IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 8, Issue 2 Ser. III (Mar – Apr 2020), PP 01-11
www.iosrjournals.org

Assessment of risk related to mass movement in Djoundé locality and vicinity (Far North-Cameroon)

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Abstract: *The Djoundé locality and vicinity (DV) is located in the Maroua II Subdivision, Far North Region (Cameroon). The conquest of green spaces and the natural resources attracted a significant population that continue to migrate and settle although the occurrence of Mass movement hazards (rock and debris falls) in the DV. This paper highlights the assessment of risks related to mass movements hazards in the DV. To that end, important bibliographic research has been done and several laboratory and field studies have been carried out. This allows to make an inventory of the vulnerabilities in the study area. The main vulnerabilities are from human, animal and material origins. The assessment shows that the human vulnerability includes the population that is made up of Men (74), Women (101) and children (665). The animal vulnerability comprises the cattle that are constituted of sheep (200), goats (350) and domestic fouls (300). The material vulnerability includes houses and equipment, farms, cars, motorbikes, bicycles and etc… In this paper, the vulnerability and risk maps of the DV are proposed. The assessment of the risks associated to the Rocks and Debris falls indicated that people and cattle, nearly 251 houses and 08 plantations can be destroyed. In case of the major hazards, the financial losses could be estimated at about 309,920,000 XAF (472,469.994 Euros). The level of risk can increase because of the weight of the history of the Islamic colonization and the poverty of the inhabitants of the DV. In order to reduce the risks, recommendations have been suggested among which, the sensitization of the population in relation to mass movements hazards, the prohibition of construction on steep slopes and the implementation of the sustainable land use policy.*

Keywords: *Vulnerability, risks, mass movements, Djoundé.*

Date of Submission: 13-04-2020 Date of Acceptance: 28-04-2020

I. Introduction

The history of planet Earth reports several natural phenomena (volcanic eruptions, earthquakes, tsunamis, floods, and mass movements) that have caused extensive damage to humans and their heritage[1]. In Cameroon, several natural phenomena such as harmful gas emanations at lakes Monoun (1984) and Nyos (1986), the recent volcanic eruptions of Mount Cameroon (1999 and 2000). The mass movements hazards on the West-Cameroon Highlands precisely in the Bambouto caldera[2,3], Kekem, Mag'haa, Limbé and Bafoussam[4,5,6,7,8].

To this end, it is noted that natural phenomena spread more throughout the national territory and especially in volcanic environments. The Far North region consists of highlands including mount Mandara and plains[9]. The department of Diamaré is made up of several councils among which Maroua II. The council of Maroua II is made up of localities such as Djoundé that constitutes the area of the present study. It covers an area of more than 7 km^2. This locality shelter one of the massifs which bear the name of Mount Djoundé which culminates at about 591 m. Mount Djoundé consists of the coalescent domes stretching in the South-North axis. These domes are bristling with many inselbergs and occupy an area of 1.15 Km^2. The latter lies between latitudes 10°38'15'' and 10° 38'45''N and longitudes 14°19'00'' and 14°20'30''E (Figure 1). The DV are animated by several phenomena including the rocks and debris falls which are accompanied by gully erosion. These phenomena were responsible of several damages on inhabitants (nearly 08 dead and one wounded) and their patrimony in March 1993, 2005 and December 2013 in the neighbouring locality (Laïndé). In 2017 on the DV, a rock fall caused the destruction of a house and the death of a dog[10]

According to Seignobos and Iyébi (2000)[11], the evolution of the city of Maroua is largely due to immigration. Indeed, with reference to the General Population and Housing Census (RGPH) of 2005, the population of the municipality of Maroua II is estimated at about 108,902 inhabitants in urban areas against 37.766 in rural areas. The economy of this community is based on two pillars (farming and lives tock) and related activities such as extraction of natural resources (rocks). The occupation of mountain slopes and the exploitation of these resources in order to obtain blocks of rock and gravel, led to the increase of the population in urban areas than in rural area. With a view to attracting the attention of competent authorities, this work aims at assessing the risks associated with mass movements in DV.

