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# Community Perception of Landslide Hazards and Settlement Expansion along the North-West Stretch of the Cameroon Volcanic Line

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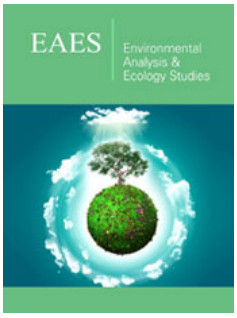


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## Abstract

The Bamenda escarpment, a geologically sensitive region located along the North-West stretch of the Cameroon Volcanic Line, spans approximately 8.4km$^2$ and is characterized by steep slopes and highly weathered residual soils. These features make the area highly prone to landslides, especially during the rainy season. Over recent decades, rapid population growth and urban expansion have led to increased settlement development in this high-risk zone, exacerbating the vulnerability of communities to landslide hazards. Despite the mounting risks, settlements continue to grow in the area, posing significant challenges to both local populations and urban planners. This study aimed to assess the local community's perception of landslide risks and explore the spatial and temporal evolution of settlements within the Bamenda escarpment over a 40-year period (1980-2020). A mixed-methods approach was employed, combining both primary and secondary data sources. Data collection involved a multi-stage random sampling design that included purposive, stratified, and systematic random sampling techniques. Remote Sensing and Geographic Information System (GIS) methods were used to analyze satellite imagery and map land use changes, focusing on the evolution of built-up areas over the four-decade period. To test the relationships between socio-demographic characteristics and landslide perception, Chi-square tests and simple linear regression analyses were conducted.

The results revealed significant spatio-temporal changes in settlement patterns, with a marked increase in built-up areas between 1980 and 2020. The expansion of settlements is largely attributed to population growth, urban sprawl, and the increasing demand for affordable housing. The study also found that the perception of landslide hazards was strongly influenced by socio-demographic factors, such as age, education, and income levels. A majority of the respondents were aware of the landslide risks in the area, but their understanding of the underlying causes, frequency, and potential impacts varied based on these socio-demographic factors. While several coping strategies were implemented, such as temporary relocation and the construction of retaining walls, these measures were found to be largely ineffective in mitigating the impacts of landslides. Furthermore, the study established a positive correlation between community perception of landslides and the evolution of settlements, suggesting that greater awareness of landslide risks could potentially influence settlement patterns and urban development in high-risk areas. Based on these findings, the study recommends targeted community education programs to raise awareness about landslide risks, improved emergency preparedness, and the development of more effective, context-specific adaptation strategies. Strengthening local government involvement and fostering community resilience through better planning and policy interventions are also critical to reducing vulnerability and enhancing long-term sustainability in the region.

**Keywords:** Bamenda escarpment; Landslide hazards; Settlement evolution; Perception; Socio-demographic factors; Coping strategies; Remote sensing; Urbanization; Cameroon volcanic line

## Introduction

The rapid growth of settlements, especially in Sub-Saharan Africa (SSA), is closely linked to demographic changes driven by population growth, urbanization, and modernization. In SSA, rapid urbanization is occurring amidst significant poverty, weak governance, and limited urban planning, making urban populations particularly vulnerable to natural hazards like landslides

[1]. Landslides are one of the most destructive natural hazards, causing damage to lives, property, and infrastructure, especially in mountainous and escarpment regions. Urban expansion in high-risk zones, such as areas with steep slopes prone to landslides, has exacerbated these risks, particularly in informal settlements where infrastructure is often inadequate (Osuteye et al. 2017). Cameroon, located in Central Africa, faces increased vulnerability to natural hazards, including landslides, due to environmental degradation, poverty, and limited Disaster Risk Reduction (DRR) capacity [2]. Urbanization in Cameroon has accelerated over the past two decades, often expanding into landslide-prone regions where land is cheaper and more accessible. The Bamenda escarpment in the northwest of the country, including the town of Sisia, is an example of such rapid urbanization, with over 21,000 people now residing in areas highly susceptible to landslides [3]. Despite the risks, settlement continues to expand, driven by limited affordable housing, lack of awareness, and perceptions that landslides are rare or manageable events [4]. While research has focused on landslide susceptibility and risk assessment in Cameroon, there is a notable gap in understanding local perceptions of landslides and how these perceptions influence settlement behavior. This study aims to fill this gap by exploring how local communities in the Bamenda escarpment perceive landslides and how these perceptions shape settlement patterns.

## Contextualization of the Study and Research Objectives

Landslides in Cameroon, especially in mountainous and escarpment regions, are increasingly recognized as a major hazard. These regions, characterized by steep slopes, unstable soils, and heavy seasonal rainfall, create conditions conducive to landslide occurrence. Recent incidents, such as the Dschang landslide in the western part of Cameroon, which resulted in fatalities and infrastructure damage, highlight the growing vulnerability of communities in landslide-prone zones [4]. These landslides are often exacerbated by poor urban planning, inadequate infrastructure, and a lack of awareness among local populations.

In the Bamenda escarpment zone, rapid urbanization has led to settlement growth in landslide-prone areas, where steep hill slopes and weathered volcanic soils make the region particularly vulnerable to landslides. Despite the known risks, many residents continue to settle in these hazardous zones due to a lack of affordable housing, economic pressures, and insufficient knowledge about the severity and frequency of landslide events. Research has focused on mapping landslide susceptibility and assessing risks, but there is limited exploration of how local perceptions of landslide risks influence settlement choices and coping strategies. Understanding local knowledge and perceptions of landslides is essential for designing effective disaster risk management strategies and reducing vulnerability in these high-risk areas.

This study aims to explore the relationship between local perceptions of landslides and the evolution of settlements in the Bamenda escarpment zone. Specifically, it seeks to answer the following research questions:

A. What is the community's perception of the nature and causes of landslides in the Bamenda escarpment zone?

B. How effective are the adaptation strategies implemented by residents to cope with landslide risks?

C. What is the relationship between community perception of landslides and the evolution of settlements in the area?

By addressing these questions, the study aims to provide valuable insights into how local perceptions of landslide risks influence settlement patterns and disaster risk management strategies. The findings will help inform urban planning and disaster preparedness efforts in landslide-prone regions, providing evidence to support more effective risk reduction policies and strategies.

## Literature Review

Landslides are particularly prevalent in Cameroon's Western Highlands, Central and Eastern Highlands, and the northwestern escarpment zone. The rapid expansion of informal settlements in these regions, often built on unstable slopes, exacerbates the risk of landslides. Studies by Guedjeo et al. [5] & Aungang et al. [6] have shown that urbanization, coupled with inadequate drainage and land-use practices, significantly increases the vulnerability of communities to landslides. Additionally, environmental degradation, such as deforestation and construction on steep slopes, has further intensified the risk of landslides in these areas [3,4].

In informal settlements, where land is often cheaper and more accessible, residents frequently settle in hazardous areas despite the risks. In cities like Bamenda, the combination of urban sprawl, population growth, and environmental degradation has led to increased exposure to landslide hazards. However, while these settlements are highly vulnerable, the response to landslide risks remains insufficient due to a lack of resources, effective disaster preparedness, and weak enforcement of urban planning regulations [6].

Globally, landslides have been a significant concern, particularly in regions with mountainous terrain and dense populations, such as Nepal, India, and Indonesia. Research in these countries has demonstrated that settlements located on unstable slopes are highly vulnerable to landslides, especially during periods of heavy rainfall [7,8]. These studies emphasize the critical role of local perceptions in shaping settlement patterns and influencing risk management strategies. In landslide-prone regions, local knowledge and experience are often key factors in adapting to risks and developing coping mechanisms, even in the absence of formal disaster management systems [9].

