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Human Adaptation Measures to Biophysical Constraints on the Eastern Slope of the Mount Cameroon

Yinkfu Randy Nkuh, Roland Nformi, Ngwani Awudu, Funwi Godlove Ngwa
Department of Geography, Faculty of Social and Management Sciences,
University of Buea P.O. Box 63 Buea, Cameroon

Abstract:- Most mountainous environments are repertoire of precious resources and characterized by many physical challenges but man has always adapted to these by his own strategies. The aim of the study was to examine man's adaptation measures to the biophysical challenges on the eastern slope of Mount Cameroon. It was an observatory and explanatory study that adopted the mixed research design involving the use of qualitative and quantitative techniques. By the simple random sampling techniques, 200 households located on the eastern slope of the Mount Cameroon were selected as key informants. Primary data was extracted from them through questionnaires, interviews, interrogations and field surveys. More so, secondary data were gotten from published related articles, Newspapers, online and offline libraries. The collected data was inputted on Excel Version 20.0 and exported to SPSS Version 19 where it was analyzed through the inferential and descriptive statistical techniques. Frequencies, percentiles, ranges and relationships were then derived. Results show that there are two factors responsible for the occurrence of biophysical challenges on the eastern slope of the mount Cameroon, that is, the natural factors and to a larger extent the anthropogenic factors. The major physical challenges are steep slopes, landslide, soil erosion and climate variability. Man has adapted to these challenges by creating embankments, raising robot structures and planting trees. All these measures have been short-lived because of population concentration, low level of technology and increasing magnetudes of the challenges. The work concludes that the eastern slope is a warehouse of resources and recommends that holistic measures such as tree planting and land use planning be done to control the emerging challenges.

Keywords:- *Human adaptation measures, Biophysical constraints, eastern slope of mount Cameroon.*

I. INTRODUCTION

According to Dean (2019), biophysical constraints refer to the limitations or restrictions imposed on living organisms or natural systems by physical and biological factors. These constraints might include: physical factors such as increasing temperatures, steep terrain or mass movements. According to Lambi (2010), the world's configuration is ubiquitous and man has settled on all sorts of environments characterized by physical challenges such as land slide, seismic zones, rive banks and on steep slopes. Understanding of biophysical constraints is essential in environmental science as they help explain the limitations and capabilities of living thing organisms within their natural environments (Lambi, 2012).

In the developed countries, for instance, the case with Meteora in Greece, humans have settled on steep slope and reaching a height of about 3000m and colonizing mountains sides and valleys settlements in such sites are due to the wild gold chase of resources by man in order to satisfied his economic demands. However, there are negative attributes attached to such environments. They are recurrent slope falls across steep slopes void of vegetation, climate perturbation enhanced by uncontrolled human activities and flood which occurs especially in rainy seasons. (UNEP, 2002).In China, Australia and many developed countries, man has conquered space by introducing technologies to design the land into agricultural landscape. In the course of such technologies, vegetation and forest which are environmental protectors are being tempered with and thereby instigating environmental constraints (Deneen, 1998).

In the developing countries such as La pas in Bolivia which forms the roof of the world, people have settled with high raise storey buildings in risky zones where the natural environments have actually been neutralized with artificial asphalts and other artificial materials which do affect the living environments. (UNEP, 2002). In Morocco, large and extensive fields of agricultural activities have been bulldozed to embrace solar panel installations. Such an action has brought about many physical challenges with escalating climate variation being the main underlying factor and characterized by soil erosion and flood (Africa News, 2021). In Cameroon, precisely in the Center region which is characterized by highlands and deep valleys, man in the quest to satisfy his exigencies has occupy all the risky environments and wetlands have even turn to be inventories of human settlements. As corroborated by Kometa (2012), the western highlands of Cameroon over the years have seen an unassessible rate of transformation thathasmany negative impacts on the environment. Slopes and valleys have been submerged to rampant cutting and fillings and therefore electing physical constraints such as flood, rockfall, landslide and soil erosion.

As indicated by Lambi (2010) and Nkemasong et al., (2023), within the eastern slope of the mount Cameroon and right to the west coastline, there have been unprecedented human activities which have caused the natural environment to be transformed. On the contrary, these sites in their natural states are very rough, and characterized by very

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challenging terrains, regardless of settling within them, man in an attempt to carry out agriculture faces a lot of challenges and thus, put himself into a lot of risk especially when trying to occupied such sites. Flooding and landslides have increased over the years as a result of human activities and occupation on the eastern slope of the Mount Cameroon.

II. STATEMENT OF THE PROBLEM

The significance of mountain areas cannot be overemphasized. The mount Cameroon landscape embodies significant pools of bio-diversities with extensive fields of rich fertile soils which are gateways for worthwhile socio-economic activities. Through history, it has served as a touristic site, aesthetic and a carbon reservoir due to its dense surrounding native forest and vegetation. It also offers perennial opportunities to the people in terms of the resources, foodstuffs, environmental conservation and regulating services. However, the multitudes of uncontrolled human activities on this slope have interfered negatively with most of its cherished endowments and leading to many biophysical constraints.The expansion of anthropogenic activities to this zones have stemmed from the inflated population growth that leapfrogged from 4.3 to 6.5 in the year 2005 and 2015, respectively and currently projected to be 436460 persons (Buea, 2023). More so, population pressure at the sub-centers of the town has pushed a greater proportion of people to locate on unstable areas. Over the years, this slope has witnessed reckless and unprecedented cuttings and feelings for farming, building and construction activities as well as resource exploitation. Most of the wetlands and dry valleys have been colonized by man with clandestine activities thus subjecting them to instability and electing frequent sedimentation in nearby streams, landslide has increase in less cohesive area, escalating soil erosion, and increasing temperature conditions. Ground mining in many parts of the slope has resulted to the extinction of native plant and animal species. In Some areas like Bukwango, Campen street and Buea town as well as Bokwai, settlements are perched on steep slopes while debris from such activities silt up the river beds and provoking landslide and floods in adjacent lowlands, respectively. Combined with the harmful anthropogenic activities are natural factors such as torrential rainfall, rock failure and the rough topography which are recipes for biophysical constraints. These therefore command holistic adaptation measures in the area and yet, the measures put in place by man have not been able to contain environmental hazards in the eastern slopes of Mount Cameroon.