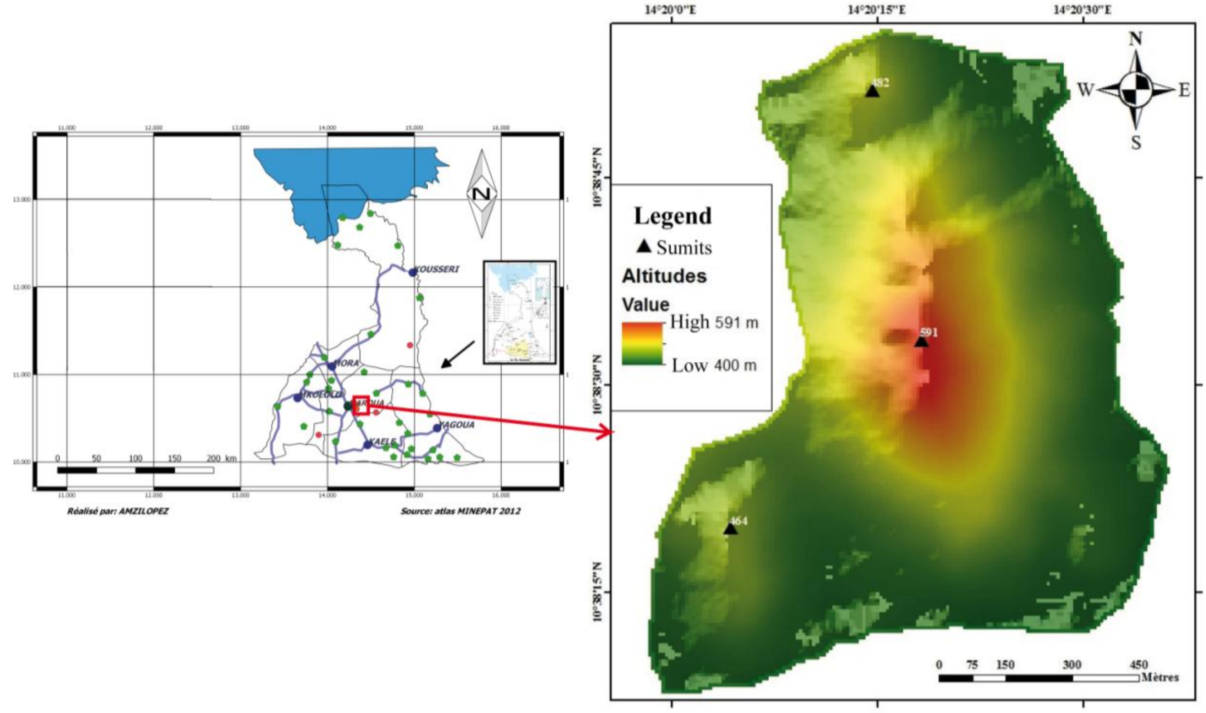

Figure 1: Location of the study area

II. Material and Methods of study

The study of various mass movements and associated risks was the subject of several phases of field and laboratory works.

Fields work

The fieldwork was carried out in several stages. The first stage was based on the inventory of most damaging mass movements. This step was done through the testimonies of local populations. The information provided was focused on the history of events in the study area. The second stage dealt with the identification of sites that are prone to potential mass movements. The third stage was focused on the study of vulnerabilities in order to get an idea of the stakes exposed to mass movements in the DV.

Laboratory work

In the course of the laboratory work, all maps were produced. Office Excel 2016 was used for the processing of digital data. Google Earth Pro for the vectorization of mass movement hazards, vulnerabilities and others parameters. These data were imported in ArcGIS 10.4.1 software for the production vulnerabilities maps. The combination of this map with the existing mass movements hazard map permitted to produce the risks map of the DV.

III. Results

Study of vulnerability in Djoundé locality and vicinities

In DV, the study of the vulnerability permitted to highlight three types notable: human, animal and material.

Human vulnerability

DV shelter a significant population that includes Men (74), Women (101) and children (665). The results are detailed in the table 1 according to the sites as well as the distribution and percentage diagrams. The information in the table 1 is presented in the form of strip diagrams. The diagram in the figure 2 illustrates the number of women, men and children identified per site and who are likely to suffer damage to the various hazards. Moreover, there are people (15 Men, 20 Women and 30 children) who are not established in the DV; but they just come between 6:00 to 9:00 am for a specific task at slaughterhouse.

Table 1: Number of children, men and women

Sites	*Children*	*Men*	*Women*
Slaughterhouse	30	15	20
Djoundé 1	400	35	55
Djoundé 2	235	24	26
Total	**665**	**74**	**101**