In Cameroon, the role of local perceptions in landslide risk management remains underexplored. However, studies have indicated that while residents in high-risk areas are often aware of the landslide threat, their understanding of the underlying causes and potential impacts varies widely. For example, Aungang et al. [6] noted that although residents of the Bamenda escarpment recognized the risks associated with landslides, economic pressures and limited access to safer areas forced many to continue living in vulnerable locations. This suggests that local knowledge of landslide hazards may not always lead to protective actions due to socioeconomic factors.

In Cameroon, coping strategies for landslide risks often involve a combination of government interventions and community-based efforts. However, these strategies are often inadequate. Studies by Fomena et al. [3] & Tchoua et al. [4] show that while local authorities have attempted to implement risk mitigation measures, such as land-use zoning and drainage infrastructure, these initiatives are frequently undermined by insufficient resources, weak enforcement, and low community involvement. Moreover, informal settlements, which are often located in the most hazardous areas, lack the resources to implement effective risk management strategies.

In contrast, successful risk management strategies in other countries, such as Japan and Italy, involve comprehensive disaster preparedness programs, early warning systems, public education campaigns, and strict regulation of land use in hazard-prone areas [10]. These approaches have proven effective in reducing both the frequency and severity of landslides. Similar strategies could be adopted in Cameroon, but only with greater community involvement in disaster risk reduction and urban planning processes.

## Materials & Methods

### Study area

The Bamenda escarpment is part of the broader geomorphological system of the Western Cameroon Highlands (WCH), located between latitude 5°46′00″N and 5°56′30″N, and longitude 10°10′00″E to 10°16′30″E. The escarpment stretches across the northwestern region of Cameroon, situated between two prominent peaks: Mount Bambouto (2,740m) to the southwest and Mount Oku (3,011m) to the northwest (Figure 1). These two mountains, along with several other volcanic formations, are integral parts of the Cameroon Volcanic Line (CVL), a region characterized by high seismic and volcanic activity [3]. The Bamenda escarpment zone experiences a tropical savannah climate that borders on a tropical monsoon climate. The region is characterized by a marked seasonality, with a long rainy season from March to October, and a relatively drier period between November and February. This variation in climate, along with high annual precipitation (ranging between 2,500mm and 3,000mm), makes the area highly prone to erosion and landslides, especially during intense rainfall events [4]. Rainfall is a primary triggering factor for landslides in the region, as heavy rains saturate the soil on steep slopes, increasing the likelihood of slope failure. Consequently, landslides are a significant hazard, particularly in highland areas like the Bamenda escarpment, where the terrain is steep and the soils are largely composed of weathered volcanic products [11].

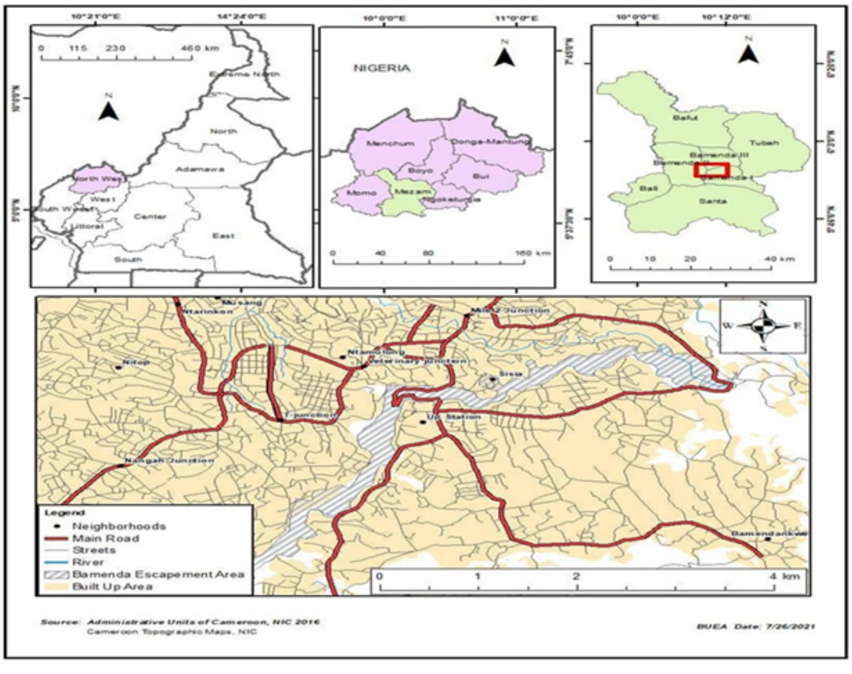


**Figure 1:** Bamenda Escarpment in Bamenda Urban Space, Northwest Region of Cameroon showing the study site of Sisia.

The average monthly temperatures in the region fluctuate between 16 °C and 30 °C, with February being the warmest month, reaching average maximum temperatures of 30 °C. The local climate is influenced by two dominant air masses: the northeastern trade winds, which bring the dry season, and the southwest monsoon winds, responsible for the rainy season. This combination of climatic factors, along with the area's rich volcanic soils, promotes the growth of savannah vegetation at lower elevations and montane forests at higher altitudes. The latter, characterized by a low canopy (ranging from 10-20m), is highly susceptible to weathering processes that weaken the stability of slopes (Ndenecho, 2005). The steep terrain, combined with a dense dendritic drainage network and high erosion rates, accelerates the movement of sediments down the slopes, exacerbating the risk of landslides. Over time, urbanization and increasing population density along the escarpment have led to significant land-use changes, negatively impacting the region's natural land cover and further heightening vulnerability to landslide events. Settlements in the area, including the city of Bamenda and surrounding neighborhoods like Sisia, continue to expand, often into hazard-prone areas where the risks of landslides are heightened [12].

## Data collection

This study employed both primary and secondary data sources to address the research objectives. Primary data were collected through a combination of household surveys, Focus Group Discussions (FGDs), and personal observations. A structured questionnaire was administered to households within the study area to gather information on local perceptions of landslide risks, settlement patterns, and adaptation strategies. In addition to the questionnaire, FGDs were conducted to obtain more in-depth qualitative data on community awareness and coping mechanisms related to landslide hazards. To assess the evolution of settlements over time, primary data were collected using a hand-held Global Positioning System (GPS) device to capture Ground Control Points (GCPs) for different land use types in the region. This data, along with satellite imagery, was used to track changes in settlement patterns from 1980 to 2020. Secondary data were sourced from published academic articles, government reports, and other relevant documents, which provided historical and contextual information on landslide events, urban development, and hazard management in the region.

## Sampling technique and sample size

A multi-stage random sampling design was employed to ensure a representative sample for the study. The sampling process was carried out in three stages: purposive, stratified, and systematic random sampling.

The first stage involved the purposive selection of the Bamenda escarpment zone as the study area. This decision was based on the region's known vulnerability to landslides, as well as the significant expansion of settlements into landslide-prone areas in recent years. The second stage involved the selection of specific study sites within the escarpment zone. Using stratified random sampling, areas were chosen based on their varying degrees of vulnerability to landslides, which were determined by factors such as slope steepness, land-use patterns, and proximity to known landslide-prone areas. One of the sites selected was the Sisia neighborhood, which is characterized by a high concentration of settlements on steep hillsides. In the third stage, households were selected for interviews using systematic random sampling. Starting from a randomly chosen household, every nth unit was selected from a complete list of households in the selected area. A total of 150 households were surveyed for the study, providing a robust sample size to ensure the reliability and validity of the results.

## Determination of settlement evolution

To evaluate the evolution of settlements within the Bamenda escarpment zone, Geographic Information System (GIS) and Remote Sensing (RS) techniques were utilized. Satellite imagery from 1980, 2000, and 2020 was obtained and processed using Erdas Imagine 9.2 software. The data were analyzed to detect Land Use/Land Cover Changes (LULCC) over the four-decade period. The change detection methodology involved overlaying vector themes of different years to visualize and quantify settlement growth and land-use transitions. A baseline dataset from 1980 was used to compare changes between the periods 1980-2000 and 2000-2020. By examining the spatio-temporal changes in settlement areas, the study was able to assess the extent of urbanization, the transformation of land from natural vegetation to built-up areas, and the possible correlation between settlement growth and landslide-prone zones.