III. CONCEPTUAL FRAME ON ADAPTATION MEASURES

In order to address this study, the conceptual framework developed by Hill (2015), and Sutton-Grier et al., (2015) entitled "Governance archetypes of adaptation strategies to sea level rise" was adopted. The model consist of hybrid approaches which Sutton-Grier et al. (2015) defined as the combination of natural and built infrastructure to protect coastlines from erosion and flooding, aiming to be more costeffective in the long term than built infrastructure alone. According to this model, archetypes are classified according to two contrasting paradigms position on the vertical axis. The first paradigm is to protect from coastal hazards which aim at fighting at the advancement of the sea to protect the threatened population and infrastructures. By accepting coastline mobility, the second paradigm is to adapt to coastal hazards. Details of these are presented in the subsequent Figure.

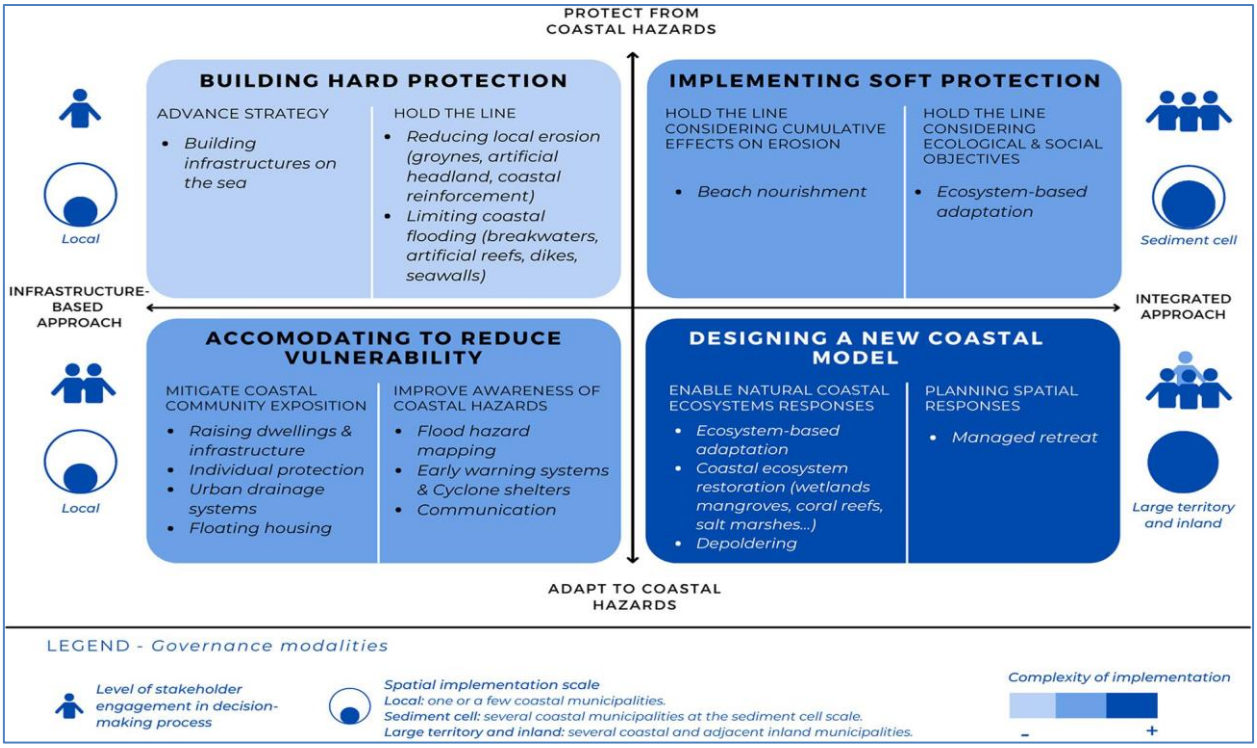

Fig. 1: Governance archetypes of adaptation strategies to sea level rise
Source: Hill et al., (2015)

The model did used hard engineering methods which are structural and hardily contain environmental hazards that are biophysical challenges on the eastern slope of mount Cameroon. Non engineering methods always last.

This model can be applied on the eastern slope of the mount Cameroon to protect the landscape against human encroachment and other natural processes. In order to protect the mountain, non-engineering methods like clandestine anthropogenic activities of subsistence farming, ground excavation, bushfire and deforestation should be prohibited and at the same time encouraging afforestation. A master plan of land use activities around the mountain should be invented, whereas, flood and landslide should predicted with weather forecast. sIn cases where human must live, robot infrastructures, effective human drainage and flood hazard mapping should be done. For the sake of landscape protection, trees should be planted in affected areas, sensitization by NGOs and the local council. There should be the promotion of scientific research geared toward environmental protections.

