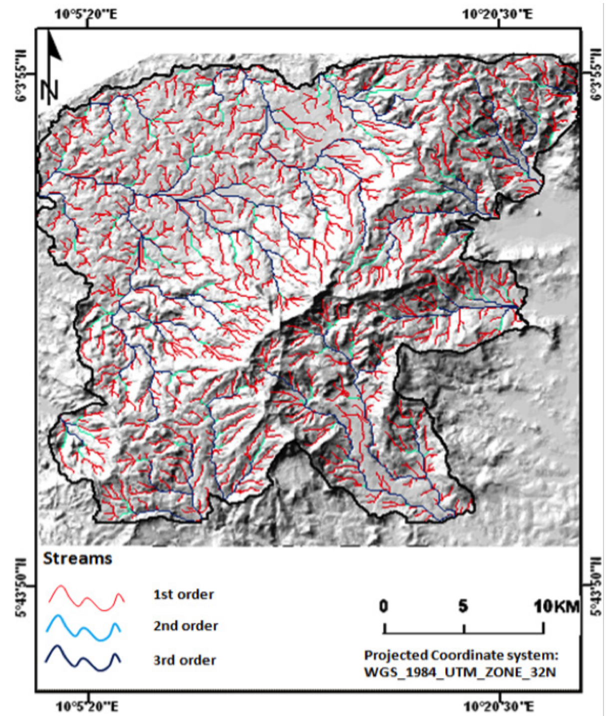


Ilustração 18 – Drainage system showing stream order.

The hydrographical network is another factor that influences the vegetation. Although the area is dominated by a radiant drainage network pattern, detail analysis shows parallel drainage networks on steep slopes (except in the area where the fault cuts across the folded bedrock) and dendritic networks in the low lowlands (Ilustração 17). Many rivers take their rise from the volcanic Mountains and flow in a radiant pattern downslope following relief barriers. Most streams at high altitude are of the first order while 3rd order streams formed by the merger of smaller springs are found at lower altitudes. Along the intermediate highlands, the very steep slopes and their quasi-resistant rocks (e.g. Rhyolite, Migmatite, and Laccolites), give rise to parallel drainage patterns with fast running streams flowing close to each other over long distances. These streams have few tributaries mostly flowing towards the same direction. The Mezam, Mefeh, Mengwe, Mungum rivers, for example, are formed by the convergence of several tributaries emanating from the volcanic mountains. The transitions from parallel, dendritic, to trellis flow patterns (Ilustração 18) shows the development of tributaries as the river gets bigger downstream. The general drainage network of the area (Ilustração 18) shows stream succession from 3rd order to 2nd order and then to 1st order streams. The drainage system favoured the growth of thicket vegetation in the plains and valleys. The vegetal cover in the river valleys and swamps was largely undisturbed during the colonial days since they were not good for cash crops. Most of the changes we have today are recent and spurred by rapid urbanisation and deforestation.

3.5. Vegetation

The study area has climax and sub-climax vegetal formations. The climax vegetation which now exists only in patches is composed of moist evergreen forest, moist montane forest, bamboo forest, and thicket vegetation. Before the 1970s, the moist montane forest was the main vegetation in the area, but it has dwindled significantly because of human activities and climate change (Afungang, 2013). Hyparrhenia (sprorobulus grassland) that occupied large parts of the volcanic mountains is a degraded form of moist montane forest. In the 1970s the area was covered by Alphine bamboo forest, Hyparrhena, moist montane forest and terminalla trees. The Alpine bamboo forest has totally disappeared and shrub terminalla trees usually found in the eastern valleys are almost gone. Today, the moist montane vegetation is fast disappearing and replaced by lush forest. Remnants of this forest made up of tall trees are found mainly around protected areas such as traditional shrines (e.g. Bambui, Nkwen and Fengi shrine). The indiscriminate felling of trees for fuel wood and infrastructural construction is affecting the vegetation. Bamboo forest and thicket climax vegetation types, mostly pure bamboo, exist in patches along river valleys. Lichens and tree species such as syzygium sp, polyscias fulva, scheflera spp and herbs like sanincula europea, Thalictrum, Rhycholcarpium are found in the uplands. Terminalla trees or shrub savannah is one of the oldest vegetation in the area. Due to anthropogenic activities shrub savannah, lichens and short trees are fast replacing the dense forest cover which existed here before the 1970s (Ndenecho, 2006). Savannah vegetation here includes grassland, parkland and scrub (branching, twisting deciduous trees like Indian bamboos), palms and eucalyptus. The moist evergreen forest with close canopy and compact roots helps hold rock and soil particles together and prevent erosion. In the last two decades, the vegetation size and species have decreased significantly (Table 02). This is in sharp contrast to the colonial vegetation where floristic species were in abundance even in very high altitudes.

