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SLOPE DYNAMIC RESPONSE TO THE GROWTH OF SPONTANEOUS SETTLEMENTS ON THE BAMENDA ESCARPMENT ZONE, NORTH WEST REGION OF CAMEROON

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ABSTRACT

Topographic units ranging from escarpments to steep slopes have not been centres of attraction to settlement construction. While these slopes have witnessed progressive settlement growth, the sprawling of settlements revealed a spontaneous pattern on the different slopes with little or no planning mechanism put in place. It is against this background that this paper seeks to investigate the slope dynamic response to the spontaneous settlement growth within the Bamenda volcanic escarpment. The study employed both primary and secondary sources of data collection techniques. Field observations, interviews and questionnaires were used to gather information. Sisia, Down Town, Ntaghan and Abangoh quarters of the escarpment face were visited. A total of 125 questionnaires were used to collect data from four quarters within the Bamenda escarpment slope using simple random sampling technique. Data on urbanization trend vis-à vis urban planning and development were gotten from MINDUH while data on landslide events and trend were obtained from the Bamenda City Council and published documents. Landsat maps as of 1984 and 2018 were used to establish the trend and pattern of settlement growth within the Bamenda escarpment face. The Pearson Product Moment Correlation Coefficient was used to test the relationship between housing construction density on steep slopes and slope dynamics. The reliability of the Correlation coefficient was determined using the Cronbach's Alpha. The findings revealed that the spontaneous settlement construction within the steep slopes is mostly driven by the problem of land scarcity and administrative bottleneck by policy makers. This unplanned construction of settlements on the fragile escarpment face of Bamenda provokes slope undercutting, loss in highland vegetation, accelerated erosion, landslides and rock fall. The slope dynamic responses are directly related to the intensity of settlement construction. This indicates a high susceptibility of escarpment slopes to landslides and rock fall within the de-vegetated and undercut slope surfaces. The study recommends an effective slope stabilization measures, the maintenance of the escarpment green space and the prevention of further settlement sprawl on the already fragile escarpment face. Above all, urban planning, implementation and evaluation should be carried out to salvage the problem of haphazard colonization of fragile zones within the urbanizing Bamenda escarpment zone.

KEY WORDS: Slope Dynamics, Response, Spontaneous Settlement, Growth Bamenda Escarpment, Cameroon

1 INTRODUCTION

Slopes are essential geomorphological components with remarkable features of the landscape that are not only confined to the mountainous and hilly areas but span through the gently sloping terrains and lowlands. The topographic configuration of the earth's surface with extensive mountainous and hilly landscapes makes these steep slopes dynamic landscapes that are often referred to as high energy environments characterized by vast instabilities (Westerberg 1999, Plummer 2003, NEMA 2007 and NEMA 2009). The high altitude and fragile steep slopes, hydraulic gravity and extreme climatic conditions are triggers of slope dynamics. Such steep slopes and high energy landscapes are conducive environments igniting geomorphic and denudational processes in shaping slopes with response to slope instability. Slope instability stems from increased shear stress on a slope or reduced shear resistance of material stabilizing the slopes. This scenario of the destabilization of the natural slope stability is a combined effect of both natural and human induced factors (Ramli *et al.* 2005). Steep or inclined slopes are naturally unstable but the human activities in the hilly and mountainous areas provoke the susceptibility of the slopes to rapid movements which are often disastrous. Such conditions have yielded significant mobile slopes especially in some highly settled mountainous areas of the world such as the Himalayas in Nepal (Laurie, 2004), the Andes in Peru (Wemple *et al.* 2000) and in Mount Kenya and Aberdares in East Africa (Ngecu and Nyamai, 2004). Rainfall is recognized as the major cause of slope instability (Liu, & Yan, 2003). A large number of rainfall-induced landslides have occurred in recent years (Crosta et al. 2008 & Santoso et al. 2011). Rahardjo *et al*., (2007) performed a series of parametric studies to understand the significance of hydrological and geotechnical parameters of a slope on its rainfall-induced instability. They revealed that rainfall intensity, soil properties, the location of the ground water table, and the slope geometry (angle, height) play a significant role in the rain-induced instability of a slope. Wang *et al*. (2004) found that the function of shear stress and yield stress of slopes in rainfall is related to the angle of slope. Unsaturated soil slopes can be stable with a very steep slope angle until it is exposed to rainfall (Niu *et al*. 2009, Li *et al*. 2009), and its stability gradually decreases or is even destroyed under the action of rainfall (Zhan *et al.* 2003, Rong *et al*. 2008). The mechanism of slope failure induced by rainfall can vary depending on the nature of slope angle. It is important to understand the mechanism and the initiation of failure of a slope to provide better countermeasures against the failure.

The Western Highlands of Cameroon lie along the Mount Cameroon Volcanic Line such that the highlands are naturally unstable and are prone to failure especially when an excessive force is applied on the slopes. This area also has the highest population of people living in landslide prone areas. A wide range of studies have been conducted on the role of geology, hydrology and geotechnical parameters in understating the geomorphic processes on mountainous areas. A gap thereof exits in neglecting the role of man-induced mechanism to slope instability. It is against this background that this paper focuses on slope dynamic response to anthropic incidence in order to understand the disequilibrium between the shear strength and shear stress angle of slopes within the Bamenda escarpment face.