IV. RESEARCH METHODOLOGY

The study was observatory and investigatory in nature adopting the mixed research design involving the use of quantitative and qualitative techniques. The observatory design facilitated field inquiries on the nature of the landscape of the Mount Cameroon taking into considerations the various anthropogenic activities while the investigatory approach instigated investigations on the nature and the types of biophysical constraints and human adaptation measures, respectively. The used of the quantitative and qualitative techniques gave way for the researcher to easily address the underlying goals of the study and thus, getting rid of the hurdles which could have arisen in using an unaccompanied technique. The main primary sources of data for the study were the used of questionnaires, interviewed guides, interrogations and direct field observations. For the secondary data, published related articles, online and offline libraries as well as records of forest related institutions and NGO organization were consulted. Research tools such as GPS was used to take points affected by human activities and while the soft wares such as ArcGIS was used to draw the cartographic maps of the affected areas. Digital cameras were also used to take photographs of some human induce geomorphic processes as manifestation of field realities. Hand tapes were also used to measure the extent of some uncontrolled land use activities such as areas characterized by stone mining, land reclamations and deforestation.

Data was analyzed using two principal statistical techniques, that is, the inferential and descriptive techniques. The inferential techniques addressed quantitative data collected from the field focusing on their relationships, correlations and projections while the descriptive techniques treated qualitative data thus, extracting their frequencies, percentiles and diversions. All these process were successfully done with the used of Microsoft Excel Version 16 and SPSS Version 17. Most outcomes of the analyses were presented on histograms, pie-charts, columns and tables. Ethic-wise, there was a strict implementation of inform consent during the data collection process and measures against cholera pandemic was well enforced.

V. RESULTS

A. Complexions of the eastern slope and fundamental human activities on mount Cameroon

The eastern slope of the mount Cameroon is characterized by undulating topography with many steep slopes and dry valleys. Steep slopes are common in elevated areas such as Buea town, CampenStreet, Bokwai and Soppo. In Bitingi, Soppo and Sampit, we have extended dry valleys originating from the mountain at heights of approximately 2500m. Some of these dry valleys contain water during months of torrential rainfall especially in June, July and August while some have been without water flow for decades. There exist native vegetation species on this Mountain starting from a height of approximately 1500m with the lower surfaces characterized by man-made vegetation such as pear and plum trees, flowers, and guava trees. There are however some perennial rivers on this slope such as the Ndongo River, and the Koke. Because of the increasing human activities, these rivers do not dry up during the dry season but their quantity of water and the flow rate drops. Many rivers dos completely dry off but resurfaces with over land flow in the wet seasons. Many of the steep slopes are degrading as well as vegetation extinction due to human pressure driven by human exigencies. The area remains an active volcanic site with perpetual signs of tremors and recurrent landslides. On this slope, there are also many table lands giving rise to flat surfaces which have attracted human settlement alongside many other socio-economic activities such as farming, and communication infrastructures. Because of population pressures within most localities around this slope, a greater proportion of it has been colonized by urban dwellers to sustain their livelihoods. Dry valleys are now inventories offarming and settlement activities while river beds are the bases of most housing foundations. Steep slopes have been submerged into rampant cuttings and feelings to suit the design of houses leading to many challenges. Presently, the eastern slope of the mount Cameroon has been transformed cultural with artificial buildings replacing native species of plants, and the geomorphic landscape. Details of anthropogenic activities on this slope are presented on map 1.

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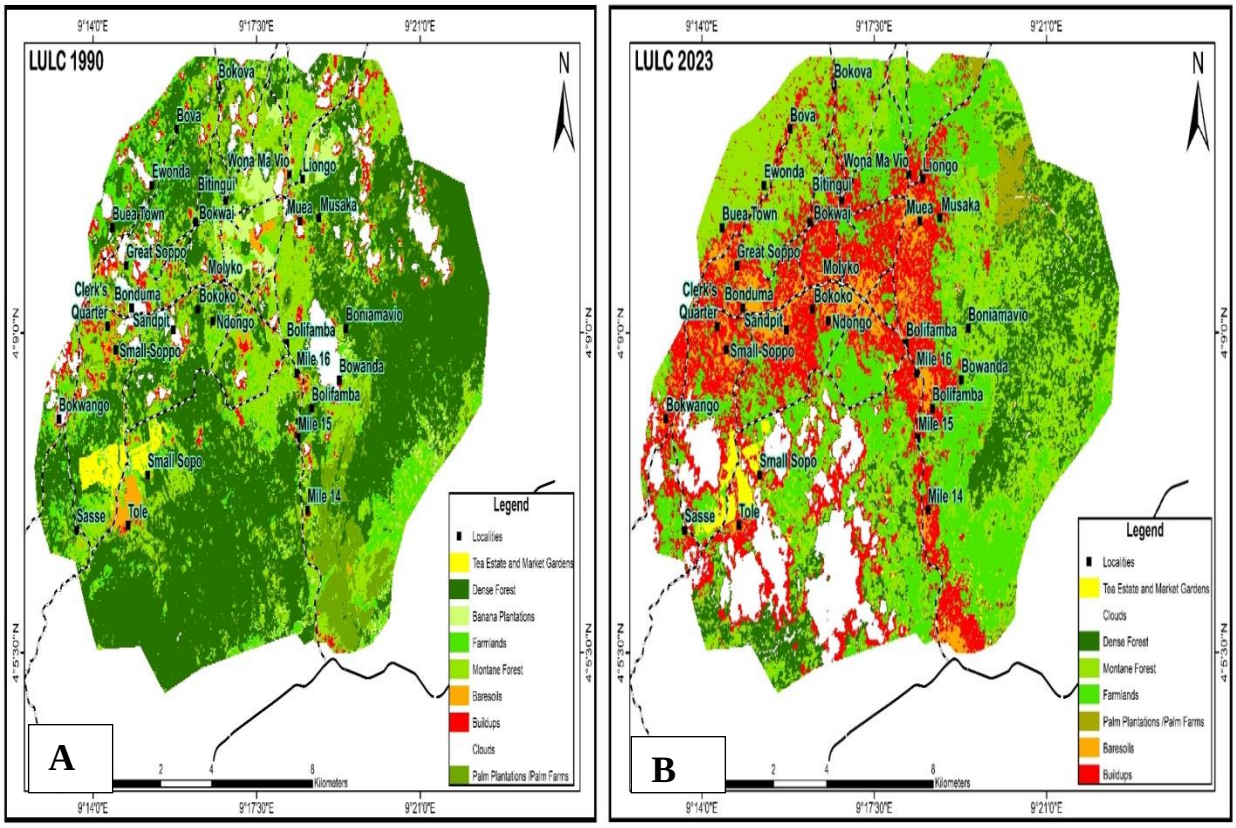