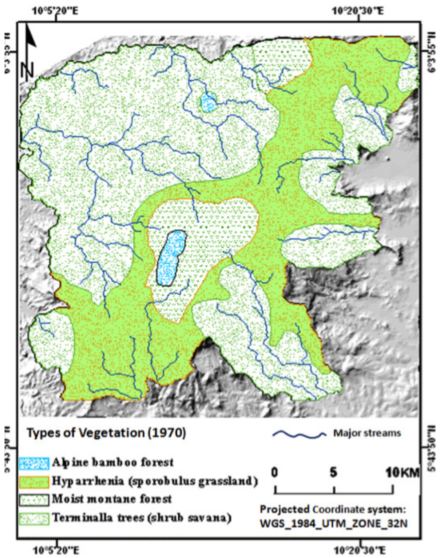


Ilustração 19 – Vegetation map derived from ORSTOM map of Bamenda Area (1970).

Table 02 – Morpho-vegetation change

Vegetation type	Description	Altitude	Floristic composition	Superficial formation	
				1965	2006
Moist evergreen forest	Juju forest	<1600 m	Hyperaemia specie	63. 3 %	54.9 %
Moist Mountains forest	Close campy	1600 m – 2200 m	Sporabulus species	5.8 %	3.7 %
Bamboo forest and thicket vegetation	Close campy	1200 m	Moss and liverwort	15.9 %	11.8 %
Tree and shrub Savannah	Dotted everywhere	1700 m	Trifolium	1.7 %	1.1 %
Grassland savannah	Every where	>1000 m	Bare ground	36.7 %	40.4 %
			Vegetal ground cover	63.7 %	42.3 %

Source: Compiled from Hawkins and Brunt (1965) and Ndenecho (2006).

Among the causes of vegetation loss are constant bush fires, overgrazing and erosion. In the colonial days, erosion was a major problem to vegetation growth and known to have greatly destroyed large swards of hyparhernia and sporobolus africanus species which makes up 90 % of the total vegetation in some areas (Hawkins and Brunt, 1965). This secondary vegetation shows how long man has influenced the vegetation of this area. In areas with intensive bush fire, the tree savannah forms shrubs and in extensive farmland areas like in Ndzenefor, Nta'a Nah and upper Bambui areas.

Areas covered by Hyparrhenia in the colonial era till the 1970s are now covered by shrubs and lichens due to grazing and crop cultivation. Presently, there is virtually no natural forest left on the intermediate highlands and volcanic Mountains, but Eucalyptus abounds from the hilltop to the slopes. This replacement has a negative impact on the morpho-vegetational structure of the area. In vegetated areas, plant roots breakdown rocks and help transport water into greater depths. The absence of vegetation limits infiltration and plant growth and facilitates runoff and erosion.

Crops types (Table 03) have an impact on the relief, erosion and landslide activity. The main activities controlling vegetation cover in the area are wildfire, livestock rearing and fuel wood exploitation. Periodic wildfires in the dry seasons and the grazing of livestock such as cows, sheep and goats on the slopes throughout the year determine, maintain and control vegetation growth. The colonial masters were not interested in livestock and this helped maintain the vegetation balance.