2 THE PROBLEM

The construction of houses on the physical landscape to accommodate the increasing human population over time appears to be one of the human landmark imprints responsible for slope dynamics. The southern volcanic slope of Bamenda presents a geological landscape of steep slopes linking up areas of Sisia, Abangoh and Ntaghan quarters of Nkwen, Mendakwe and Mankon. The steep volcanic face is separated by a chain of crystalline plateau that appears as a gentle and rolling landscape extending to the urbanizing low granitic hillocks of Mankon and Nkwen City of Bamenda. The slope face therefore presents a condition which is much conducive for slope movements or dynamics. The urbanized crystalline plateau of Mankon and Nkwen appears to be stable given the lower slope angles. Land scarcity within the granitic landscape seems to have pushed people to occupy the fragile steep volcanic slopes which appear highly susceptible to landslide, rock fall and soil erosion. The steep zone of the escarpment face was demarcated as green zone by the Bamenda City Council in 2007. Contrary to the conservationist tendency, the rapid growth in human population provoked an illegal acquisition of steep slopes spearheaded by uncontrolled settlement expansion within this mobile slope. These spontaneous settlement constructions are responsible for the accelerated soil erosion, landslides and rock fall given the rapid disappearance of the natural vegetation cover on an already vulnerable slope. The trend of differential erosion and transportation processes appears to be facilitated by the slope undercutting ignited by settlement construction and farming activities that are remarkably observed along the southern slopes of the Bamenda escarpment region. Stream channels are increasingly being diverted, widened and deepened at the slope face with traces of sediments from landfills appearing on channel beds. The upper segment of the escarpment otherwise known as the government residential area (up station) covering a greater parts of Mendakwe appears to generate huge amounts of runoff downslope passing through the steep escarpment face into the gentle crystalline plateau of Nkwen and Mankon. The high hydraulic action originating from up station seems vocal and rapid especially in cut and fills sites. The steep slopes naturally facilitate soil movement but soil erosion and landslides appear to respond more rapidly in areas where the slopes are uncovered, unprotected and naked. Within the southern slopes of Bamenda, the spontaneous settlement growth seems to be responsible for slope dynamics as erosion become natural and accelerated.

3 THE STUDY AREA

The Bamenda escarpment is located at the flanks of Mankon, Mendakwe and Nkwen volcanic chain which lies between $6^{o}20'$ and $7^{o}00'$N of the Equator and $9^{0}50'$ and 10^{0} 25' East of the Greenwich Meridian. The volcanic escarpment face is bounded to the South by the granitic plateau of Mankon extending to Bafut Sub-division, to the South West by Tubah Sub-division, to the north by Akum and Santa and North East by Bali (Figure 1). Bamenda is found in the Western Highlands of Cameroon with two seasons, being the dry season of four months (usually from Mid-November to Mid-March) and a rainy season of eight months (from Mid-March-Mid-November). A cold and misty climate is experienced in the high plateau around the Mendakwe area at elevations between 2100m to 2250m above sea level where maximum mean temperature of 22^{0}C and a minimum mean temperature of 19.5^{0}C are recorded. The rainfall ranges from 2000 to 2560 mm (Regional Meteorological Service for Bamenda, 2018). The geological and petrographic nature of the Bamenda escarpment consist predominantly of volcanic extrusions of trachytes and rhyolites which overlie the basement rock while the gentle granitic hillocks of Mankon and Nkwen are more crystalline (Kang and Kometa, 2019). The topographic landscape has several tributary streams (1^{st} order to 4^{th} order) draining into the River Mezam. The streams are highly seasonal with dry valleys appearing in the dry season and regular flow of streams in the rainy season. The steep slopes together with the hydraulic competence from the vertical slope profile make the slopes dynamic. The slope harbours both the natural and man-made vegetation with the ability to protect the slope from differential erosion, rock fall and landslides common along this volcanic chain. The study involving the escarpment is justified by the fact that the area bears two distinct geological units with one being the fragile steep volcanic slopes covering the quarters of Sisia, Down Town, Ntaghan and Abangoh and the other with a relatively stable urbanizing crystalline plateau of Old Town, Ntamulung, Ndamukong and Bayelle. A varied and spontaneous form of development spans across the escarpment as the rapidly growing and dense Bamenda metropolis is expanding towards the Bamenda escarpment.

The city appears to be an attractive and core zone that has attracted a spontaneous settlement growth and vegetal disappearance which has generated a complicated slope dynamic response pattern in terms of space and time. The increasing construction of houses is now being shifted into the already steep and mobile volcanic escarpment face thereby facilitating vulnerability of the communities to landslides, rock fall and soil erosion. The steeply inclined slopes justify the liability of settlement to collapse as the slope is continuously being affected by hydraulic and fluvial processes acting on such steep slopes.

