

Research Article

Assessment of Potential Risks Related to Mass Movement Hazards along the Southern Escarpment of the Bamileke Plateau (West-Cameroon Highlands)

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Submitted: 2024, Mar 14; Accepted: 2024, Apr 16; Published: 2024, May

Citation: Ndonbou, R. M., Nkouathio, D. G., Dongmo, A. K., Tontsa, L., Tefogoum, G. Z., et al. (2024). Assessment of Potential Risks Related to Mass Movement Hazards along the Southern Escarpment of the Bamileke Plateau (West-Cameroon Highlands). *J Invest Bank Finance*, 2(1), 01-09.

Abstract

The South Escarpment of the Bamileke Plateaus (SEBP) is located on the CVL and is part of the WCH. It is subject to risks related to mass movements. This region has significant potential for agro-pastoral many activities. It is for this reason that the demographic explosion is important there. The population in place practices many activities and owns several assets. This is the essence of the vulnerability to mass movements in this region. This vulnerability is human and material. Assessing the risk of mass movement also requires an assessment of vulnerability. Field campaigns have made it possible to identify the various vulnerable sites. Falling rocks, landslides and subsidence are the main mass movements in the region. The mass movement density map and probable area map highlight these mass movements. By questioning the populations and using the documents, we estimated the losses. The population is estimated at around 195.181 inhabitants. The estimated loss of agro-pastoral activities is 62.251.150 FCFA or 115.455.96 USD. The SEBP is covered by approximately 279.0335 km of road. It is full of many homes and public buildings. The estimated loss of buildings and properties amounts to 2778509.700 FCFA or 5151001.33 USD. By questioning the populations and using the documents, we estimated the losses. The population is estimated at around 195,181 inhabitants. The estimated loss of agro-pastoral activities is 62.251.150 FCFA or 115.455.96 USD. The SEBP is covered by approximately 279.0335 km of road. It is full of many homes and public buildings. The estimated loss of buildings and properties amounts to 2778509.700 FCFA or 5151001.33 USD. By questioning the populations and using the documents, we estimated the losses. The population is estimated at around 195,181 inhabitants. The estimated loss of agro-pastoral activities is 62.251.150 FCFA or 115.455.96 USD. The SEBP is covered by approximately 279.0335 km of road. It is full of many homes and public buildings. The estimated loss of buildings and properties amounts to 2778509.700 FCFA or 5151001.33 USD.

Keywords: Vulnerability, Mass Movements, Southern Escarpment of the Bamileke Plateau, Agro-Pastoral Activities

1. Introduction

The Cameroon Volcanic Line (CVL) is the seat of many natural hazards with which several risks are associated. It faces the most hazards of volcanic origin and mass movements [1-7]. Mass movements are among the most frequent natural risks, and cause the most damages, both human and material, and even environmental [4,6]. The southern continental portion of the CVL is dominated by the Western Cameroon Highlands (WCH). The WCH form a geomorphological entity located between 5-7°N and 9-11°E comprising a set of plateaus interspersed in places with two plains in particular, Mbo and Ndop). It is the area most threatened by mass movements in Cameroon [2]. In addition to landslides, which constitute the major hazard with around 25% occurrence, it also faces collapses, falling rock

and mudslides. For example landslides and falling rock in the locality of Bamenda [8]. The Fossong-Wentcheng landslide in August 1978 which caused 6 deaths; from Nkongsamba to 1998 and Melong in 1978, of Ngouaché in October 2019 which killed 43 people; Subsidences and collapses in the locality of Njintout in Fouban in September 2018 [1,9,10]. The HTOCs include the Southern Escarpment of the Bamileke Plateaus (SEBP) which is located between 5°19'58.8"-5°5'16.8"N and 9°57'43.2"-10°18'10.8"E. It is located between the Bamenda and Manengouba mountains and is characterized by mountainous regions and volcanic massifs bordered by formations of granitoids, gneiss and amphibolites. It is covered by basaltic, mylonitic, granitic and gneissic formations [11]. The soils in the localities are ferralitic, humus and hydromorphic. This area