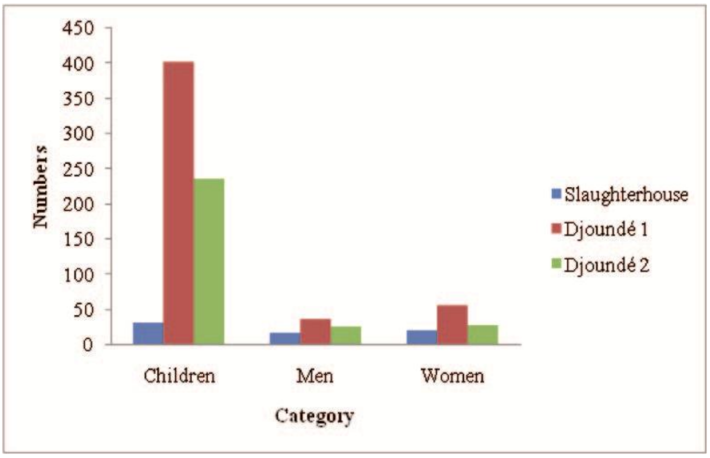

Figure 2: Histogram of the number of men, women and children surveyed

Animal vulnerability

The animal vulnerability is made up of cattle that are sheep (200), goats (350), and domestic fouls (300). Note that there are shepherds and their cattle from Kongola, Dougoï and many other localities that come to DV for grazing because of its important vegetation cover.

Material vulnerability

In DV, one can quote as vulnerability, the presence of a plethora of dwelling in beaten bricks earth and in breeze blocks which are built on the piedmont of the solid mass as well as on the mountain which carries rocky outcrop likely to all possible falls (Fig. 6a, b, c and d). However, road traffic to Kossewa via Gayak may also be affected. For this purpose, we have listed houses in bricks earth and those in breeze blocks. Moreover, besides the already built dwellings, we notice the presence of the foundations, those of clay represent a total of 19 and the foundation in breeze blocks gives a total of 22 (Fig. 6f). From these constructions we have those more exposed, less exposed homes and Poorly exposed to mass movements. The table 2 highlights the number and type of vulnerable habitations as well as the percentage chart.

Table 2: Distribution of the types of constructions identified

Sites	*More exposed homes*	*Less exposed homes*	*Poorly exposed homes*
Slaughterhouse	21	32	49
Djoundé 1	10	7	46
Djoundé 2	51	30	5
Total	**82**	**69**	**100**

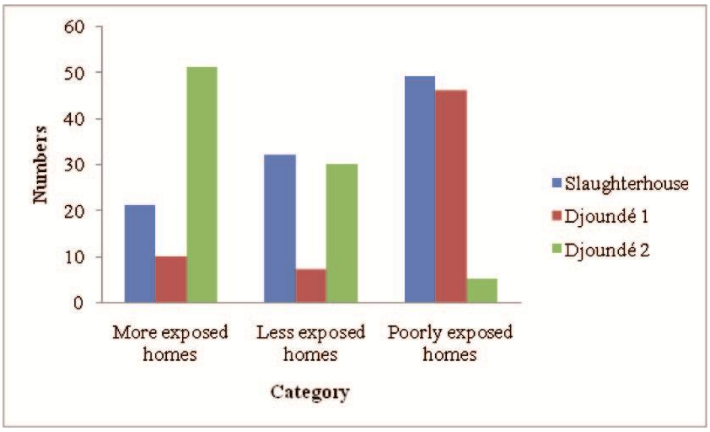

Figure 3: Histogram of distribution of homes of the most vulnerable to weak vulnerabilities

The figure 3 highlights the most vulnerable houses and those with low vulnerabilities. The degree of vulnerability is linked to the layout of the houses near the massif on the one hand and on the trajectory of the rocky outcrops on the massif on the other. It should also be noted that of all these constructions, the most vulnerable houses are those where the position of the building is lengthwise, parallel and located on the same extension as the massif. On the other hand, the least vulnerable are those located on the side of the massif in the width direction and perpendicular to the orientation of the massif (Fig. 6). Other material vulnerabilities relate to the furnishings (cars, tricycles, motorcycles, bicycles) likely to be damaged that were identified in the various houses during our field survey. The table 3 and figure 4 summarize the results of this study which was carried out by site.

Table 3: Movable means to register in the study area.

Sites	***Car***	***Tricycle***	***Motorbike***	***Bicycle***	***Any holder***
Slaughterhouse	6	30	5	70	0
Djoundé 1	0	0	47	20	4
Djoundé 3	7	0	30	30	0
Total	**13**	**30**	**82**	**120**	**4**