Table 03 – Crop type and vegetation cover

Crop type	Relief	Soil cover capacity
Coffee and fruit trees	Gentle slopes and Lowlands	Total protection from soil loss
Plantains and bananas	Lowlands	Effective protection and negligible soil loss
Cereals and root crops	Plain and valleys	Average protection, increase soil loss
Pastures	High plateau and escarpment	Weak and less protection with high and important soil loss

Source: Annual report of the Ministry of agriculture for Mezam and field work observation (2009).

3.6. Climatic condition

Cameroon has a tropical rainfall regime characterized by high precipitation and a short period of intense sunshine. The climate of the study area is generally cool and dry compared to the rest of the country with temperatures ranging between 13 and 22 degrees Celsius (Ndenecho, 2011). The rainfall regime here is highly variable at inter-annual and inter-seasonal scales. The strong seasonal cycle is characterized by high rainfall from March to October with little or no rainfall from November to February. The area's climate depends on the alternation of the South West Monsoon winds and the Harmattan trade winds systems. More so, the shift in the intertropical conversion zone (Ilustração 12) and wind movement affects the vegetation.

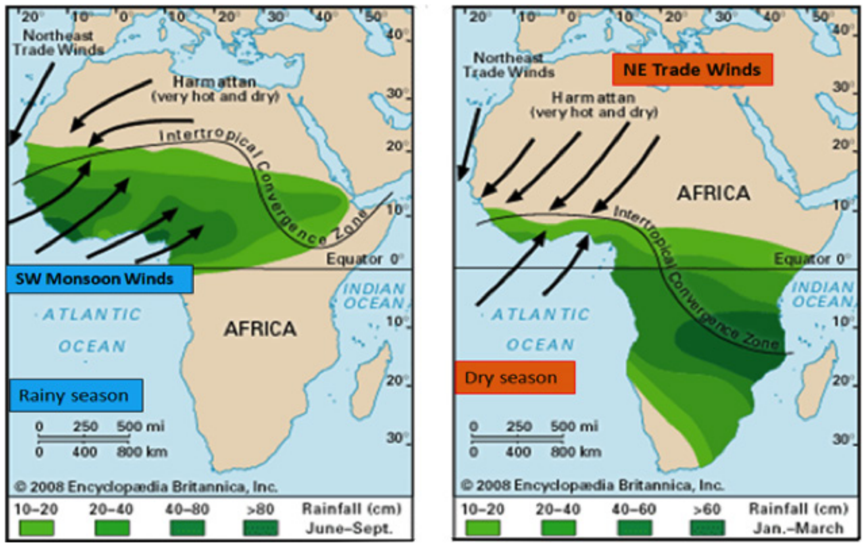


Ilustração 20 – Wind systems affecting the area.

Rainfall varies from 3048 to 1778 mm annually (Ilustração 21) with NW facing slopes receiving higher rainfall (frontal rainfall) than SW facing slopes due to the Bamenda escarpment. During the Harmattan season, morning temperatures are cold (12-15 °C) and mid-day temperatures sometimes rise to 39 °C. The reverse occurs during the rainy season but follow the same daily trend like in the dry season. Temperatures range between 25-45 °C in the dry season and 12-20 °C in the rainy season. The skies have cloud cover for the most part of the year, allowing annual temperatures to exceed 25 °C. The high temperature and rainfall increase vegetation growth and the micro-climate favours landslides. For instance, the windward slopes and high altitudes have more landslides than leeward slopes and lowland areas (Afungang and Bateira, 2016).