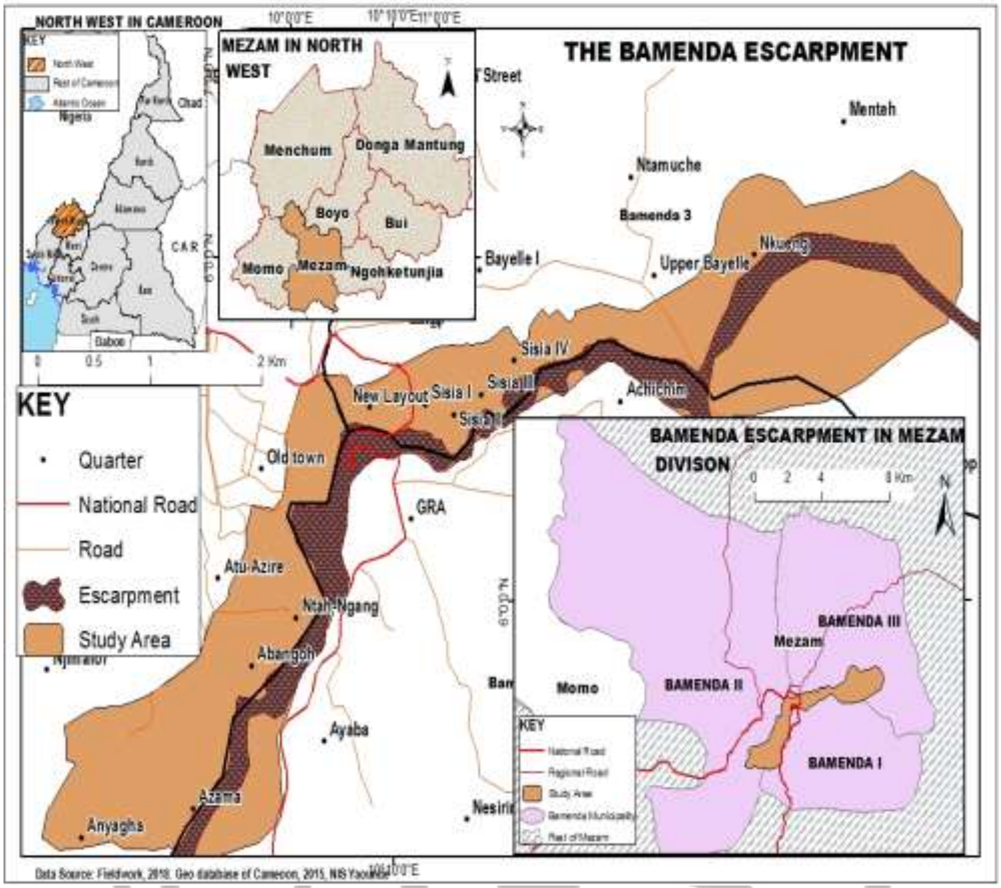

Figure 1: Location of the volcanic south eastern slopes of Bamenda
Source: Fieldwork, (2019)

4 METHODS AND TECHNIQUES

Primary and secondary data collection techniques were used to obtain information from the field. Broad survey field observation and questionnaires enabled the acquisition of information related to housing construction on the slopes and corresponding landslide, rock fall, soil erosion, housing, transportation and deposition of eroded materials downslopes. This provided first-hand information on housing triggers on slope movements in the different topographic units. An extensive interview was conducted with the Bamenda City Council officials and the Delegates of Housing and Urban Development on issues related to land allocation and the respect of a green zone at the escarpment face demarcated from human interference. From field observation and interviews conducted, questionnaires were used to gather varied information from house owners and land users on the rationale for inhabiting steep slopes vis-à-vis slope dynamic responses. A total of 125 questionnaires were used to sample the opinion of house owners and city dwellers on slope development and slope dynamic nexus. The questionnaires were distributed only to households along the Bamenda escarpment slope of Sisia, Down Town, Ntaghana and Abangoh using a random sampling technique. 75% of the questionnaires were distributed to house owners while 25% were distributed to non-house owners. The high percentage distributed to house owners was explained by the fact that their action in constructing on the slope has a direct impact on slope dynamics while the 25% was due to the fact that non-house owners exert less influence on slopes but seemingly bear the consequences of slope dynamics over time. The rainfall trend was gotten from the North West Regional Service for Meteorology in Bamenda to establish the relationship between monthly rainfall and the probability for slope dynamics. Data on population and housing construction trends were obtained from the Bamenda City Council as well as the Ministry of Housing and Urban Development.

The spontaneous housing construction on the escarpment face and population growth trend provided evidences of an urbanizing process within the fragile Bamenda escarpment slope. The trend in housing sprawl over time and space was established and mapped out using the Landsat 4 and 8 Images to determine the growth of settlement between 2007 and 2019. The volcanic escarpment face was mapped out to show the double geological slope pattern that characterize the highly urbanized crystalline Old Town, Ntamulung, Bayele and Big Mankon plateau at the foot of the escarpment and the degrading steep slope face of Sisia, Down Town, Ntaghan and Abangoh. This was aided by the use of Geographic Information Systems (GIS) and Digital Elevation Model (DEM). The aerial view using GIS and DEM analysis presented the landslide and rock fall zones, dominant housing extension pattern along the slope and the hydrographic networks within the slopes facilitating slope dynamics. The depths of valleys and stream channels across the escarpment face were measured. Equally, housing density within the sampled four quarters (Sisia, Down Town, Ntaghan and Abangoh) along the escarpment slope were established to determine the intensity and susceptibility of the slope to landslide, rock fall, soil erosion and house collapse. This provided information on the dominant direction of settlement construction over time. The data collected in the process were analysed using the Pearson's Product Moment Correlation (r) to show the relationship between housing construction density on steep slopes and slope dynamics as manifested through landslides, rock fall, erosion, the transportation and deposition of escarpment slope materials. The results of the Correlation Coefficient were adjusted using the Coefficient of Determination r^2 while the reliability of the statistical results was determined using the Cronbach's Alpha. Given the influence of other variables other than spontaneous settlement construction triggering slope dynamics which are not specified in the study, the adjusted r^2 was used to enable the researchers determine the response of slope dynamics to settlement construction. The results from the Product Moment Correlation Coefficient and other related findings were presented using maps, tables, charts and graphs to support the evidences and facts from the field

5 PRESENTATION AND DISCUSSION OF RESULTS

The results presented on the response of slope dynamics to spontaneous settlement construction on the south eastern slope of Bamenda considered the trend and pattern of housing construction, slope de-vegetation and slope dynamic indicators as well as planning lapses to sustainable slope stability over time. Such availability of results provides the way forward to policy makers, urban planners, developers and individuals to consider human actions on slopes for sustainable growth and development.

5.1 The hydro-geological nature of the Bamenda escarpment and housing growth pattern

The Bamenda escarpment slopes appear to have been developed on a complex geological structure with double geological settings where alternating hard and soft rocks have yielded to differential rock types and slope stability. The slopes therefore consist of trachytes and rhyolites that stand out remarkably on the escarpment zone. The escarpment therefore shows a high percentage of acid volcanic rock types (trachyte and rhyolites) that forms the already steep slopes of Sisia, Down Town, Ntaghan and Abangoh. These volcanic rocks positively respond to instability due to their high water holding capacity of the rocks. The steep escarpment face is supported by stable gentle undulating crystalline plateau extending to the highly urbanized city of Bamenda. At the foot of the escarpment is the crystalline basement complex consisting of gneisses and granites covering Old Town, Ntamulung, Ndamukong, Bayelle and Alachu quarters of Nkwen and Mankon. The Southern Highlands of Bamenda therefore comprise of volcanic escarpment and the crystalline granitic basement (Figure 2).