is home to several localities vulnerable to mass movements including Santchou, Kekem and Bafang. It covers a total area of approximately 1030 km². The climate in the area varies according to the localities. In Santchou, it is of the Cameroonian type while in Kekem and Bafang, it is of the tropical type. This climate is characterized by the alternation of a dry season and a rainy season. The average temperature is 22.6°C with 197.03 mm of rain per year. The hydrographic network is of the sub-dendritic type and is oriented towards the SW. These geological and geographical factors have contributed for several decades to the occurrence of mass movements including landslides, falling rock and subsidence [7]. Despite the presence of these hazards, this locality attracts and shelters a large active population

because of its strong agro-pastoral potential. This population as well as their property and their activities are exposed to the multiple risks that prevail in the region. The evaluation of these potential risks associated with mass movements in the SEBP has not been the subject of previous study. It is for this reason that the present study aims to conduct an assessment of the risks associated with movements in this locality. It will provide an overview of the human and material losses incurred in the event of mass movements. Knowing the stakes, serious risk management can be considered in order to preserve people and their environment. This study could also be applied in several other regions threatened by any natural risk.

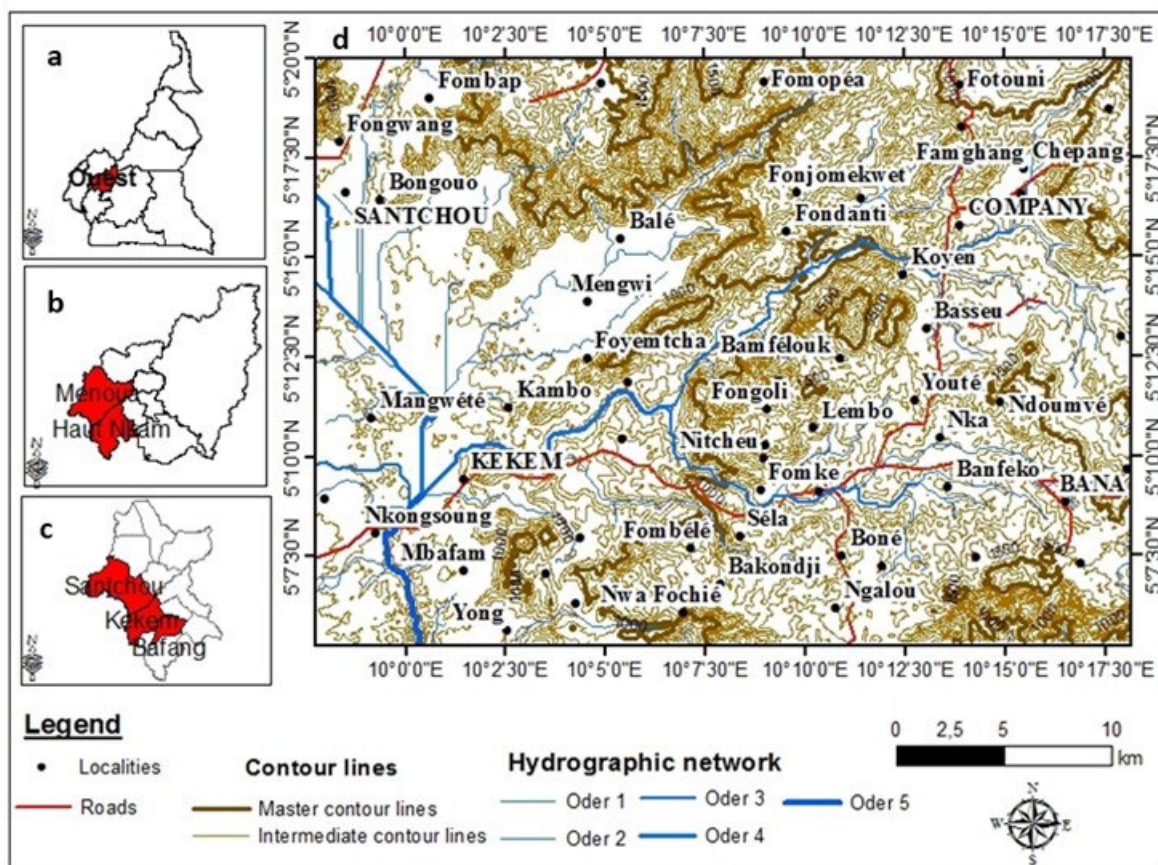


Figure. 1: Location map of SEBP a) Cameroon b) Western Region c) Localities in the SEBP d) SEBP

2. Methodology

To assess the risks associated with mass movements in the SEBP we have adopted a working method that includes alternating field work and laboratory work.

• Field Work

Three field visits provided important information for assessing the risks associated with mass movements in the study area. A census of the areas having undergone mass movements or likely to undergo them has been made. Subsequently, an inventory of the various vulnerabilities was made. The location of these sites through geographic data was made using GPS. This was at times possible thanks to several interviews with the population. However, to estimate the population that increases the degree of risk in these environments, the number of localities covering the