## Perception analysis

To assess local perceptions of landslide hazards, content analysis was conducted on data collected through the questionnaires, interviews, and FGDs. The data were analyzed using the Statistical Package for the Social Sciences (SPSS) to derive both descriptive and inferential statistics. The analysis focused on understanding how local residents perceive the causes, frequency, and severity of landslides, as well as their understanding of the risks involved. By analyzing socio-demographic variables, the study also explored whether factors such as age, gender, education level, and length of residence influenced individuals' perceptions of landslide risk.

## Adaptation analysis

An important aspect of this study was to assess the coping strategies adopted by residents in response to landslide risks. To do this, respondents were asked to identify adaptation strategies they had adopted to mitigate landslide risks, such as relocating to safer areas, building embankments, or using sandbags. The effectiveness of these strategies was evaluated using a Likert scale, where respondents rated the perceived success of each strategy. Additionally, the study hypothesized several socio-economic and institutional factors that might influence the adoption of adaptation strategies, including financial resources, access to information, community collaboration, and willingness to move to safer areas. The relationship between these factors and the success of adaptation strategies was analyzed to identify which variables were most strongly associated with effective coping measures.

## Statistical analysis

The data collected were subjected to various statistical analyses using SPSS to test both descriptive and inferential hypotheses. The Chi-Square test was used to examine the relationship between socio-demographic characteristics (such as age, education, and income) and perceptions of landslide risks. The Chi-Square formula used was:

$$X^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where:

$X^2$=Chi-Square statistic

$O_i$=Observed frequency

$E_i$=Expected frequency

A One-Way Analysis of Variance (ANOVA) was performed to test whether there were significant differences in the effectiveness of various adaptation strategies based on the respondents' perceptions of landslide risk. The Simple Linear Regression analysis was used to explore the relationship between community perceptions of landslides and the evolution of settlements. The linear regression equation was expressed as:

$$Y = a + bX$$

Where:

$Y$= Dependent variable (settlement expansion)

$X$= Independent variable (perception of landslides)

$a$=Intercept (value of Y when X=0)

$b$=Slope (rate of exchange in Y per unit change in X)

This regression model provided insights into the extent to which community perceptions influence the growth of settlements in landslide-prone areas. Through these methodologies, the study aimed to provide a comprehensive understanding of the dynamics of settlement evolution, perception of landslide risks, and adaptation strategies in the Bamenda escarpment zone.

## Originality of the Study, Results and Discussion

### Results and discussion

**Socio-demographic characteristics of the respondents:** The survey sample comprised 150 respondents from the Bamenda escarpment area. The gender distribution showed that 27% of respondents were male, while 73% were female. Age-wise, the respondents were divided as follows: 7% were in the 18-27 years range, 17% in the 28-37 years range, 33% in the 38-47 years range, 23% in the 48-57 years range, and 20% were above 57 years. The lowest percentage of respondents (7%) fell within the 18-27 age bracket, which likely reflects the higher mobility and economic activity of this group, making them less likely to stay in one location.

Occupationally, the largest proportion of respondents (24%) were farmers, followed by unskilled workers (24%), and business owners (20%). The significant proportion (24%) of respondents involved in farming mirrors the findings of Mbanga (2018), who noted that agriculture is a dominant livelihood activity in the region. The remaining respondents were either unemployed (20%) or engaged in other forms of work. In terms of educational attainment, 30% had completed primary school, 17% had attended secondary school, 36% were high school graduates, and 17% held university degrees. Regarding marital status, 57% were married, 37% were single, and 6% were widows or widowers.

The data on household size revealed that 47% of respondents had between 4 and 6 household members, 33% had 1 to 3 members, and 20% had 7 to 9 members. The religious composition of the community was predominantly Christian, with 73% identifying as Christians, while 7% were Muslim. In terms of income, 47% of respondents reported earnings between 51,000-100,000 CFA, 40% earned below 50,000 CFA, and the remaining 13% earned between 101,000-150,000 CFA. This income distribution suggests that a majority of respondents fall into the medium-income group.

**Communities' awareness and perception of the causes of landslide hazards:** Results revealed that, 50% of the inhabitants of the Bamenda escarpment area are barely aware of landslide occurrences, 30% of the respondents are very much aware of landslide occurrences, while 20% are unaware and unsure of landslide occurrences in the area. This is consistent with findings by Islam et al. [13], who emphasized the role of terrain and deforestation in landslide risk. Furthermore, the respondents' views on the factors contributing to landslides align with the observations made by Kang et al. [14,15], who identified illegal construction and deforestation as critical factors exacerbating landslide hazards. This means that a greater proportion of the inhabitants know about landslide occurrences that is how, when and why they occur. The level of awareness of the inhabitants can be as a result of their duration of stay in the area.

The respondents shared their views on the factors responsible for landslide occurrences (Figure 2). In response to the recent landslide occurrence in the area, a total of 30% agreed that the most important factor responsible for landslide occurrences is slope instability. Slope instability is a function of the texture of the soil in the area. Soils which are sandy than clayey in texture, soils where deforestation and farming are intense experience numerous landslides. Some 23% of the respondents revealed that landslides occurrence in the area is due to illegal construction of houses. Areas marked as not suitable for construction are being sold out for construction. In addition, slope instability, a function of activities like agriculture, deforestation and construction on steep slopes was highlighted by 30% of the respondents. About 20% of the respondents agreed that landslide occurrences is influenced by inappropriate land management and intensive rainfall. Land uses that are not supposed to be found on slopes are common in the area thereby influencing slope instability. When it rains intensively, there is a high probability of landslides occurrences. This is in line with the findings of Islam et al. [13]. Also, there were other associated factors influencing landslides such as the absence of the right construction strategies on slopes, agriculture, deforestation etc. However, it is worth noting that all the above mentioned factors are interconnected as one factor influences another in triggering landslide occurrences. Other factors were identified by the findings of Kang et al. [14,15] which revealed that the spontaneous settlement construction within steep slopes is mostly driven by the problem of land scarcity and administrative bottleneck by policy makers.

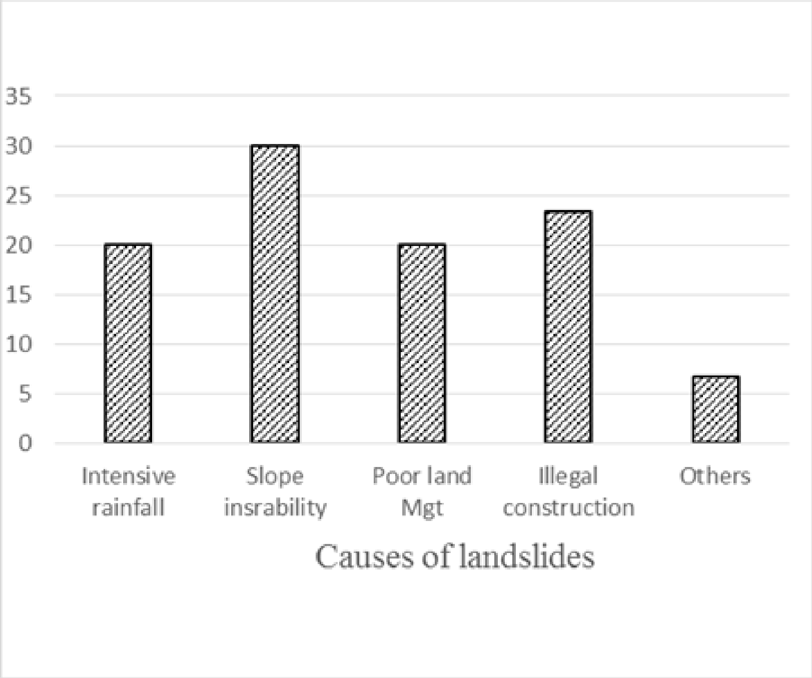


**Figure 2:** Factors influencing landslides.

**Frequency and impacts of landslide occurrences:** Figure 3 shows the responses of how often landslide occurs in the Bamenda escarpment zone. With regards to its occurrence, 43% of the respondents had no idea of how often landslides occur in the Bamenda escarpment, 40% attested that landslides do not occur so often, 10% agreed that landslides often occur in the area, while 7% were of the view that landslides occur very often. This is because landslides in the Bamenda station are not as frequent as in other areas such as in Limbe.