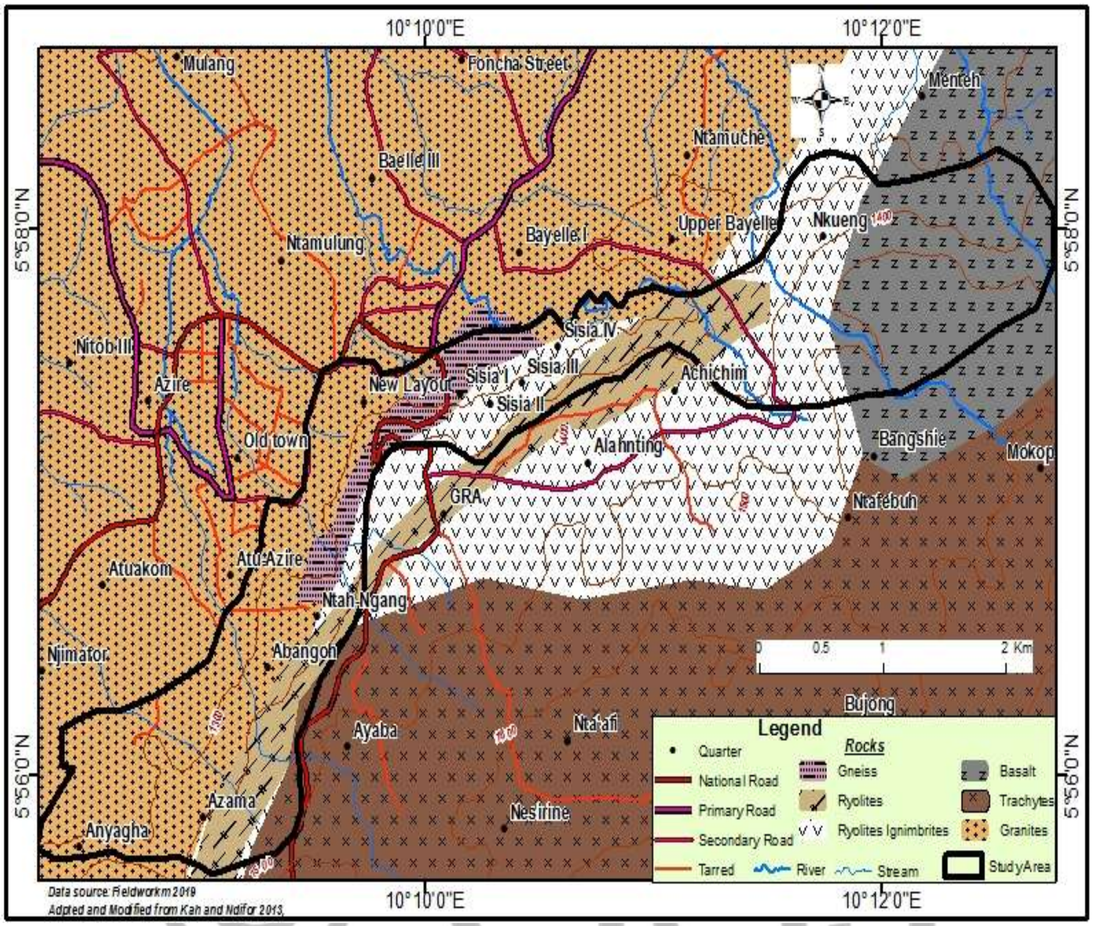

Figure 2: Double Geological setting of the Southern Highlands of Bamenda
Source: Fieldwork, (2019)

The escarpments portray a free face slope with an altitude which is generally between 1500 and 2200m above sea level. The volcanic highland areas have lava plateaux with slope gradients which are greater than 35%.. The slope instability scenario is provoked by the action of tributary streams that drain the escarpment face through the urbanizing crystalline plateau of Nkwen and Mankon into the River Mezam.

In terms of relief variation, the escarpment presents differential results characterized by changing altitude and slope gradients (Table 1). The altitudinal difference is an indication of the slope susceptibility to failure or human risk habitation.

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Table 1: Differential slope characteristics in the Northern Highlands of Bamenda

Location	Slope characteristics within the Bamenda northern highlands			
	Altitude Range (m)	Slope gradient	Soil texture	Vegetation
Bamenda Escarpment	1600-2200	>35%	Fine Volcanic	Grassland
Mankon Plateau	1500-2000	20-35%	Coarse basaltic	Grassland & semi-montane forest
Nkwen Plateau	1200-1500	14-28%	Coarse granitic	Grassland & semi-montane forest

Source: Adapted from AVL/EBI/JHO, (1986) and Modified by Authors, (2018) Findings show that the Nkwen landscape is dominated by a range with altitudes between 1200-1500m with a corresponding slope gradient between 14-28%. The Mankon Plateau equally ranges from 1500-2000m with an estimated slope gradient of 20-35%. By implication, the Mankon Plateau has much high granitic hillocks than those of Nkwen. Of the most remarkable is the Bamenda escarpment slope face with an altitudinal range between 1600-2200m. The slope gradient is greater than 35% indicating that the volcanic escarpment face is fragile, steep and liable to natural instability even with minimal human pressure and activities on the slope. Table 2 illustrates the physical properties of the soils on the Bamenda escarpment slopes.

Table 2: Physical characteristics of the soil on the Bamenda escarpment

Sample	Depth (cm)	Water density (%)	Dry density (%)	Porosity (%)	Degree of saturation (%)
Sisia 4	50-75	33.57	1.06	52.38	68.05
Sisia 2	10-35	39.52	1.02	53.70	74.95
Sisia 3	30-55	28.79	1.05	58.33	51.82
Abangoh 4	10-55	43.17	0.92	64.28	61.88
Abangoh 5	12-37	31.57	1.18	47.92	76.91

Source: Guedjo et al., (2013)

The results show that soil depth varies along the escarpment face. Soil depth generally decreases with increasing altitude. In a similar manner, the degree of soil saturation equally depends on the angle of the slope as well as the nature of the rock types. Trachytes and rhyolites that form the highlands are water absorbing rocks and so, have high water saturation capacity especially during the rainy season. The implication of the soil properties within the highland zone revealed that majority of the slope has soil saturation greater than 50%. This indicates that the slopes are usually saturated and given the steepness of the slopes, there is the probability of slope movement which leads to instability. This explains why the slopes of Sisia, Ntaghan and Abangoh quarters of Nkwen and Mankon are seasonally prone to failures. This is due to the response of the slope or soil to climatic and seasonal oscillation causing the absorption and the release of moisture within the escarpment soils or slopes.