study area was counted. An estimate of income related to agro-pastoral activity was made using interviews with some farmers, neighborhood chiefs, village chiefs,

• Laboratory Work

The laboratory work made it possible to determine certain data of the various vulnerabilities; but above all to produce ESPB vulnerability and risk maps. This was made possible through the use of several mapping tools and software. The exploitation of satellite images made it possible to find other vulnerable sites in order to complete the field data on this aspect. Subsequently, the geographical coordinates of each site vulnerable to a given type of mass movement were plotted on a map in the ArcGIS software and this operation allowed us to have a mass movement density map. Road constructions and mileage have been

identified in the software ArcGIS on the aerial map extracted in Google Earth 2015. Documentary analysis also allowed us to complete the information obtained in the field. The exploitation of the Communal Development Plan (CDP) of each locality allowed us to have an estimate on the number of inhabitants of the said localities. We also consulted the reports of the ACEFA projects (Improving the Competitiveness of Agro-pastoral Family Farms) of certain localities to have an overview of the financial income of each sector of agro-pastoral activities. A map of the potential risks associated with mass movements in the SEBP was produced following the superposition of the map of vulnerabilities and that of the susceptibility of mass movements.

3. Results

The study of vulnerability has made it possible to evoke two important types: human and material. Before studying this vulnerability, it is good to have an idea of the vulnerable sites and the probable zones. The density map of mass movements on the SEBP highlights all of these vulnerable sites. The legend used shows us the sites dominated by landslides, falling rock and subsidence. The susceptibility map (Fig.3) highlights the different probable zones of the next mass movements. On these maps, landslides are located on slopes and along roads. The subsidence's are in areas that are not necessarily at high altitude, and the falling rock on some slopes contain large blocks of suspended rock.

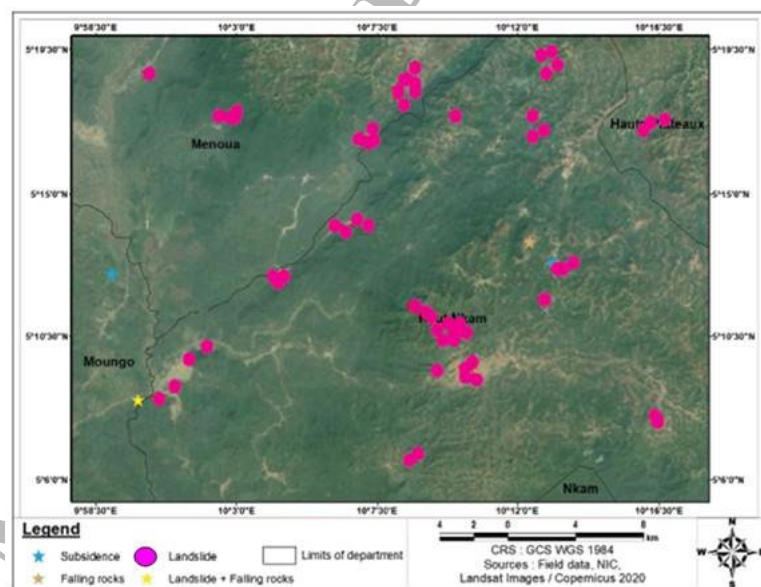


Figure 2: Mass Movement Density Map of the SEBP (extracted from Google Earth)