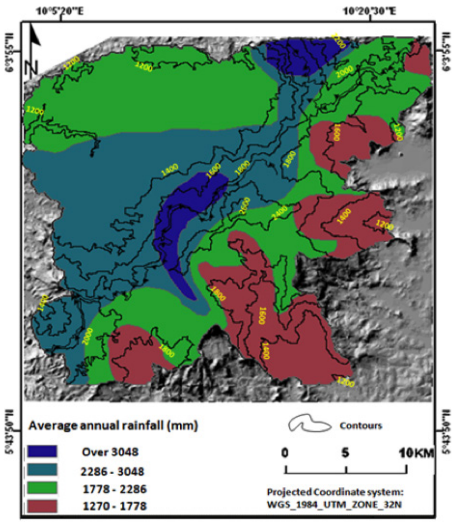


Ilustração 21 – Rainfall Map of Bamenda mountain.

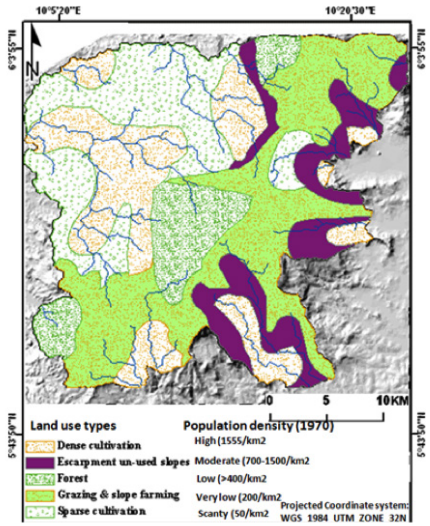


Ilustração 22 – Land use and population density of the study area in 1970.

3.7. Land use dynamics

The land use system, rainfall and landslides are some of the factors affecting vegetation in the area. Bobrowsky and Lynn (2013), in their guide to understanding landslides, noted that human use of land potentially brings dynamics to the natural soil cover destabilizing its equilibrium and rendering it susceptible to attack. Guzzetti (2008) noted that landslides caused by heavy and prolonged rainfall have more impact on used lands. The land use of the Bamenda mountain region began to change in a rapid way since the 1940s with the introduction of massive agricultural reforms. In those colonial days, the government of the Southern Cameroons working under the British trusteeship set up small farmers' cooperatives for Arabica and Robusta coffee production. The lowlands were occupied by forest and crop cultivation, the volcanic mountains were occupied by forest and used for grazing and agroforestry, while the eastern valleys were unused or natural land (Ilustração 22). Today, anthropogenic activities (e.g., road and house construction) spurred by rapid population growth and urbanization now occupies about 70 % of the landscape.

The vegetation is under serious threat from natural processes including erosion and landslides. Hungr (1995) noted that these processes can affect land cover materials far off the site of the incident and can have a profound impact on the sediment budget on hill slopes and the entire catchment especially within 10 – 100 years (medium scale). This is very true in the area as the creation of industries, factories and learning/economic institutions caused the destruction of large hectares of forest and natural vegetation as erosion has transported large crustal materials from hundreds of meters into the valleys (Afungang, 2013).

The study area has a population of about 300 000 people, most of whom are living along the Bamenda escarpment and lowlands. In the 1970s, the highest population density in the area was 1555/km^2 in the city centre and 50/km^2 in the highland areas with large parts without any human presence (Afungang, 2015). Today, this area has a population density of about 2255.52/km^2 with an annual growth rate of 7.95 % forcing many to inhabit unstable slopes (Ilustração 23). Agriculture is the main economic activity and source of livelihood. About 70 % of the total workforce is engaged in this sector and agriculture occupies about 70 % of the total surface area (Table 05). Shifting cultivation and animal husbandry that used to be the main farming methods in the area has evolved to mechanised agriculture. Before 1960 the countryside was marginally affected by peasant agriculture until the introduction of coffee and cocoa farming in the 1970s and the recent in flocks of rural-urban migrates. The scarcity of arable land has pushed many to occupy and cultivate steep slopes. In the last four decades, the urban space has grown rapidly with roads, house and recreational facilities forcing agricultural activities to the hinterlands. A survey on land use carried out by the Bamenda Urban council, Tubah council, and field work showed a marked change in the way land is used. Between 1960 and 1980 most of the area was arable land occupied by forest or used for farming and livestock rearing. Between 1980 and 2009 large swaths of the forest were cleared to make for road and house construction (Table 04). These activities have diminished the vegetal cover favouring water infiltration and the breakdown of soil aggregates. The infiltration has increased pore pressure while peculation of water into fractured rocks had sometimes caused the rocks to be pulled down by gravity.