Map 1(A) and (B) Show the land use cover changes of the eastern slope prior to 1990 and 2023
Source: Cosmos (2023)

Map 1 (A) and (B) show pictorial views of land use activities trends on the eastern slope of the Mount Cameroon to 1990 and 2023.

Table 1: Land use trends on the eastern slope of mount Cameroon between 1990 and 2023

S	1990	1990% COVER	2023	2023% COVER
Tea Estate and Market Gardens	2273	1.21	3120	1.66
Cloud Cover	11335	6.04	16469	8.77
Dense Forest (Rainforest)	86176	45.92	18358	9.78
Montane Forest	39974	21.30	45800	24.40
Farmlands	13458	7.17	43448	23.15
Banana Plantations /Palm Farms	7016	3.74	2635	1.40
Buildups	6848	3.65	13465	7.17
Baresoils	2420	1.29	44387	23.65
Palm Plantations /Palm Farms	18182	9.69	/	/
Total	187682	100	187682	100

Source: Derived from map1 (A) and (B)

In line with the information on Table 1, the eastern slope has experienced increasing human pressure over the years which have affected the various control factors in the area like vegetation. Buildup environments have outsized the natural environment that is, skyrocketing from 1.29% experienced in 1990 to 23.65% in 2023 while forest areas have dwindled from 45.92% in 1990 to 9.78% in 2023, and this applies to other natural controls. All these have resulted to rapid landscape mutation and provoking some of the physical challenges. This therefore gives evidence that there are mixed factors responsible for the physical constraints occurring on the eastern slope, that is, human induce factors and natural factors.

B. Common biophysical challenges

Intensive field survey revealed that there are multitudes of physical constraints existing on the eastern slope of the mount Cameroon, with the most common and threatening ones being steep slopes, landslide, floods, eruptions and climate variability as presented on Figure 2.