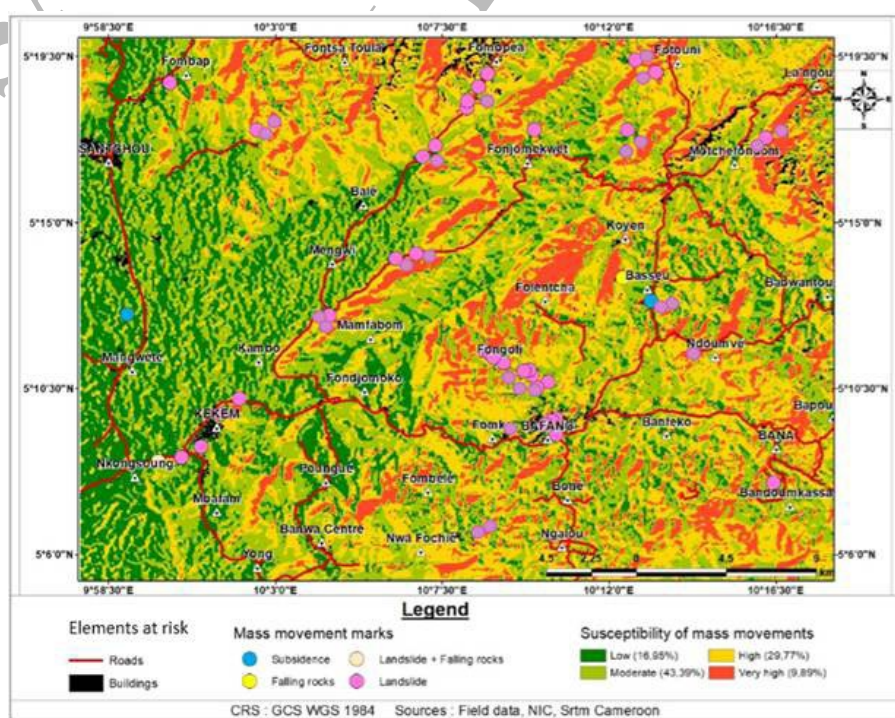


Figure 3: Mass Movement Susceptibility Map with Vulnerable Sites of the SEBP

3.1. Human Vulnerability

The SEBP has enormous potential for agro-pastoral activities, which makes it a real zone of hatching and blooming of the populations which are for the majority autochthonous. This population is mainly made up of Mbo and Bamileke who are

more represented in Santchou and Kekem. The Bamileke are the most common ethnic group in the region. These populations constitute the main vulnerability in the study area. Figure 4 is the population distribution histogram.