Table 04 – Land use dynamics from 1960 to 2009 in some parts within the study area

	Village	Construction and urbanisation	Farmland	Forest	Pasture	Recreation
1960 – 1980	Bambui	Few roads and houses 20 % of the total land	Few farms 20 % of the total land	Dense Forest	Large	Few outdoor activities
	Bambili	Few houses and human occupation	Extensive agriculture	Thick herbaceous vegetation	Pastoral lands	Recreational
	Kedjom keku		Shifting cultivation			Few infra-structure
	Kedjom ketinguh		Small cultivated parcels	Wide or extensive coffee farms		
	Nkwen	Small dense agglomera-tions		Small agrarian landscape		
	Mendakwe	Few and poorly constructed roads		Large coffee farms		
1980 – 2009	Bambui	Intense infrastructural development	Intensive farming	Mark level of deforestation	Small pastures	Many out-door space
	Bambili	Semi urban		Deforestation	Farmer	Sporting infra-structure
	Kedjom keku	Small concentration of buildings	Market gardening		Grazer	Infrastructure very low
	Kedjom ketinguh				Farmer/grazer conflicts	
	Nkwen	Rapid infrastructure development	Large group farms	>80 % of de-forestation	Intensive rearing	7 football pitches
	Mendakwe	Rapid construction of new roads	Extensive cereal and grain cultivation	Mark level of deforestation for fuel wood	Intensive animal rearing	Four football pitches

Soil vibration from heavy vehicle traffic and road construction activities has sometimes caused intense erosion and slope movements. For instance, soil vibration during the construction of the Up Station-Bamenda new road is believed to have triggered the 2009

Siesia landslide that killed 1 person, displaced dozens and destroyed eight houses. From 1960 to 2009, over 40 principal roads and secondary roads have been constructed within the Bamenda Urban council area (Afungang, 2010). The roads include the Bamenda – Fundong highway, the Bambui – Ndop highway; the Bamenda "Ring Road" and the Up station – Bamenda new road. Rapid population growth has pressurized the construction of new roads. There are about 18 principal roads and 130 secondary roads in the study area. The satellite images of part of the study area taken in 2012 show an expanding road network and house construction. The exploitation of basaltic and granitic rocks used for gravel during infrastructural construction also helps to destabilize the slope. Similarly, the removal of sand on the riverbanks also destabilises the riverbank causing landslides in some areas. The concave and convex banks of the river Menjwe, Lebacan, Memfe and the Keshinze rivers are in a state of rapid dynamics as sand is constantly removed from the riverbed. Construction works have hugely affected the vegetation over the years.

Conclusion

Details from the physiographic characteristics and anthropogenic activities of the study area showed us that the area has lost about 70 % of its natural vegetation. It has also been revealed that colonial activities didn't influence the vegetation significantly. The colonial masters opened only three large farms in the area and the low population density helped preserve the vegetation. They did very little to improve the infrastructure as the area's rich subsoil resources (petroleum) hadn't yet been discovered. Massive deforestation only started in the 1980s and 1990s with urbanisation and the development of infrastructure. The geomorphologic characterization of the area showed that the physical milieu constraints is fast losing its importance as the population now occupy steep slopes and escarpments previously uninhabited. Topography and rainfall were the two most important factors influencing the vegetation. On the other hand, farming and road construction were the most important human activities causing vegetation dynamics. The detail description of the physical and anthropogenic characteristics of the area can be used by environmental planners during decision making.

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