Hydrologically, this highland escarpment constitutes a haven for tributary. The tributaries of the Mezam river basin radiate from the surrounding volcanic chain and granitic basement complex and drain into the River Mezam. The availability of these tributaries in the Bamenda escarpment indicates the potentials of slope dynamics given the seasonal sponge effects of the rocks to hold and release water. The free face slope along the Bamenda-Tubah landscape shows numerous waterfalls indicating that the landscape has failed to maintain a constant and continuous gradient. The high fluvial activity and stream competence on the escarpment face seem to facilitate landslide, rock fall and soil erosion that increases transport loads of stream channels into the crystalline plateau at the foot of the escarpment. Some of the streams disappear at the escarpment of Ntaghan, Abangoh and Sisia and only reappear at the foot of the escarpment especially at Old Town Valley and Abanjah. The spring sources flow on the surface constituting streams depending on the seasonal flow pattern of the streams.. Nevertheless, most streams are highly vulnerable and liable to seasonality effects so much so that some streams and springs cease to flow while others substantially are reduced in volume.

5.2 Slope dynamic response to settlement growth trend and pattern

Given the hydro-geological nature of the Bamenda escarpment as well as the metropolitanisation of the city that spans in all directions, part of the escarpment has been remarkably threatened through settlement construction. The construction of houses and other infrastructure on slopes for a long time remains an outstanding indicator of land use change and development drivers. The trend and pattern of settlement construction has thus witnessed a positive growth with a spontaneous construction of homes presenting a situation of uncontrolled growth pattern. The Bamenda escarpment face is known for its steep slopes that extend from the Abangoh in the south east to the north west of the Tubah Highlands. The escarpment stretches to the north of Mendakwe making the relief complex. Figure 3 presents a comparative spatial growth of settlements as of 2000 and 2019 within the Bamenda escarpment slopes. The results revealed that there has been an increase in the number of houses constructed between 2000 and 2019. The pattern of growth shows a dominant direction spanning more to the south western slopes of Sisia, Abanjah and New layout than is the case in the south eastern slopes of Ntaghan and Abangoh. Findings on the growth pattern of settlements revealed that the summit of the escarpment face which coincides with government residential area (Up Station) and other Mendakwe communities are equally experiencing significant increases in the number of houses constructed. As a consequence, the Bamenda escarpment slopes are put under vertical and horizontal pressure in the midst of settlement construction. Considering the nature of the Southern Highlands and the resulting pressure that arises from settlement construction, slope dynamic tends to shift from natural to human induced instability.

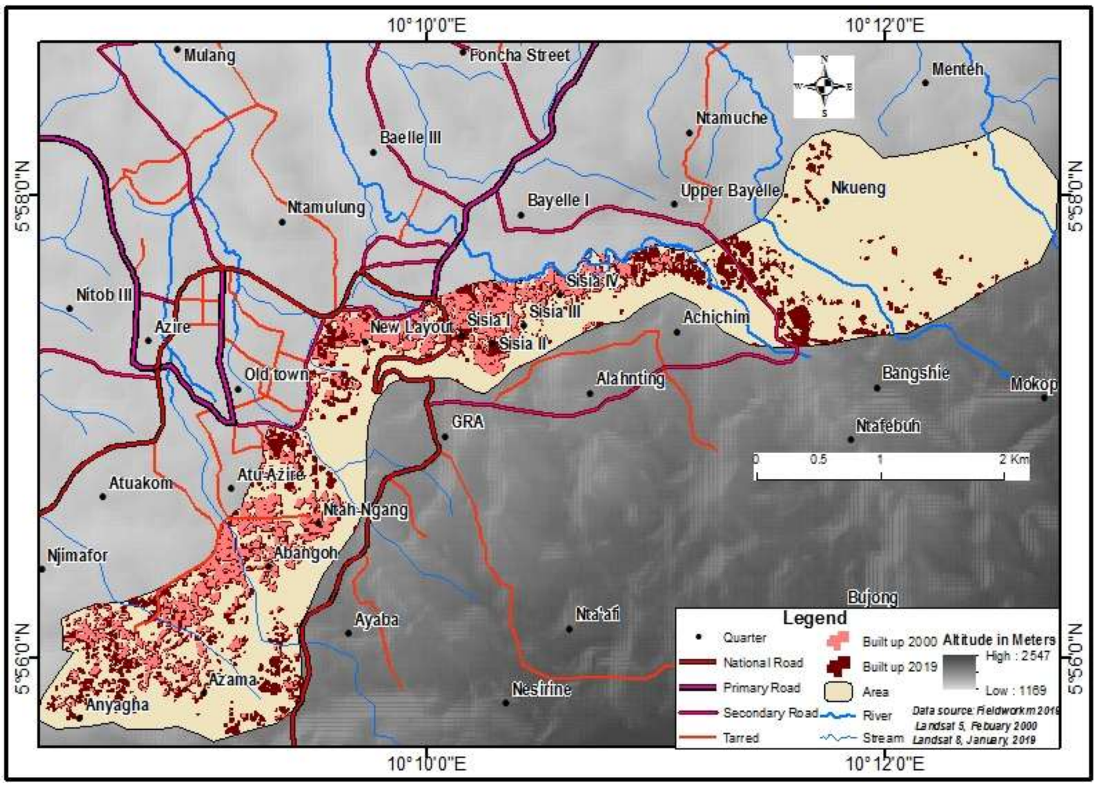

Figure 3: The 2000 and 2018 settlement growth pattern on
the Bamenda escarpment zone
Source: Fieldwork, (2019)

The increasing construction of homes on this escarpment is seemingly converting the natural vegetation into an artificial landscape. As a consequence, the escarpment face is becoming a hotbed for land acquisition. The issuing trend of building permits continues to rise irrespective of the green zone accord delimiting the zone from human occupation (Figure 4).