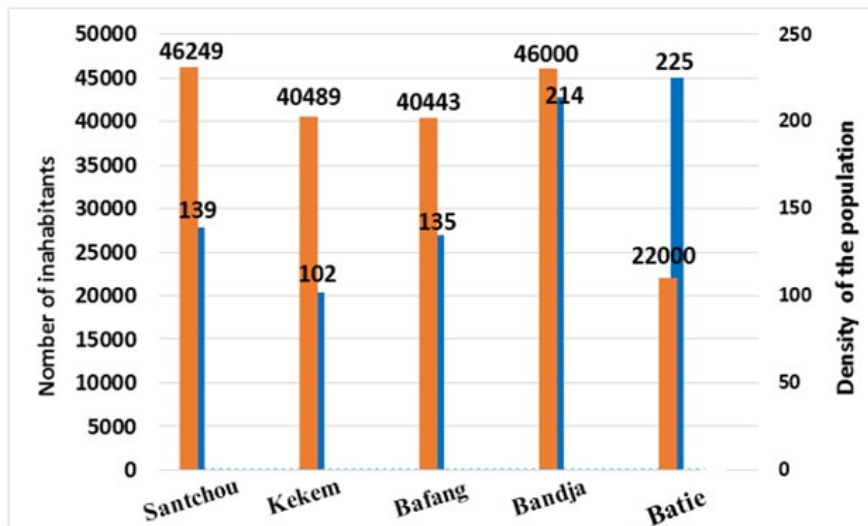


Figure 4: Histogram of Population Distribution in the Study Area

About 195.181 people are exposed to mass movements in the study area. Santchou is the most populated locality with 46.249 inhabitants or 139 inhabitants per km² while Batie is the least populated locality with 22.000 inhabitants or 225 inhabitants per km². Apart from Batie, the number of inhabitants in the localities is estimated at more than 40.000 inhabitants.

3.2. Hardware Vulnerability

Material vulnerability, on the other hand, represents all of the human heritage (plantations, constructions) which could also be affected by a potential mass movement. It should be remembered that the main activity of the populations in this study area remains agriculture, fishing and animal husbandry.

■ Agropastoral Activity

The local economy in the study area is dominated by the practice of primary sector activities (agriculture, fishing and livestock). Agricultural activity is sufficiently important in the different localities of the study area. 90% of the populations of Santchou, Kekem and Bafang practice agriculture. The land cover map (Fig. 2) shows that 9255.33 hectares make up agricultural land, ie 8.99% of the total area of the study area. Most agricultural land is located in high and moderate risk areas. Few lands are located in very high risk areas and very little in low risk areas.

It is based on the cultivation of coffee, cocoa and palm oil which, moreover, constitute the dominant enterprise and the main source of income in the localities. To these are added the crops of bananas, plantains, maize, peppers, beans, tubers (cassava, potatoes, macabos and yams), fruits (pineapples, plums, papayas and mangoes). The production of cereals and market gardening is less important in certain localities (Santchou). Some products (oil palm, cassava) are processed on site before being marketed, while others (coffee and cocoa) are directly exported abroad. On the other hand, the crops of bananas, plantains and macabos are directly sold in the local markets by the populations.

Animal husbandry boils down to raising poultry, pigs and small ruminants for marketing and also for self-consumption by the populations. The populations of Bafang are the most affected by this activity.

Fishing is practiced in the localities of Santchou and Kekem respectively in the Menoua, Black Water and Nkam rivers. This is angling. In Bafang on the other hand, the fishing activity is almost non-existent because the populations are very little interested in it due to the poverty of the existing waterways in terms of fish species.