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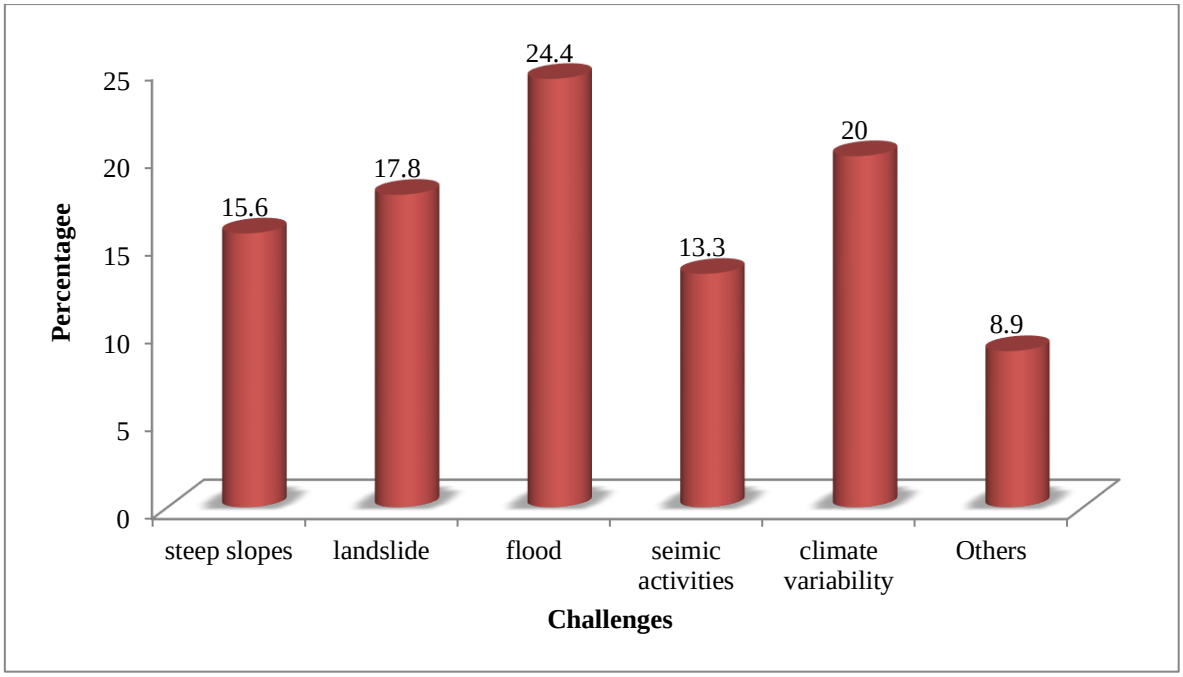
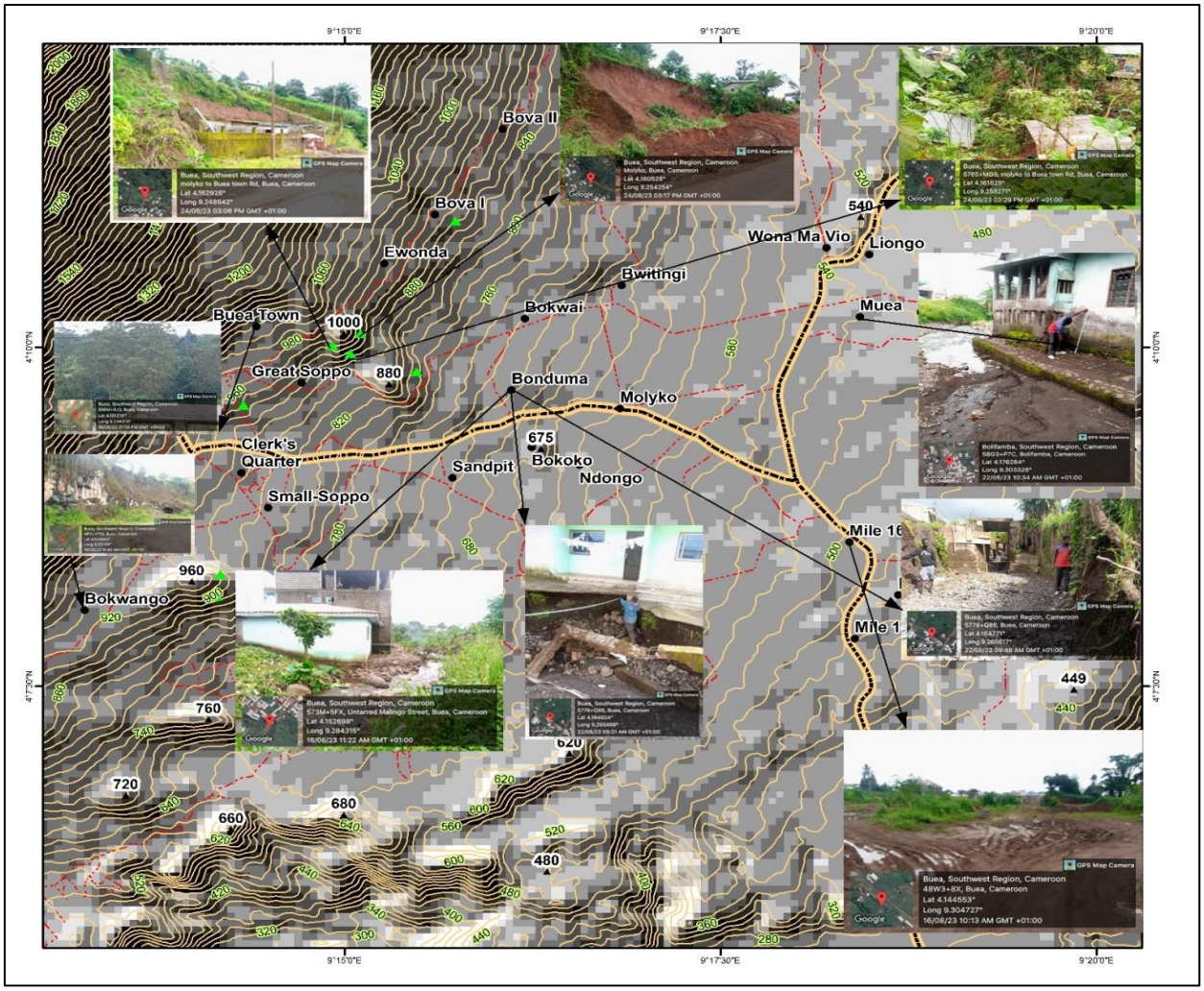