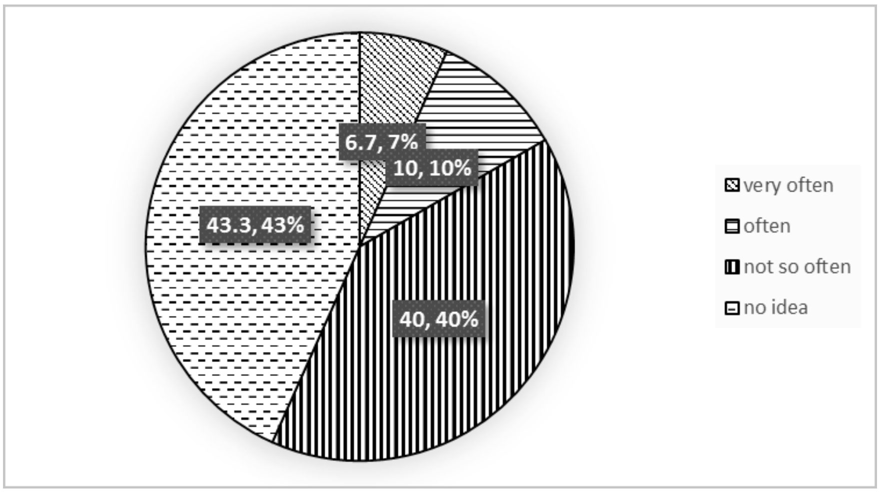


**Figure 3:** Frequency of landslide occurrences
**Source:** (fieldwork, 2021)

Table 1 shows that landslides in the Bamenda escarpment do not occur frequently (every year). They display an irregular pattern of occurrence. For instance, since the landslide that occurred in 2009, the next landslide occurred 11years later in 2020. The relatively infrequent nature of landslides in the Bamenda escarpment, as reported by 43% of respondents, mirrors findings from Chaturvedi & Dutt [16], who highlighted that communities often underestimate the risk of disasters that do not occur annually. As a result of this, landslides in the area are rare events. Because they are rare people do not show prevention behaviour and are not well prepared for an adverse event. Thus, findings of the study comply with the findings of Chaturvedi & Dutt [16] in their study on evaluating public perception on landslide risk in the Himalayas Mandi town found that respondents showed a lack of awareness of the scientific causes of landslide among Mandi residents. Most of the respondents were of the belief that they were living in a safe place due to the irregularity of landslide occurrence.

**Table 1:** Past landslides occurrence in the Bamenda Escarpment.

| Day | Month | Year | Location |
|---|---|---|---|
| 24th | August | 2004 | Up Station |
| 4th | August | 2009 | Sisia |
| 29th | September | 2020 | Sisia |

**Source:** Bamenda city council archives.

With regards to the impacts of landslides, 40% of the respondents attested that landslides have dangerous impacts. This was the view of most of the people who have lived in the area for long and have been victims of landslide hazards. Another 30% opined that the impacts of landslides were normal (not dangerous), 16% of the respondents agreed that landslide occurrences were more of spiritual than scientific causes because they believed that landslides occurred only when they have done something wrong. Some 13% were of the view that landslide occurrences are not dangerous at all because they have never been victims.

In terms of impacts, the loss of lives and destruction of infrastructure was noted as the primary consequence, with 37% of respondents highlighting this, which is consistent with the findings of Ndi [17], who emphasized the devastating impact of landslides on both human life and infrastructure. This is because when landslides occur, both uphill and downhill settlements are affected as debris are brought down from the slopes, destroying houses and sometimes burying people alive (Plate 1) as also reported by Ndi [17]. This always result to tremendous damages especially when the landslide is accompanied by rainfall. However, 13% opined that landslides destroy natural resources, results to erosion and release debris into water ways causing pollution. Some 10% were of the view that landslides cause damage to landscape by modifying them from high to lowland, or from a gentle sloping to a steep sloping land, blocking roads and water ways. This corrobotes the findings of Edris Alam [18] who highlighted that over the last thirty years, Bangladesh has been experiencing hill cutting problems and subsequent landslide occurrence in its south-eastern hilly region. Plate 2 shows an image a landslide that occurred in Bamenda escarpment, blocking a major transportation route and distorting movements.

**Reasons for continuous stay in the area:** Despite the numerous landslide occurrences in Bamenda escarpment and their impacts, people still continue to occupy the area. The reasons why people still settle in the Bamenda Station escarpment are shown on Figure 4.

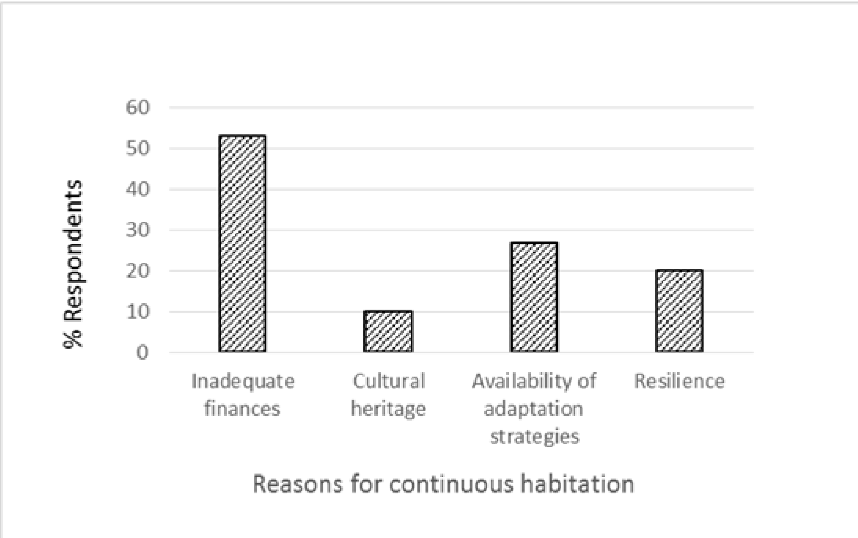


**Figure 4:** Reasons for continuous habitation.

Results obtained from the field showed that 53% of the respondents are still living in the area because of inadequate finances. This is due to the fact that houses/land in the area are relatively cheaper than in other parts of Bamenda. This is in line with the work of Patankar & Patwardhan [19] who noticed that the continuous occupation of regularly flooded areas of Mumbai was largely due to poverty. Some 27% of the respondents attested living in the area due to availability of adaptation strategies. Another 20% of the respondents equally said they have not left the Bamenda escarpment despite landslide occurrences because of their ability to recover after a landslide occurrence (resilience) and 10% highlighted cultural factors as the reason they are attached to the area. Some of the respondents even attested to have inherited houses from their parents. Furthermore, the availability of adaptation strategies, such as temporal relocation, is noted as a reason for continued habitation, suggesting a resilient community despite the hazards, echoing findings from Kang et al. [14,15] on the persistence of settlement in landslide-prone areas due to economic and policy constraints.