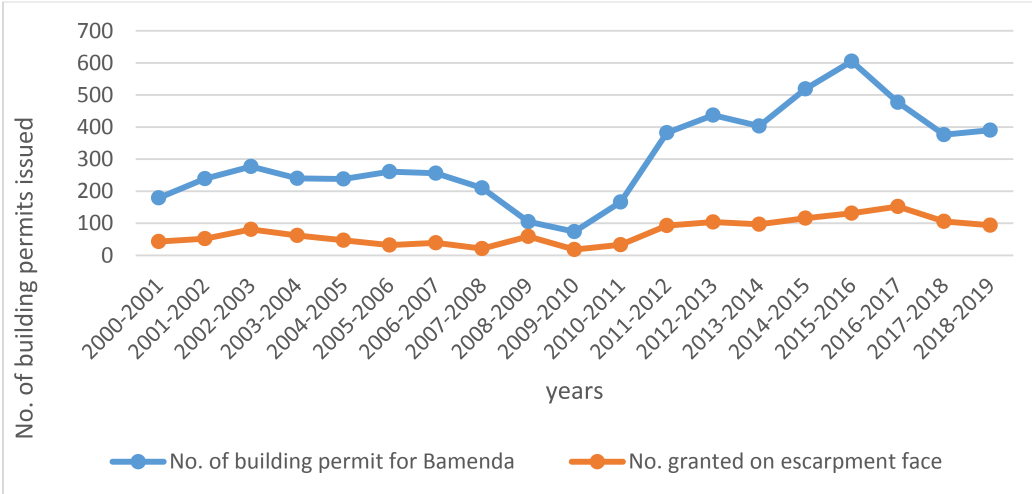

Figure 4: Trend in the building permits issued for Bamenda and the escarpment zone
Source: Bamenda City Council and MINDUH, (2019)

The trend in the housing construction from the year 2000 to 2019 shows a positive growth as indicated by the registered number of building permits issued by the Bamenda City Council. While the general curve of building permits issued in Bamenda over time continue to override that of the escarpment zone especially in Sisia, New layout, Ntaghan and Abangoh, the results revealed that the steep escarpment face has over the years witness an increase in the density of housing construction over time. This continuous construction process does not respect the escarpment face as a green zone. Hence, there is a rapid vegetation loss which is today commonplace within this area. The spatial density of settlement shows a more positive growth in the area covering Sisia, Abanjah and New Layout (Figure 5).

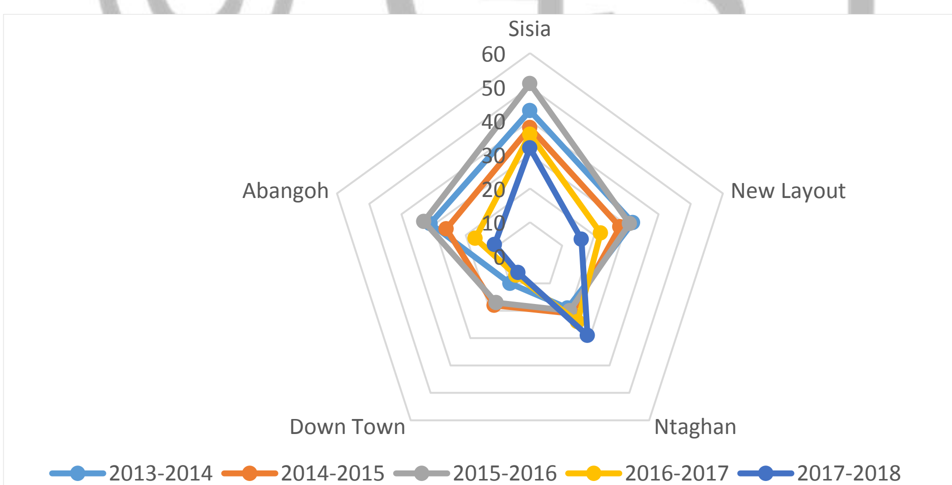

Figure 5: Yearly density of houses on the Bamenda escarpment
Source: Fieldwork, (2019)

The findings revealed that the degree of spatial expansion of settlements on the Bamenda escarpment show differential density. Sisia I, II, III and IV have, over the years, been a pressure zone for settlement construction. This is equally the case for the New Layout area that has witnessed a considerable housing sprawl effect. The average housing density on the Sisia steep slopes was estimated at 60houses/km^2 while at New Layout it was 40houses/km^2. On the other hand, the south western slopes present a different picture of housing density with average housing density of 30/km^2 at Ntaghan and 35houses/km^2 at the Abangoh escarpment zone. This situation of increasing housing density contradicts the result of Terry, (2008) on the limit on slope pressure and potential development (Table 3). According to slope limit and range of development potentials, slopes greater than 25% are not suitable for settlement construction. Within the Bamenda escarpment, slope gradients of greater than 35% are being used for settlement construction. This is the case of Sisia III, IV, New Layout, Ntaghan and Abangoh. These slopes have witnessed the cut and fill process as a means to obtain available land for construction. The excavation of the slopes increases the loss of vegetation while provoking the already fragile steep slopes to slope failures. Most of the households equally carry out crop cultivation and soil tillage which further accelerates erosion and slope instability. Rock fall and a series of landslides have been observed on the steep slopes of Sisia, New Layout, Down Town and Abangoh.

Table 3: Slope limits and range of development potentials

Slope range (%)	Development potential
0-3	Generally suitable for settlement and other land uses
3-8	Suitable for medium density residential development, agriculture, industrial and institutional uses
8-15	Suitable for moderate to low density residential development, careful location of commercial, industrial and institutional uses
15-25	Only suitable for low density residential, limited agricultural and recreational uses
>25	Only use for open space and certain recreational uses and not for human habitation.