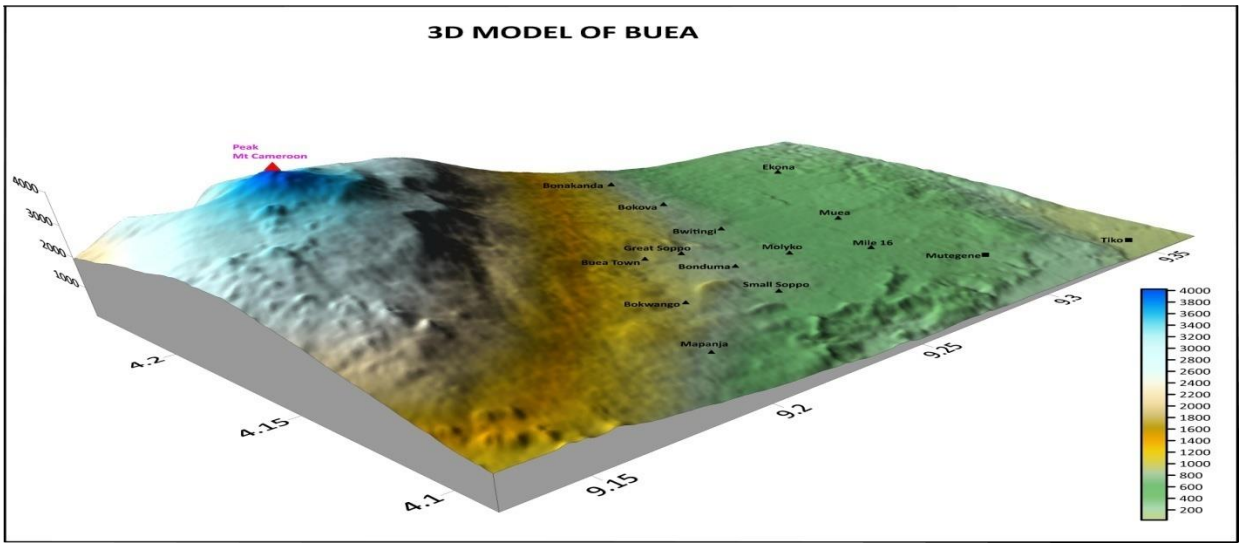
Fig. 2: Common biophysical challenges on the eastern slope of Mount Cameroon
Source: Fieldwork (2023)

The most common biophysical challenges are flood and climate variability as indicated by 24.4% and 20% of the population respectively (Figure 2). Floods are stemming from the fact that the multitudinous population of the area in their effortsto satisfy their exigencies has colonized most pathways of running water such as dry valleys and wetlands, such that during the intensive rainfall which usually occurs in the June, July, August and September months, runoff finds it difficult to get to the outskirts of the town and thus diverting to inhabited homes and polluting them. In the same light, climate change has been instigated by uncontrolled human activities and the fast built-ups within the urban landscape. Today, the micro and congenial temperature conditions which existed across this slope long ago has taken a new trend with elevated temperature conditions as well as rainfall dynamics which affect human comforts. Night temperatures are becoming unbearable for the urban dwellers and it has become a big problem in the area which was never so. Another major physical challenge is landslide as supported by 17.8% of the respondents. There have been recurrent landslide on this slope over the years, and this is because most of the forest have been removed by man making the ground to be less cohesive and more susceptible to forces of denudation such as rainfall, gravity and wind. More so, humans do excavate ground stones from steep slope making them unstable and instigating the occurrence of landslides. The population also pointed that steep slopes pose challenges to most of their activities. This is true of the areas dominated by steep slopes most especially around Soppo, CapenStreet, Buea town, Bokwai and Bukwango. This makes things very difficult for construction activities as they have to spend much money leveling the survey piece of land to suit the design of building structures. More so, these risky zones are highly prone to mass movements. As pointed by 13.3% of the respondents, seismic activities has been a long phenomenon in the area. This is so because the area falls within the volcanic line which has sometimes manifested through volcanicity in the area like the case of 1999 and 2000. Vibrations from this phenomenon affect building infrastructures. Another serious issue face mostly by farmers is soil erosion and this is experience more on steep slopes void of vegetation cover like Upper farms.



Map 2: Impact map of physical constraint on the eastern slope of Mount Cameroon
Source: Nkendem (2023)

Map 2 presents the repercussions of these constraints such as flood affecting buildings, farmlands and water bodies. Landslide and soil erosion as well as others are also manifesting at an increasing rate on the eastern slope of Mount Cameroon. Map 3 further shows the digital elevation map of the area which has added evidence to the steep terrain of the area which is another vital constraint.



Map 3: Digital elevation map of the eastern slope of Mount Cameroon
Source: Realized by Nkendem (2023)

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There are justifications that majority of the congested population around Buea town, Soppo, Bokwaiand Bukwango and found on steep slopes which are characterized by gullies (Map 3). These pose many physical challenges which range landslide, environmental degradation and soil erosion which do affect habitations, agricultural activities and free movements within the environment. Plate 1 shows some of the physical challenges on the eastern slope of Mount Cameroon.

Plate 1: Manifestations of physical constraints in in Bokwai and Buea Town, eastern slopes of Mount Cameroon
Source: Fieldwork (2022)

Plate 1 shows how instability of the environment and torrential rainfall has affected some housing facilities and the landscape on the eastern slopes of the Mount Cameroon.

C. Human adaptation measures

Because of the perennial and intergenerational opportunities that people derive by exploiting the endowments on this slope, the multitudes of the physical challenges occurring on this slope have been weakened by some conservative actions of man (Figure 3).