**Test on perception of landslide awareness and households' socio-economic characteristics:** The data collected was subjected to chi square contingency analysis to establish if Socio-demographic characteristics influence the perception of landslides awareness The chi-square analysis indicates that age, education, and income significantly influence landslide awareness, supporting previous studies that have shown a correlation between education and risk perception [16]. This means that landslide awareness is influenced by age, level of education and income of respondents. The level of education of community members has a highly significant impact on landslide awareness. The more educated a community is the more will be their level of awareness. Therefore, the study shows that landslides awareness is influenced by households' socio-economic characteristics of age, level of education and income (Table 2).

**Table 2:** Summarized results of the Chi square tests.

| Socio-Demographic Characteristics | Pearson Chi-Square | df | Asymptotic Significance (2-sided) | Remark |
|---|---|---|---|---|
| Gender | 3.409[a] | 3 | 0.333 | Not significant |
| Age group | 35.587[a] | 12 | 0.023 | significant |
| Level of education | 25.690[a] | 9 | 0.002 | significant |
| Income | 15.238[a] | 6 | 0.018 | significant |

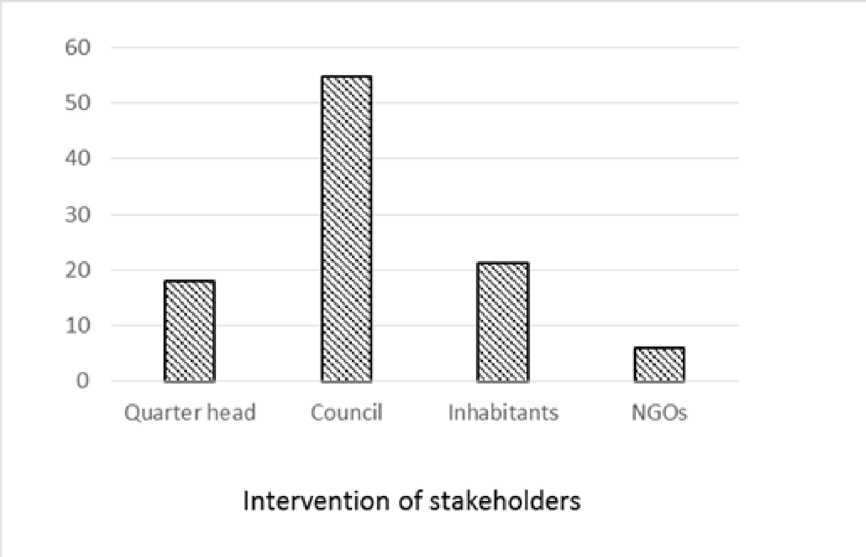


**Figure 5:** Stakeholders implementing adaptation strategies.

**Coping strategies and stakeholders involved:** Results showed that 43% of the respondents agreed coping strategies have been implemented in the area while 57% were not aware. The stakeholders involved in implementing the strategies are many and varied as shown on Figure 4. Field results revealed that 54% of the respondents agreed that most of the strategies are being implemented by the council, 21% were of the view that the inhabitants are the ones mostly involved in implementing strategies, 18% highlighted the quarter head while 6% witnessed that strategies were being implemented by Non-Governmental Organizations. This is because when landslides occur in the area the council is the first governmental body that gets notified and they intervene immediately by providing medical and moral assistance to the victims. The implementation of coping strategies by various stakeholders, such as the local council, inhabitants, and NGOs, reflects a collaborative approach to mitigating landslide impacts. This is consistent with the work of Sengupta et al. [20] & Usongo et al. [21], who emphasized the importance of multi-stakeholder involvement in disaster risk management. Attempts to relocate people from the Bamenda escarpment have also been made by the council, especially by the city Mayor Paul Achobong and the Mayor of Bamenda III who passed an evacuation order after the September 29th 2020 landslide that killed an 8-year-old and rendered many people homeless. The involvement of the council in the evacuation of affected individuals, particularly after the 2020 landslide, underscores the role of local authorities in disaster management, as also noted by Mbanga [22,23] (Figure 5).

**Effectiveness of adaptation strategies to landslides:** Respondents were asked on the strategies employed by various stakeholders as well as the level of effectiveness of these strategies to address landslides occurrences and its impacts. Figure 6 presents the result of the rating.

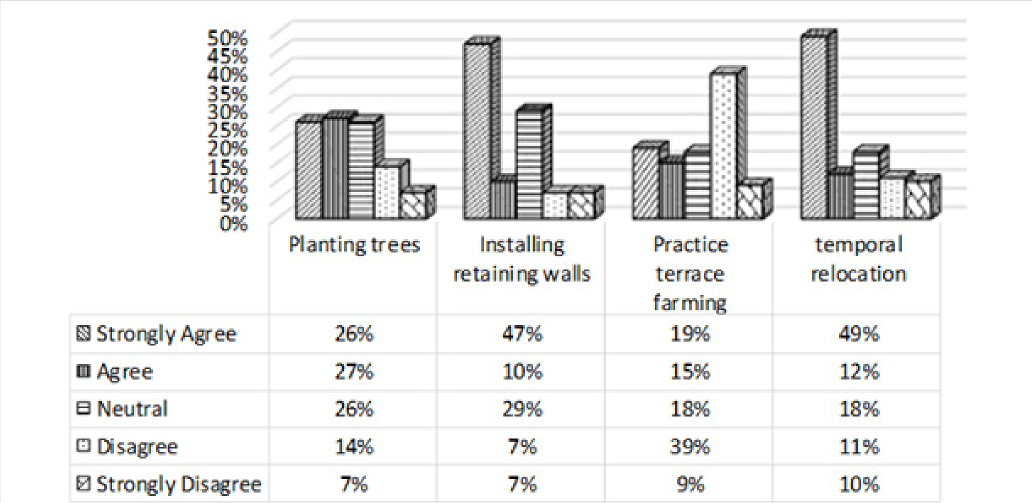


**Figure 6:** Level of effectiveness of adaptation strategies.

The effectiveness of adaptation strategies such as temporal relocation, stone walls, and terrace farming around the Bamenda escarpment has shown mixed results. Temporal relocation has emerged as the most effective strategy, with 49% of respondents strongly agreeing that it is the most frequent and successful approach, aligning with findings from other regions where temporary evacuation is a common response to landslide threats [18]. The construction of resistant stone walls follows as the second most effective strategy, supported by 47% of respondents. However, the effectiveness of other strategies, such as terrace farming and tree planting, appears limited. While 39% of respondents disagreed with the effectiveness of terrace farming, only 26% found tree planting to be useful. These results suggest the need for more research to tailor these interventions to the specific geotechnical characteristics of the Bamenda escarpment. As noted by Sengupta et al. [20] & Usongo et al. [21], a thorough study of the area's geological and geotechnical parameters is essential to better understand the factors influencing landslides and to design more effective coping measures.

**Test of hypothesis on the effectiveness of adaptation strategies:** Tables 3 & 4 show the results of ANOVA on the effectiveness of adaptation strategies put in place. The ANOVA results confirm a significant difference in the perceived effectiveness of adaptation strategies. The findings suggest that while some measures like temporal relocation are deemed effective, others, like terrace farming and tree planting, are less impactful. This aligns with the recommendations of Sengupta et al. [20] for a more context-specific approach to landslide mitigation.