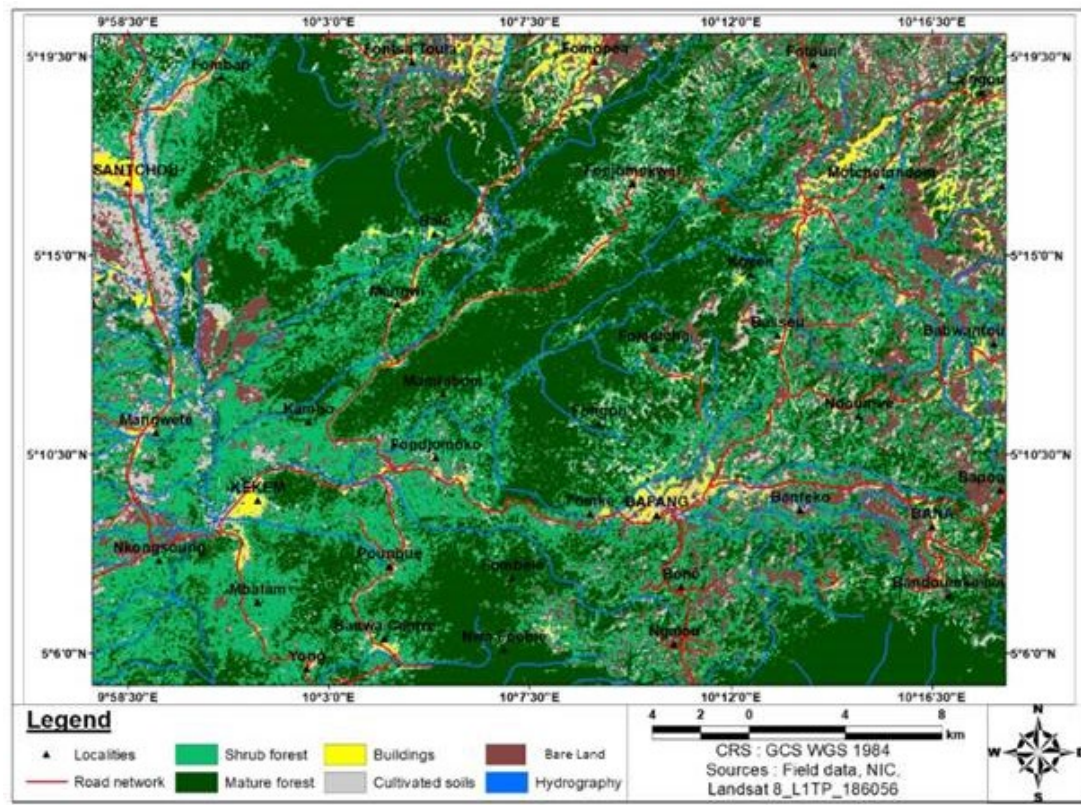


Figure 5: Land Use Map of the SEBP Below Illustrates Some Aspects of Agro-pastoral Activity in the Region



Figure 6: Some Products of Agro-Pastoral Activities in the Study Area

Thanks to the information obtained from the indigenous populations (planters, cultivators and breeders), village and district chiefs, directors of agricultural cooperatives, traders, by exploiting the CDPs of certain localities, as well as certain documents obtained Ministry of Agriculture and Rural Development (MARD) more specifically at the technical unit of Haut-Nkam of the Consolidation and Sustainability Program of the Agro-pastoral Council (PCP-CSPAC), we estimated the

income from agro-pastoral activity in the study zone. These revenues have been carefully compiled in Table 2 below. These are the potential losses of the various sectors of activity.

According to Table 1, the total income from agro-pastoral activities in the localities of the study area is estimated at 62.251.150 FCFA or 115.455.96 USD.

Sectors	Products	Income (FCFA)
Agriculture	Cocoa trees	456.900
	coffee trees	173.100
	But	656.100
	Sugar cane	155.000
	Bananas - plantains	1500.000
	Palm oil	385.300
	Plums	800.000
Breeding	Pork meat and piglets	821.150
	Local hens	77.600
sin	Pisces	1200.000
---	Estimated total income from agro-pastoral activity in the study area	62.251.150

Table 1: Income from Agro-Pastoral Activities

■ The Constructions

In addition to the vulnerability linked to agro-pastoral activity, there is also that linked to construction. These are public infrastructures and family homes located in high-risk areas. In the localities of the study area, there is a strong urbanization. The land cover map shows that the dwellings occupy 23.8329 Km² or 2.31% of the total area of the study area. There are houses built of temporary materials and durable materials. It should be noted that in the majority of neighborhoods, houses are built of durable materials. However, some planter camps are built with temporary materials. The foundations of the houses in the locality of Santchou are built of stuffed concrete blocks while those of the localities of Kekem and Bafang are built of rock materials. Administrative and public buildings are constructed

of durable materials and well plastered.

The SEBP is crossed by paved roads (National N°5, Provincial N°19) to which are added the unpaved roads that run through the districts. A fairly developed electrical and telephone network crosses the said localities. The estimated loss of buildings and properties amounts to 2778509.700FCFA or \$5.151.001.33 in high and very high risk areas. The total length of roads in the region amounts to 279.0335 km. Many roads are located in high and very high risk areas.