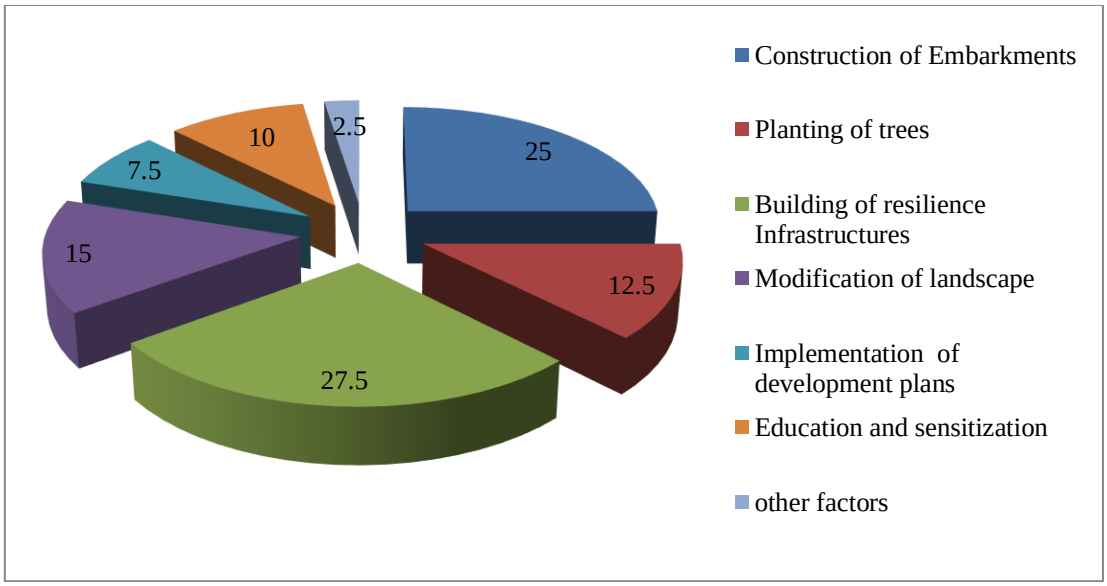

Fig. 3: Human adaptation measures to biophysical challenges on Mount Cameroon
Source: Fieldwork (2023)

As presented on Figure 3, 27.5% of the population adapt by constructing resilience infrastructures made up of rods, stones and gravels and making sure that the foundations are well planted into the ground for stability, 25% of them have constructed embankments in affected areas such as steep slopes, river banks and dry valleys to maintain stability while 12.5% have engaged into tree planting especially in landslide and flood areas like in Buea and Campen street. Furthermore, 15% has arranged and settled in deep valleys by removing and filling grounds, respectively to suit the design of their activities, 10% has been the education and sensitization of the inhabitants on the risk attached to some particular environments such as around steep slopes and dry valleys while 7.5% has strictly followed the development plan of Buea by avoiding risky areas, 2.5% has adopted some minor measures such as widening of river channels and transferring from risk prone areas.

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Plate 2: Evidence of man's adaptation to terrain challenges in Bokwai, eastern slope of mount Cameroon
Source: Fieldwork (2022)

Plate 2 shows the various strategies that man has imposed in order to make a living on the eastern slope of manCameroon. Plate 2 (B) shows more of the weakness of some adaptation measures.

D. Challenges with adaptation measures

Adapting to biophysical constraints on Mount Cameroon has been a herculean task to a greater proportion of the inhabitants found on this slope. Many factors explain why it has been difficult to deal with these challenges as indicated on Figure 4.

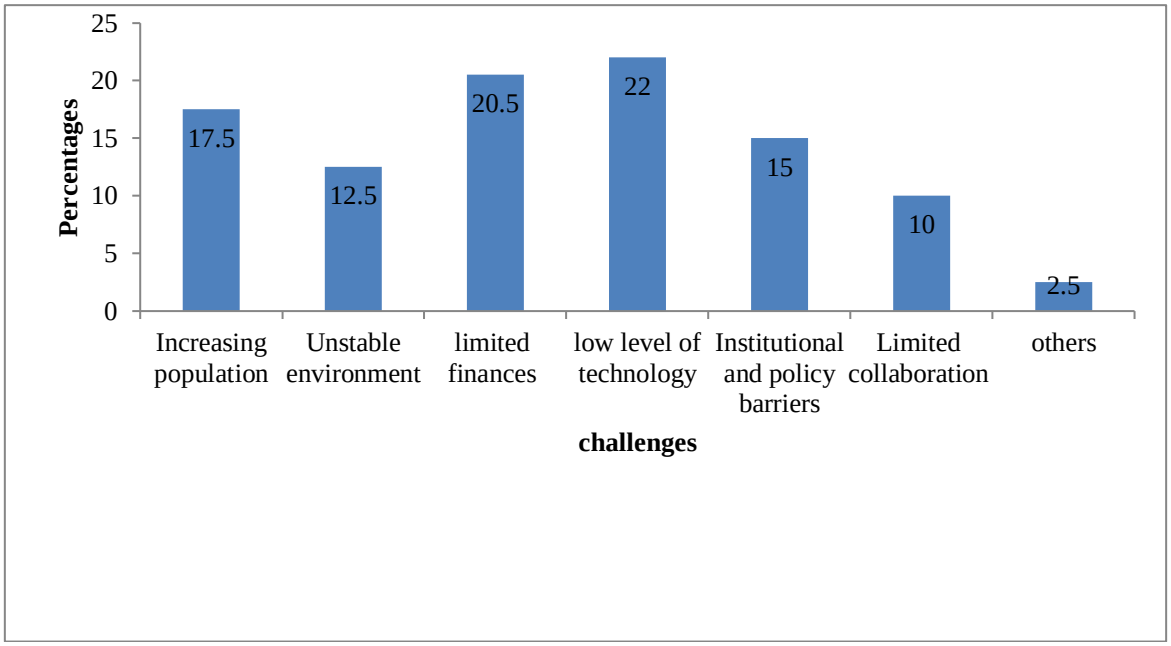

Fig. 4: Factors hindering the success of adaptation measures to physical constraints on mount Cameroon
Source: Fieldwork (2023)

From Figure 4, a majority (22%) of the population confirmed that their main challenge is low level of technology, 20.5% complained of limited finances and 17.5% pointed at the rapid increasing population in the area. Furthermore, 15% of the population said that institutional and policy barriers remain another challenge while 12.5% claimed of the unstable nature of the environment which is characterized by frequent mass movements and others. 10% revealed that there is the lack of collaboration amongst the community dwellers while 2.5% said that there is the issue of public perceptions to hazards and short term focus.