**Table 3:** Results of ANOVA on the effectiveness of adaptation strategies.

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Planting trees | 150 | 372 | 2.48 | 1.459329 |
| Installing retaining walls | 150 | 324 | 2.16 | 1.638658 |
| Practice terrace farming | 150 | 459 | 3.06 | 1.667517 |
| Temporal relocation | 150 | 330 | 2.2 | 1.973154 |

**Table 4:** Anova test results.

| Source of Variation | SS | df | MS | F | P-Value | F Critical |
|---|---|---|---|---|---|---|
| Between Groups | 77.565 | 3 | 25.855 | 15.34727 | 1.25E-09 | 2.619854 |
| Within Groups | 1004.06 | 596 | 1.684664 | | | |
| Total | 1081.625 | 599 | | | | |

**Settlement evolution within the escarpment zone between 1980 and 2020**: Figures 7-9 show the evolution of Land Use Land Cover change maps for 1980, 2000 and 2020 respectively within the Bamenda escarpment. Land cover change analysis over the period 1980 to 2020 within the Bamenda escarpment revealed four important LULC types; built-up areas, grassland/farmland, dense forest and bare soils as shown in Table 5. In 1980, the built-up area covered a total surface area of 280.9 hectares of land, constituting 18.8% of the total surface area. The highest land cover class was dense forest, covering a total surface of 490 hectares which was 31.7% of the total surface area. This was followed by bare soils with a total surface area of 410 hectares making up 26.5%. Grassland and farmlands also constituted 368hectares of land. This means that in 1980, the Bamenda escarpment area was predominantly made up of dense forest, bare soils and farmlands. Built-ups occupied the smallest proportion of the surface area (Table 5 & Figure 10).