Figure 7 illustrates cases of constructions located near niches and Table 2 provides a brief overview of important constructions vulnerable to mass movement throughout the study area.



Figure 7: Sliding Niche Near the Constructions: A) Fomoepa B) Bafang

No.	Buildings	No.	Buildings
1	CAPLAME by Santchou	9	Urban municipality of Kekem
2	Santchou telephone antenna	10	Saint Francis Xavier Parish of Kekem
3	National N° 5	11	Kindergarten of Djimbong I
4	Municipal slaughter house of Kekem	12	Public School of Djimbong I
5	CAM Water	13	EEC Church of Djibouti I
6	Saint Francis Xavier Mayan Bilingual College of Kekem	14	Technical, Industrial and Paramedical College of Kekem
7	Saint Francis Xavier Primary School of Kekem	15	Saint Francis Xavier Primary School of Kekem
8	Saint Francis Xavier Catholic Hospital of Kekem	16	Saint Francis Xavier Parish of Kekem

Table 2: List of Some Important Xonstructions Located in Areas at Risk and Which are Home to Many Populations

4. Discussion

SEBP is an area with high population potential. These populations live there and are attracted by the many potentialities offered by this region. These populations carry out many agro-pastoral and commercial activities. This situation is observed on the volcanoes of the LVC in particular, Mount Manenguba, Bambouto and Bamenda where the fertility of the soil gives rise to areas suitable for diversified agriculture, and areas covered with a grassy meadow, favorable to the activity. Pastoral [6]. This region is subject to many instabilities related to landslides, falling rock and subsidence. The growing anthropic occupation of this locality increases the vulnerability at the same time. The latter is controlled by the presence of man. Because beyond human vulnerability, which includes men, women and children of all ages, there are two other types of vulnerability directly regulated by human activities. This is material vulnerability which includes (1) houses built of hard and temporary materials preferably close to areas of agricultural activities which are mostly exposed to hazards. This is linked to the unbridled conquest of green spaces conducive to their activities. This is often the source of conflicts between farmers and herders in the calderas of the Bambouto Mountains [5]. (2) Cattle and fields are linked to agro-pastoral activities and constitute one of the major economic sources of the population. These vulnerabilities, mainly developed in areas prey to mass movement, increase the degree of risk in these regions [1]. Significant material and human damage is thus noted in the regions neighboring the SEBP. For example, the landslide in Limbé in 2001 caused 24 deaths, destroyed 120 houses and left more than 2800 people homeless; that of Mag'haa on July 20, 2003 killed 20 people and killed several cattle; destroyed 120 houses and left more than 2,800 people homeless; that of Mag'haa on July 20, 2003 killed 20 people and killed several cattle; destroyed 120 houses and left more than 2,800 people homeless; that of Mag'haa on July 20, 2003 killed 20 people and killed several cattle [5,12,13].

The Tchouaffé landslide by Kekem on Saturday October 20, 2007 causing loss of human life and destroying the Bafoussam-Douala axis [14]. That of Gouaché in the 3rd Arrondissement of Bafoussam which occurred on the night of Monday October 28, 2019 taking stock of approximately 43 dead men, 11 injured with more than 15 houses destroyed with more than

150 homeless. That of Fompea on the night of Friday July 12 to Saturday July 13, 2019 in the Yantou district, causing 3 deaths and extensive material damage [15, 16]. Assessing the risk of mass movement in a given locality also requires assessing vulnerability. As part of this study, a quantitative and qualitative assessment of the risks associated with mass movements in the region was made. In the study area, houses, roads, plantations are truly exposed to mass movements. This exposure is quite simply linked to the fact that the populations are looking for new exploitable surfaces for their multiple activities, and thus find themselves exploiting the steep and unstable slopes to settle there. In several other similar areas at risk of mass movement, the causes of exposure to risk are virtually all similar [3,4,6]. This vulnerability is linked to people, their activities and their assets. Human vulnerability is quite significant in the region because the populations there practice a lot of agricultural and pastoral activities. It is estimated at 195.181 inhabitants with a density of 815 inhabitants per km². In the Bamenda Mountains, there is a population estimated at more than 50,000 inhabitants against 3.000 in the caldera [3]. This population is less important in the Caldera of Mounts Bambouto (4000 inhabitants) and Manengouba (700 inhabitants). In the locality of Djoundé and its surroundings (Far North Cameroon) the populations practice many activities and live in areas at risk of mass movements. This population is made up of men (74), women (101) and children (665) exposed in one way or another to the risk [4].