VI. DISCUSSION OF FINDINGS

The eastern slope of the mount Cameroon is endowed with varieties of cherished resources and these have attracted the human population who seek to satisfy their needfulness. Although the area is rough, it is characterized by favorable temperature which attracts human habitation coupled with its rich volcanic soils that form the basis of lucrative agricultural activities. These findings tight to that of Kometa, (2015) who in assessing the implications of wetland utilization on environmental degradation on this very site noted that it was covered with extensive layer of

rich fertile soil for agricultural activities and as well as congenial climate conditions favorable for bio-diversity survivals.

The surge population inhabiting this slope has been grappling with many physical challenges instigated by both anthropogenic and natural factors. The clearing of forest for agricultural activities by man has rendered the slope void of vegetation thereby exposing it to many forces of denudation such as landslide and soil erosion. On the other side, the eastern slope in its natural state is characterized by deep valleys and steep slopes which make human survival unsustainable. These findings are consistence with that of Balgah et al., (2017) who in assessing the implications of land cover changes on development in the Tubah Subdivision, noted that the uncontrolled exploitation of the environment resulted to negative externalities such as land deformation and abject deforestation. In the same light, Lambi et al., (2017) in evaluating the water resources on this eastern slope noted that the presence of steep slopes have influenced the spatial flow pattern of water with those at the edge of the slope having more sustainable water sources as compared to those located at higher attitudes.

There have been elaborated manifestations of these physical challenges on man's activities across this slope over decades. As earlier mentioned, the complex terrain on this site has instigated the occurrence of seasonal flood during period of torrential rainfall while rock fall and landslide has gradually become the new normal in the area. Diurnal temperatures have been elevating due the exaggerated human activities such as poor farming and misplaced settlements around wetlands and thus, affecting the whole population inhabiting this slope. There have also been soil erosion and land degradation affecting farmers and other anthropogenic activities. This finding is similar to that of Nkemasong et al., (2023) on the frequency of flooding and landslide on the same slope.

The common local adaptation measures include; the construction of embankments, resilience house as well as the planting of tree. Although these measures have not actually been successful, they have however weakened the increase in the occurrence of these constraints as well as their destructive capacity. Even though landslide and soil erosion still occur in many areas on this slope, their magnitudes have limits due to these adaptation measures. Embankments or retaining walls to hold slopes in place are common in Campen streets, Buea town, Bukwango, Bokwai and Soppo which are located on high elevations. The findings on forest planting and the construction of embankments as measures to control physical constraints tight with that of Mazurek (2021) who stated that by planting plant trees, shrubs and grasses along the edges of fields and river banks, farmers and households will be able to solve to some extent erosion and sedimentation problems whereas flood and landslide can be controlled with robot embankments.

With regards to the fact that the eastern slope of the Mount Cameroon is a mobile zone coupled with the low level of technology, most of the adaptation measures have been short-lived. Some are just applicable for some period of time while some been difficult. For instance, the concentration of population on this slope has made difficult to carry sustainable practices such as afforestation to control slope stability. There is also a very low level of technology to carry raise robot or resilience housing structures around wetlands and river banks. These findings are consistence with those of Balgah et al., (2017), Nkemansong et al., (2023), and Nchangri (2020) who in working on the implication of land use on Mount Cameroon and unprecedented floods along the coastline of Cameroon, noted that most adaptation challenges circles around high population concentrations, low level of technology and increasing nature of natural disasters. The Buea council of recent has been clearing road blockage after mass movements but long lasting solution like mapping floods and mass movement prone zones as well as sensitization is still very minimal to contain their occurrence.

VII. CONCLUSION

The eastern slope of Mount Cameroon has over the year been a site of population concentration because of its potentials. People are involved into different activities on this slope and amongst which are settlement, farming and exploiting activities. There area has been characterized by seismic activities subjecting it to many physical issues such as landslide, soil erosion, steep slopes and climate variability. The occurrence of these physical challenges has instigated many challenges on the population that execute activities across this slope. As such, because of its values that have sustained a greater proportion of this population over the years, majority of them have engaged themselves into many adaptation measures to cope with the challenges. Some of these adaptation measures are the construction of embankments, planting of forest, clearing gutters and the construction of resilience infrastructures. Because of the low level of technology, population expansion and the magnitudes of the physical challenges, most of the adaptation measures have failed and many people have been highly sensitive to repercussions of these physical challenges. However, in consideration of the fact that this site still offers perennial and inter-generational opportunities to most of its occupants, practical and sustainable measures must therefore be implemented in order to revamp the area to its natural states and to amplify the benefits that people derived from it. This therefore called for hazard prone zones mapping and constant sensitization through research works, television and radio programs.

VIII. RECOMMENDATIONS

In order to improve on the natural state of the eastern slope and for its endowments to regenerate as well as ensuring the security of the inhabitants of the area, the government should promote scientific researches which aim at implementing conservation activities in the area, a mastered plan of land use activities should be develop and financial assistance should be made available for the local council to executes some of its environmental conservation activities. The council should also monitor and controlled housing construction activities on this site as well as destroy some of the houses found in dangerous areas. The

population should avoid settling in risky environments, avoid deforestation and embraces afforestation. Furthermore, non-governmental organization should train people on environmental conservation and also assists the local council financially

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