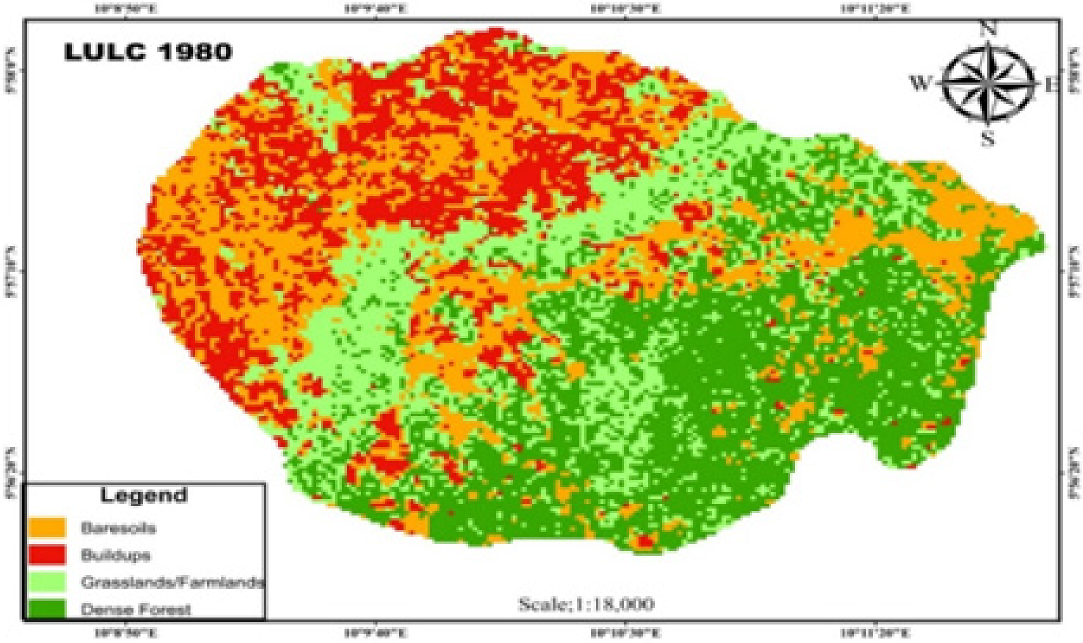


**Figure 7:** LULC in 1980 around Bamenda Escarpment.

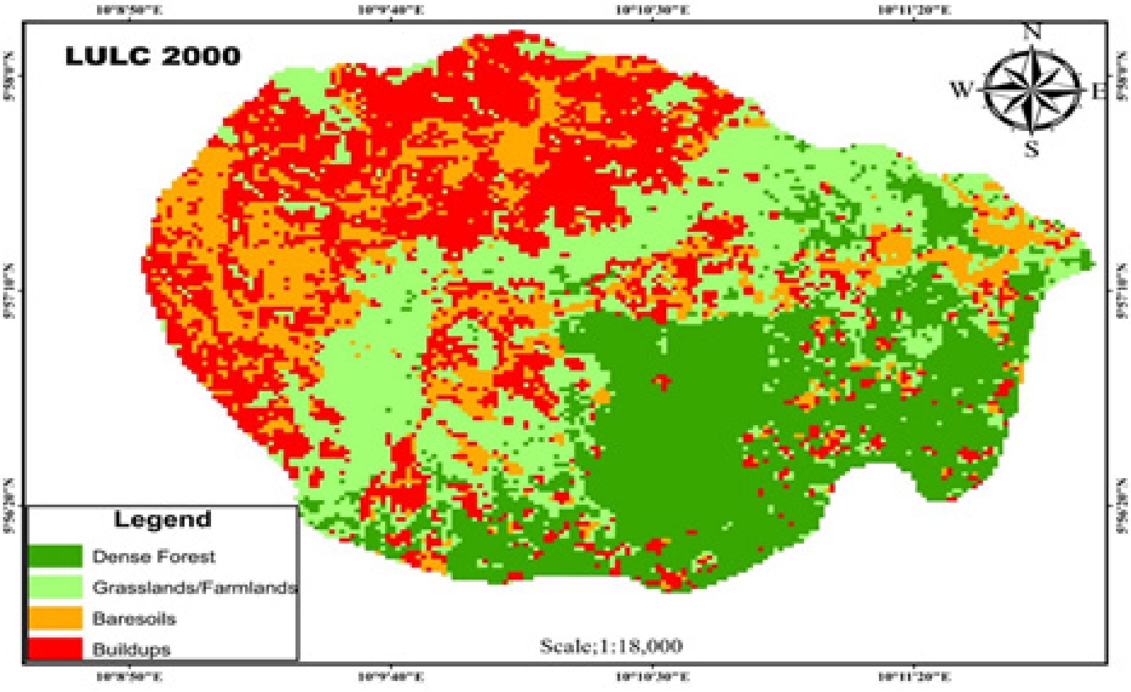


**Figure 8:** LULC 2000 around Bamenda Escarpment.

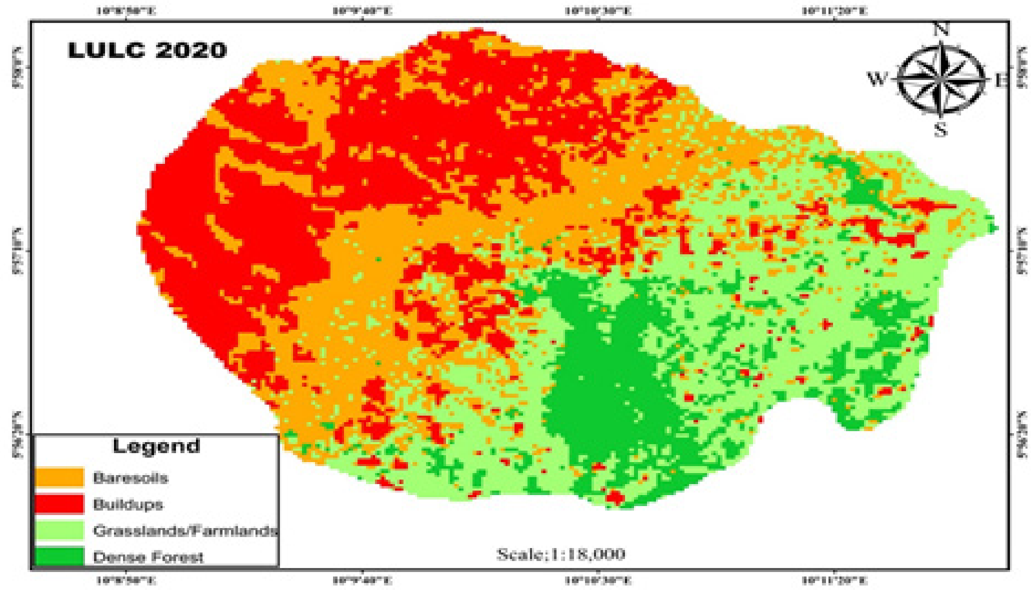


**Figure 9:** LULC 2020 around Bamenda Escarpment.

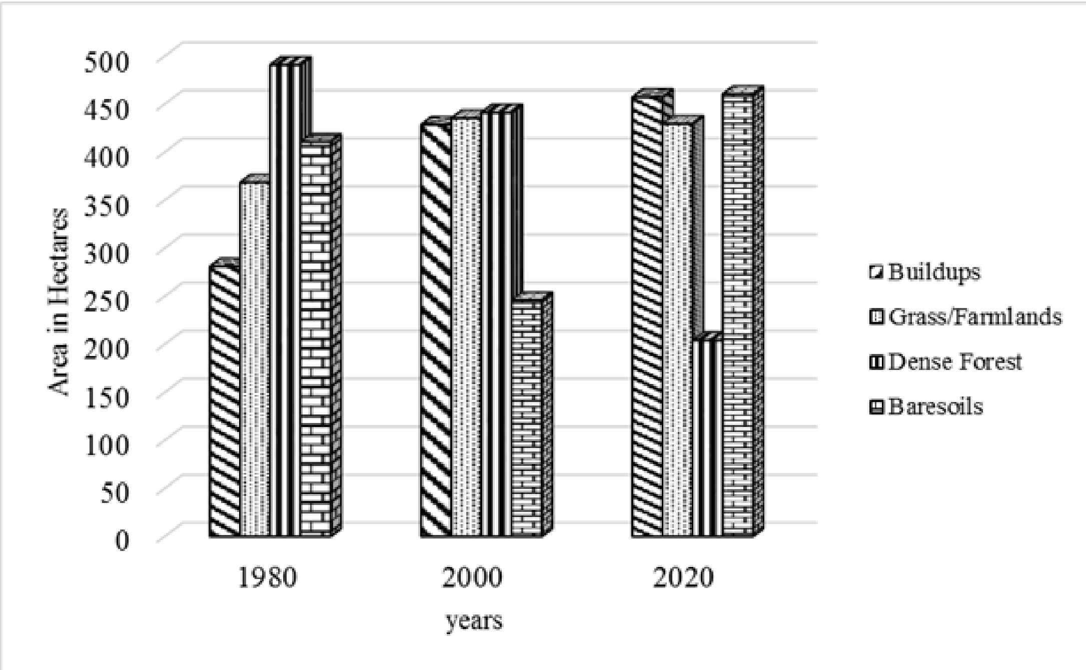


**Figure 10:** LULC 1980 to 2020.

**Table 5:** Surface area occupied by various land uses within the Bamenda escarpment.

| LULC Class | 1980 | | 2000 | | 2020 | |
|---|---|---|---|---|---|---|
| | Area (Hectares) | % | Area (Hectares) | % | Area (Hectares) | % |
| Buildups | 280.9 | 18.1 | 428.5 | 27.6 | 457.2 | 29.5 |
| Grass/Farmlands | 368.3 | 23.8 | 435.2 | 28.1 | 429.4 | 27.7 |
| Dense Forest | 490.8 | 31.7 | 441.2 | 28.4 | 204 | 13.2 |
| Bare soils | 410.7 | 26.5 | 245.8 | 15.9 | 460.3 | 29.7 |
| Total | 1550.8 | 100 | 1550.8 | 100 | 1550.8 | 100 |

**Source:** (Analysis of Landsat Images)

In the year 2000 built-up areas experienced a drastic increase in surface area. The drastic increase in built-up areas can be attributed to population growth and urban expansion. Population growth and other socio-economic factors. It can also be seen from the table that the area covered by vegetation also reduced. Dense forest occupies the highest surface area of 441.2 hectares (28%), although it has reduced significantly from that of 1980. Meanwhile built-up areas showed a drastic increase from 280.9 hectares (18%) in 1980, to 428 hectares (27%) in 2000. This increase can be as a result of population growth and urban expansion in the town of Bamenda. This is in line with the findings of Kang et al. [14,15] & Mbanga [22,23], who opined that settlement growth within the steep slopes of Bamenda is mostly driven by the problem of land scarcity and administrative bottleneck policy makers. Bare soils showed a reduction covering 245 hectares (15%), farmlands experienced an increased to 435 hectares (28%). Results show that dense forest in 2020 showed a steady decrease in surface area while built-up areas increased drastically. This shows that the largest percentage of the total land surface of Bamenda escarpment in 2020 was made up of settlements. This could be as a result of increasing population in the area both from within the town as well as out of the town. The reason why there has been a drastic increase in population can be attributed to the fact that cost of living in the area is low, as well as accessibility to strategic areas within the town from the escarpment zone is easy.

Results revealed that built-up areas increased from 428 hectares (27%) in 2000 to 457.2hectares (29.5%) in 2020. The dense forest showed a decrease from 441.2 hectares in 1980 to 204 hectares in 2020 with evidence of massive deforestation that has occurred in the escarpment zone. Population influx into the area has created the need for more houses, infrastructure and amenities which cannot be achieved without cutting down the forest. The results revealed that the built-up areas experienced a steady increase from 1980 to 2020. The total surface area occupied by the built-up areas was 280.9ha (18.1%), 428.5ha (27.6%) and 457.2ha (29.5%) respectively for 1980, 2000 and 2020 (Table 4) representing a total increase of 176.3 hectares. This evolution, marked by a 176.3-hectare increase in built-up areas, corroborates the findings of Kang et al. [14,15] & Mbanga [22,23], who highlighted the role of population growth and land scarcity in driving settlement expansion in landslide-prone areas. The study also underscores the environmental consequences of urban sprawl, including deforestation and soil degradation, which contribute to the region's vulnerability to landslides.

Results obtained from the analysis of Landsat 5(1980), 7(2000) and 8(2020) images shows varying percentages and surface areas of the various LULC classes. In 1980 for instance, Built-up areas occupied a total surface area of 280.9Ha (Figure 10). This surface area was seen to have increased drastically in 2000 where built up areas covered a total surface area of 428.5Ha. Further changes in built-up area was also seen in 2020 where they occupied 457.2Ha (Figure 10). All this is plotted and presented on Figure 11. This therefore shows that within a period of 40years, settlement increase stood 176.3Ha. Tables 6 & 7 show the analysis of the hypothesis which states there is no significant relationship between perception of landslides and evolution of settlement around the escarpment. This hypothesis is tested and verified at a 5% significance level (0.05).

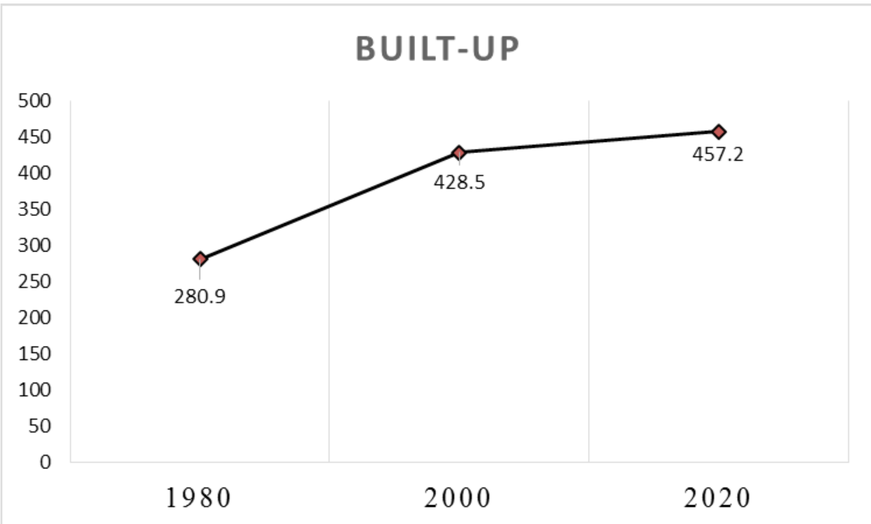


**Figure 11:** Temporal variation in Built up areas.

**Table 6:** Regression Statistics.

| | |
|---|---|
| Multiple R | 0.682783267 |
| R Square | 0.466192989 |
| Adjusted R Square | -0.067614021 |
| Standard Error | 97.74236021 |
| Observations | 3 |