Source: Terry, (2008)

Land scarcity within the highly urbanized Bamenda city centre of Nkwen and Mankon has pushed people to acquire land on the steep escarpment face. Such moves are largely seen as environmental risk to the increasing population that does not see any danger of locating or inhabiting such risk zones. This environmental problem lie in the future occurrences of landslides and rock fall with the possibility of causing a great loss of lives and property. Table 4 shows the household perception to slope dynamics within the Bamenda escarpment zone.

Table 4: Perception of households' exposured to slope instability indicators within the northern face of the Bamenda escarpment

Location on the escarpment slope	No. of sampled households	No. of exposed households	% of exposed households	Remark
Sisia	35	26	74.28	Very High
New Layout	20	11	55.0	Moderate
Down Town	15	6	40.0	Low
Ntaghan	25	14	56.0	Moderate
Abangoh	30	21	70.0	Very High
Total	125	78	62.40	High

Source: Field work, (2019)

The findings revealed that households located along the Bamenda escarpment slope experience a high degree of exposure to landslide, rock fall and accelerated soil erosion as determinants of slope dynamics with an exposure rating of 62.40%. For the whole slope profile, the majority of households at Sisia and Abangoh revealed a very high percentage of exposure with about 74.28% and 70.0% respectively. This indicates that the slopes of Sisia and Abangoh are increasingly being converted into built-up areas so much so that a large number of houses are constructed close to potential rock collapse zone. The New Layout and Ntaghan areas show a moderate exposure of 56.0% while Down Town revealed a low percentage of household exposure of 40.0%. The low percentage (40.0%) of household exposure is explained by the low housing density within the Down Town escarpment zone. There is a positive relationship between increase housing density on the steep slopes and increase exposure to slope dynamic indicators. The exposure of households to slope dynamic threats is a function of altitudinal location (Figure 4). The location of households within the escarpment face presents a differential exposure index to slope dynamic threats or indicators. As landslides, rock fall, soil erosion, channel widening and deepening effects continue to characterize the slope form, the degree of household exposure varies depending on the actual location of the house to the steep slope face. The exposure index was measured at a scale of 10 converted into percentages

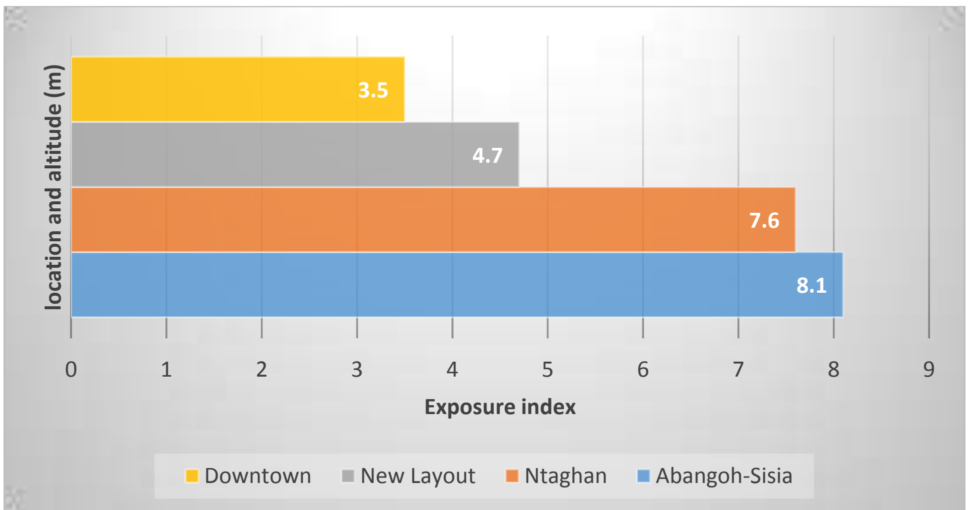

Figure 4: Altitudinal determinant of households' exposure to slope instability on the slopes of the Bamenda escarpment
Source: Fieldwork, (2019)

The results revealed a direct relationship between altitude and exposure of households to threats of slope failure. Households in high altitude areas above 2000m corresponding to Abangoh and Sisia are more exposed to slope dynamic impacts with exposure index of 8.1 (81%). At Ntaghan, the households present an exposure index of 7.6 (76%) while that of New Layout and Down Town areas at low elevations on the escarpment slopes show exposure index of 4.7 (47%) and 3.5 (35%) respectively. In a similar way, the more houses are being constructed on the steep slopes of the escarpment, the higher the degree of exposure. This explains why households at New Layout and Down Town Bamenda revealed a lower exposure index as these areas have over the years witnessed a reduced incidence of rock fall and landslides compared to Abangoh, Sisia and Ntaghan. The illegal encroachment and acquisition of land by city dwellers in the green zone in recent years has been criticized by poor planning and planning lapses to sustainably maintain slope stability.

5.3 Environmental Planning Lapses to Sustainable Slope Stability

Environmental planning has been poorly carried out within the Cameroonian context. The Cameroon laws show the strength and extent to which human activities on the landscape should be made without compromising the environment nor placing humankind at risk. This however denotes that certain environments such as steep slopes, wetlands, valleys and geo-hazards prone zones should not be inhabited by mankind. As man has the policy of working out against nature and superimposing their interests contrary to the laws of nature which are put in place to guide their activities, planning becomes difficult. Poor planning and environmental governance within the Bamenda escarpment slope face has been blamed by the inability of government officials, municipal authorities, traditional authorities and the population to recognize the steep escarpment area as a “no go zone”. Houses have been constructed very close to rock fall areas while others have been built on the rolling rock surfaces which serve as foundations (Figure 6). Houses have equally been constructed close to deepening and widening stream channels thus exposing the households to high hydraulic activities that characterize the slopes of the Bamenda escarpment.

Fig 6a: Construction of houses around rock fall zone at Sisia III-Nkwen

Fig 6b: Construction of houses on rocks and close to widening stream channel at Sisia
Source: Fieldwork, (2019)

The occupation of these fragile zones by individuals is attributed to their greed and the urge to pressurize government personnel, urban planners and developers to apportion them land in this fragile escarpment zone. As a result, the state officials meant to execute the laws, by assign to them areas on the escarpment for construction that should otherwise be protected. From this distribution, it can thus be inferred that bribery and corruption, nepotism, tribalism and favouritism override justice and environmental preservation and conservation.