On the other hand, in the caldera of Lefo, human vulnerability is less important because it is estimated at only 60 inhabitants [6]. In general, the population explosion in a region is not often linked to a trivial fact. This explosion can be linked either to the fertility of the soil in the region or to its geographical position. People are attracted by a factor that is beneficial to them. On the SEBP, populations are most concentrated in areas with high potential for agro-pastoral and commercial activities. This is clearly observed in Table 1. Material vulnerability highlights the balance sheet on people's assets. These are agro-pastoral activities and constructions. The estimated loss related to the agro-pastoral activities carried out by these populations is 62.251.150 FCFA or 115.455.96 USD. This loss is also very significant in the Caldeiras of the Bambouto Mountains (348.000.000 Fr), Manengouba (35.000.000 Fr) and Bamenda

(30.000.000 Fr) especially with regard to crops. This difference may be due to the fertility of the soils in these calderas. Indeed, soils developed on volcanic rocks are more fertile than soils developed on plutonic and metamorphic rocks. In the caldera of Lefo, there is an estimated loss of 140.000.000 FCFA with regard to livestock activities [6]. In the locality of Djoundé and its surroundings (Far North-Cameroon), 08 plantations can be destroyed in the event of a disaster [4]. The SEBP is traversed by a network of approximately 279.0335 km of road. In addition, the estimated loss to constructions amounts to 2778509.700 FCFA i.e. 5151001.33 USD. In the caldera of Lefo the estimated loss of housing amounts to 100.000.000 FCFA. Mass movements are among the major risks that cause the most damage to the surface of the continents. Losses vary from region to region. This variation is a function of the human, material and even animal potential of the region. In case of disaster, loss of human life can be recorded, hectares of plantations can be damaged, road networks can be interrupted, thus causing a huge brake on traffic, animals can be destroyed [2,4,6]. All these losses are increasingly galvanizing decision makers to take significant risk reduction measures in localities constantly threatened by mass movements.

5. Conclusion

Assessing mass movement risk also involves assessing vulnerability. This assessment is crucial when it comes to fighting mass movements. This is why it goes through a quantitative and qualitative risk assessment. On the SEBP, the vulnerability is human and material. Human vulnerability reports an estimated population of more than 195.181 inhabitants with a density of 815 inhabitants per km². Material vulnerability includes agro-pastoral activities and constructions. The populations practice agriculture and animal husbandry. The estimated loss is to 62.251.150 FCFA or 115.455.96 USD. Concerning constructions, the SEBP is crossed by paved axes (National N°5, Provincial N°19) to which are added the unpaved roads which run through the districts. The total length of roads in the region amounts to 279.0335 km. There are also many public buildings. The estimated loss for the constructions amounts to 2778509.700FCFA i.e. 5151001.33 USD. To reduce or avoid material and human losses on the SEBP, the following recommendations are proposed:

- Sensitize and educate the populations on the existence of the risk of mass movement;
- Avoid building in high-risk areas;
- Plant trees like eucalyptus that have sunk deep into the ground;
- Avoid frequenting unstable areas during periods of heavy rainfall;

Avoid abusive deforestation.

In addition, this study can be extended to other localities prone to the risk of mass movements in Cameroon and in the world. Nevertheless, it will contribute to reducing the loss of human life and the material loss caused during mass movements [17-25].

Acknowledgements

The authors thank Dr. Zangmo Tofogoum Ghislain Department of Earth Sciences, Faculty of Science, and University of Maroua Cameroon for reviewing and improving the quality of the

manuscript before submission.

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