**Table 7:** Anova.

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 8343.48 | 8343.48 | 0.87334 | 0.005215386 |
| Residual | 1 | 9553.57 | 9553.57 | | |
| Total | 2 | 17897 | | | |

The Multiple R value (0.68) is the Pearson Correlation Coefficient value. This value expresses the strength of the linear relationship. With a value of 0.68, the results show that correlation between perception of inhabitants and the evolution settlements is fairly strong. The R2 value of 0.46 reveals that 46% of the settlements that evolved around the Bamenda escarpment were influenced by perception of the inhabitants. This means that perception is only responsible for 46% of settlements growth in the area. Hence, other factors such as affordable housing, social amenities, fertile soils, socio-political instability accounts for the remaining 54% of settlements. Table 7 shows the degree of freedom, sum of squares, means squares, F statistics and F significance (P value). Since the P-value (0.0052) is less than the level of significance (0.05), the study concludes there is a significant relationship between inhabitants' perception of landslides and the evolution of housing around the Bamenda escarpment.

### Originality of the study

This study offers several unique contributions to the understanding of landslide risk management, particularly in the Bamenda escarpment area of Cameroon. The originality of the study can be summarized through the following aspects:

A. **Context-specific focus on the Bamenda escarpment:** Research on landslides in the Bamenda escarpment is limited, making this study an important contribution. The region's steep terrain, rapid urbanization, and high population density present unique challenges that have yet to be fully explored. By focusing on this understudied area, the study provides local insights into the interaction between socio-economic factors and natural hazards like landslides.

B. **Integration of socio-demographic factors with landslide risk perception:** This study is among the few to explore the relationship between socio-demographic factors-such as age, education, and income-and residents' awareness and perception of landslide risks. By linking demographic profiles to risk awareness, the study offers a nuanced understanding of how various groups perceive and respond to landslide hazards, informing more targeted risk communication strategies.

C. **Innovative Use of Land Use/Land Cover (LULC) analysis:** A key methodological innovation is the use of remote sensing-based LULC analysis to track settlement growth and environmental degradation in the escarpment area from 1980 to 2020. This analysis helps visualize the spatial dynamics of landslide risk, underscoring the tension between urban expansion and environmental sustainability in rapidly growing cities of the Global South.

D. **Cultural and perceptual insights on landslide causes:** The study highlights how cultural beliefs and traditional knowledge shape residents' understanding of landslides. Some respondents attribute landslides to spiritual causes, illustrating the importance of considering local belief systems when designing disaster risk management strategies. This perspective is often overlooked in scientific studies but is crucial for effective risk communication in culturally diverse settings.

E. **Coping strategies in resource-constrained contexts:** Unlike studies in more developed regions, this research examines how residents in resource-constrained areas like the Bamenda escarpment adopt coping strategies such as temporary relocation and retaining wall construction. These strategies, although not always effective, offer insights into how communities adapt to natural hazards in low-resource settings, which can inform policies for similar regions.

F. **Policy and practical applications:** This study contributes to Disaster Risk Reduction (DRR) by integrating socio-demographic factors, land use changes, and coping strategies to suggest targeted risk mitigation measures. It offers a comprehensive approach that combines both physical and socio-economic factors, providing practical recommendations for local governments, NGOs, and communities to enhance disaster preparedness.

G. **Cross-disciplinary approach:** The research adopts an interdisciplinary methodology, blending environmental science, social science, and urban planning. This cross-disciplinary approach broadens the scope of the study, making it more applicable to other regions facing similar challenges, and offers a holistic view of the landslide risk problem.

## General Conclusion

This study explored the socio-demographic characteristics, perceptions, and coping strategies of residents in the Bamenda escarpment, a landslide-prone area in Cameroon. By examining the interplay between socio-economic factors, land use patterns, and risk awareness, several key conclusions emerge:

a. **Socio-demographic characteristics and awareness**

The study found that younger residents and those with lower education and income levels exhibited lower awareness of landslide risks. Conversely, those with higher education and income were more informed about the causes and impacts of landslides.

This highlights the importance of education in enhancing risk awareness and preparedness, particularly for younger and less educated groups.

**b. Perception of landslide causes and frequency**

While most residents recognized the occurrence of landslides, many lacked specific knowledge about their causes and frequency. Commonly cited causes included slope instability, illegal construction, deforestation, and poor land management. However, many residents did not perceive landslides as an immediate threat, often attributing them to spiritual causes or viewing them as rare events.

**c. Impacts of landslides**

The study found that landslides were acknowledged for their destructive impacts, particularly the loss of life and infrastructure damage. However, some respondents minimized the severity, influenced by spiritual beliefs about the causes of landslides. This mixed perception suggests the need for a more tailored risk communication strategy that considers both scientific and cultural perspectives.

**d. Coping strategies and effectiveness**

Coping strategies in the Bamenda escarpment include temporary relocation, retaining wall construction, and tree planting. While temporary relocation has been effective in mitigating immediate risks, other strategies, such as tree planting and terracing, have been less successful due to insufficient maintenance and lack of long-term planning. Stakeholder involvement, including local governments and NGOs, has been crucial, but there is a need for more coordinated disaster risk reduction efforts.

**e. Settlement growth and land use change**

The LULC analysis revealed significant urbanization between 1980 and 2020, with built-up areas increasing and forest cover decreasing. Despite the high landslide risk, the demand for affordable housing and proximity to economic opportunities led to rapid settlement growth in hazard-prone areas. This socio-economic pressure contributes to the persistence of settlements on steep slopes, underscoring the complex relationship between urban growth and disaster vulnerability.

**f. Linking socio-demographic characteristics to landslide awareness and settlement evolution**

Statistical analysis confirmed that socio-demographic factors like age, education, and income influence landslide awareness and settlement decisions. Younger, less educated individuals exhibited lower awareness of landslide risks, which in turn affected their settlement choices. The study also showed that residents' perceptions of landslide risks played a significant role in shaping settlement evolution, with socio-economic factors often outweighing perceived risk in settlement decisions.

## Key Recommendations

Based on these findings, the following recommendations are proposed:

**A. Strengthening risk education and awareness programs**

Targeted education programs are needed to raise awareness about landslide risks, particularly among younger and less educated populations. These programs should combine scientific knowledge with culturally relevant information to improve public understanding and preparedness.

**B. Enhancing land use planning and regulation**

Effective land-use planning is essential to mitigate the risks of urbanization in high-risk areas. Authorities should enforce zoning laws that restrict settlement on steep slopes and implement stricter regulations to prevent deforestation and illegal construction on unstable land.

**C. Improving disaster preparedness and adaptation strategies**

Local governments should invest in disaster preparedness, including the maintenance of adaptation measures like retaining walls, development of early warning systems, and facilitating temporary relocations during high-risk seasons. These strategies should be evaluated regularly for effectiveness.

**D. Promoting sustainable land management practices**

Residents should be encouraged to adopt sustainable agricultural and construction practices, such as terrace farming and reforestation, to stabilize slopes and reduce the risk of landslides.

**E. Fostering collaborative approaches to disaster risk management**

A multi-stakeholder approach involving local government, NGOs, residents, and other organizations is essential to develop comprehensive and sustainable disaster risk management strategies that can better address the region's growing vulnerability to landslides.

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