While the poor appear to scrupulously maintain environmental laws, the rich have the tendency of resorting to bribery and corruption to acquire land for settlement construction. This is a problem of environmental planning lapses in the equitable restriction of vulnerable zones for all. The lapses are further visible through the non-respect of the Bamenda Master Plan that spells out the escarpment zone as a green zone since 2007 and that this zone should be void of human interference and development. Ironically, the same officials that delimited the escarpment sit in their offices and assign land to city dwellers with land certificates along with building permits. The authorization of settlement construction within the volcanic escarpment that is hydro-geologically unstable provokes landslide occurence, rock fall and differential erosion as the process of erosion along the humanized steep escarpment slopes become accelerated. Such human-induced construction processes and other activities on slopes are responsible for slope dynamics. Evidences in environmental planning lapses show that housing construction within the escarpment zone lacks the services of environmentalists, planners and developers in understanding the risk involved in inhabiting such hazard prone zone. The construction of houses without an adequate knowledge of the environment and operational processes on slopes only leaves the infrastructural setup to the risk of collapse as well as a loss of lives. Table 5 presents the hypothetical testing of the relationship between housing construction and slope dynamics within the Bamenda escarpment zone.

Table 5: Correlation between housing construction density on steep slopes and slope dynamics response in the Bamenda Southern Highland

Variables		Housing construction density on steep slope	Increase slope dynamics
Housing construction on steep slope	Pearson Correlation	1	.650**
	Sig. (2-tailed)		.000
	N	125	125
Iincrease slope dynamics	Pearson Correlation	.650**	1
	Sig. (2-tailed)	.000	
	N	125	125

**. Correlation is significant at the 0.01 level (2-tailed).

Case Processing Summary	N	%
Valid	125	100.0
Excluded[a]	0	.0
Total	125	100.0

Cronbach's Alpha reliability test	N of Items
.787	2

Source: Field work, (2019)

The Pearson's Product Moment Correlation results revealed a strong and positive relationship of 0.65 between housing construction density and an increase in slope dynamics within the Bamenda escarpment zone. The positive correlation is statistically significant at 0.01 level and at 2 tailed test. The results indicate that housing construction density on steep escarpment face alone accounts for about 65% of slope dynamic processes within the slopes. Nevertheless, using the coefficient of determination r^2, an increase density of housing construction alone accounts for about 0.42 representing 42% of slope dynamics. As a result, about 58% of slope dynamic response within the Bamenda escarpment is controlled or explained by other factors such as road construction, rainfall characteristics, nature of the rock, soil, relief and hydrography of the area. The reliability of the Pearson Product Moment Correlation was determined using the Cronbach's Alpha indicating that the results are reliable at 0.787. By implication, the results of housing construction density triggering slope dynamics within the Bamenda escarpment are statistically reliable at 78.7%. The reliability of the results suggests some recommendations in order to reduce the risks involved in inhabiting or occupying the Bamenda volcanic escarpment.

6 CONCLUSION AND RECOMMENDATIONS

Investment in housing construction and infrastructural development has over the years been an aspect of the aspirations of many stakeholders. Whilst settlement construction has taken an uncontrolled pace of development, the nature of housing construction however does not respect the environmental policies of conservation, preservation and risk avoidance. The spontaneous housing construction has therefore created mix feelings amidst the nature of the topography in which wetlands, steep slopes and escarpments have been viewed by some stakeholders as new settlement frontiers. Such quest for available land has pushed many to acquire land at the Bamenda escarpment considering the land scarcity scenario in the urbanizing Bamenda Nkwen-Mankon Plateau at the foot of the escarpment. Housing density has been increasing within the steep slopes presenting a more dominant pattern in the south western direction of Sisia and the New Layout than in the south eastern slopes of Ntaghan and Abangoh. The increase in housing density thus creates a significant loss of vegetation in an already fragile high energy area. This facilitates slope movement given that the escarpment face is susceptible to landslides, rock fall and natural soil erosion. The human influence manifested through the settlement construct further worsened slope dynamics as erosion becomes accelerated in areas of high housing density. The results revealed a positive and strong correlation of 0.65 and adjusted at 0.42 between housing construction density on the escarpment and increased slope dynamics within the Bamenda volcanic escarpment. This indicates that housing construction alone accounted for about 42% of the observed slope dynamics within this escarpment zone. The results are equally reliable at 78.7% using the Cronbach's Alpha. Hence, housing construction within the escarpment is largely blamed for the observed landslides, rock fall and the movement of soil materials downslope which should not be neglected.

Whilst the spontaneous growth in housing construction is encouraged to shelter the increasing population over time, the policies of environmental management, planning and development should be at the centre of infrastructural works and human actions. The Bamenda Master Plan should be respected by all with high condemnation of bureaucracy, bribery, corruption, tribalism, favouritism and administrative bottlenecks in the allocation of land within wetlands, steep slopes and green zones. While the demolition of houses goes with sentiment, allocation of land for settlement construction should not be based on sentiment. As a consequence, city dwellers should be discouraged from acquiring land on the escarpment even with high socio-cultural, economic, religious and political affiliations. Collective prevention is better than collective reaction. Hence, the escarpment slopes should be avoided for settlement construction and habitation. The Bamenda City Council, the Ministry of Housing and Urban Development and other NGOs should in strict compliance ensure the maintenance of Urban Green Zone of the Bamenda escarpment. Individuals should equally consider their safety in building in hazard prone zones. Rather, it in their best interest to opt for the acquisition of land in stable zones. The study further recommends an adequate provision of proper drains within the escarpment, as well as carrying on afforestation and reafforestation while reducing slope excavations. Furthermore, the stakeholders should invest on protective slope walls as slope stabilizing measures in order to minimize the future increase in slope dynamics. It is therefore the responsibility of all stakeholders to monitor escarpment preservation and conservation in order to reduce unprecedented casualties and property loss within the escarpment and geo-hydrological escarpment zone.

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