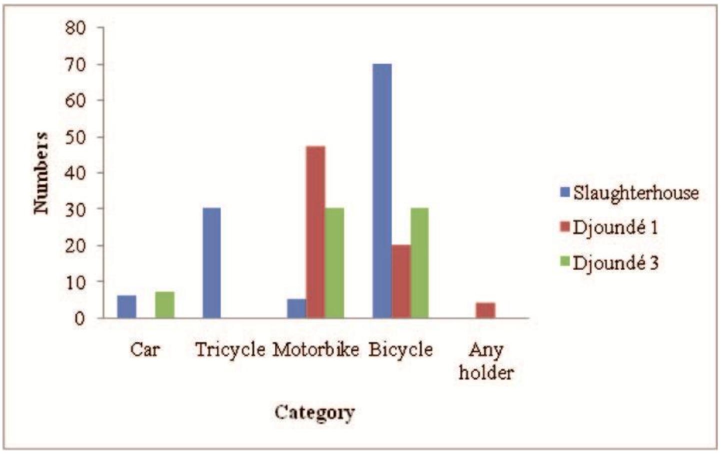

Figure 4: Histogram of the movable means by site of study

Figure 5 highlights the spatial distribution of the vulnerability in DV. Houses and farms dominate the southern area of the study area. The upper part of the Djoundé Mountain is not occupied by human activities because of its uneven topography.

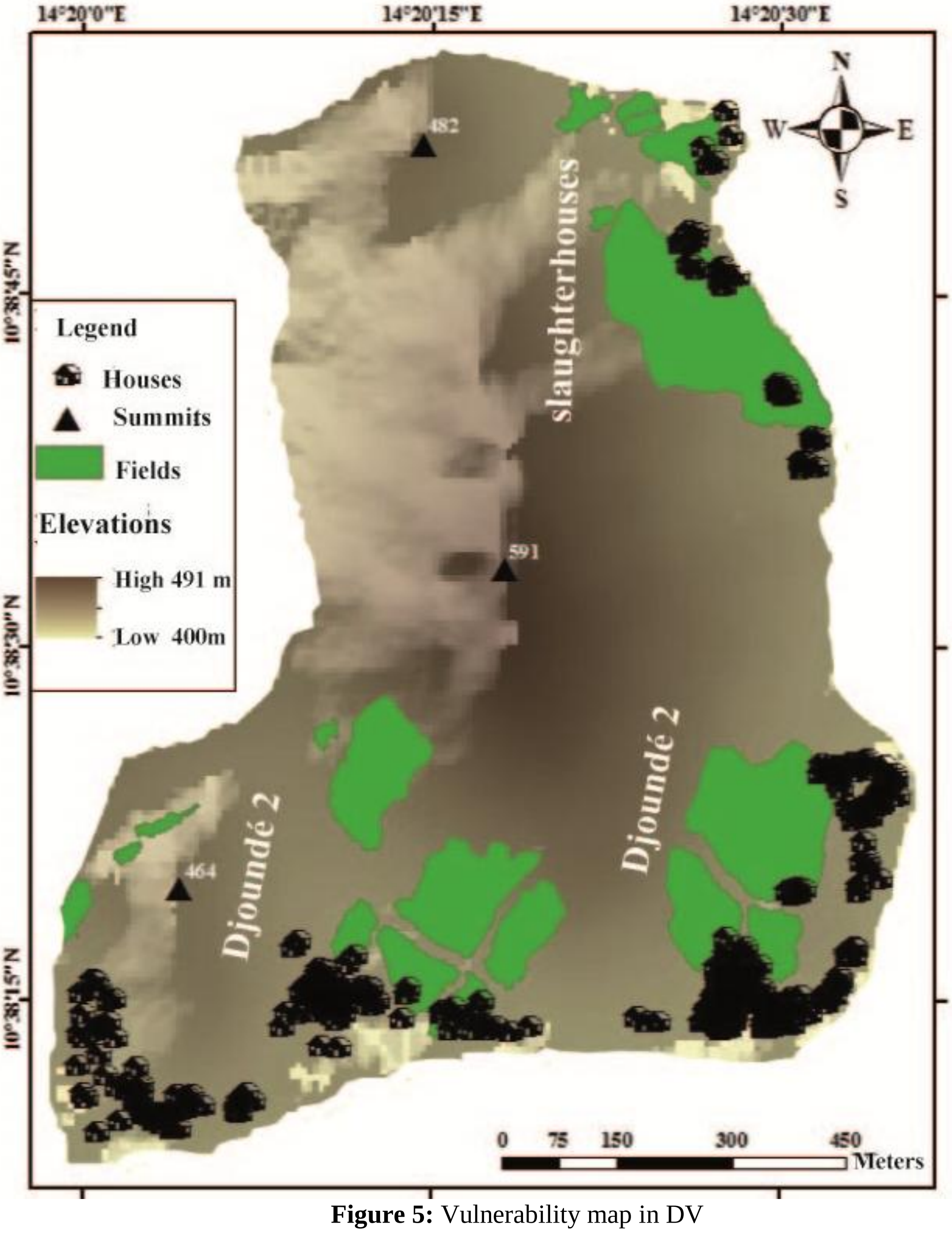

Figure 5: Vulnerability map in DV

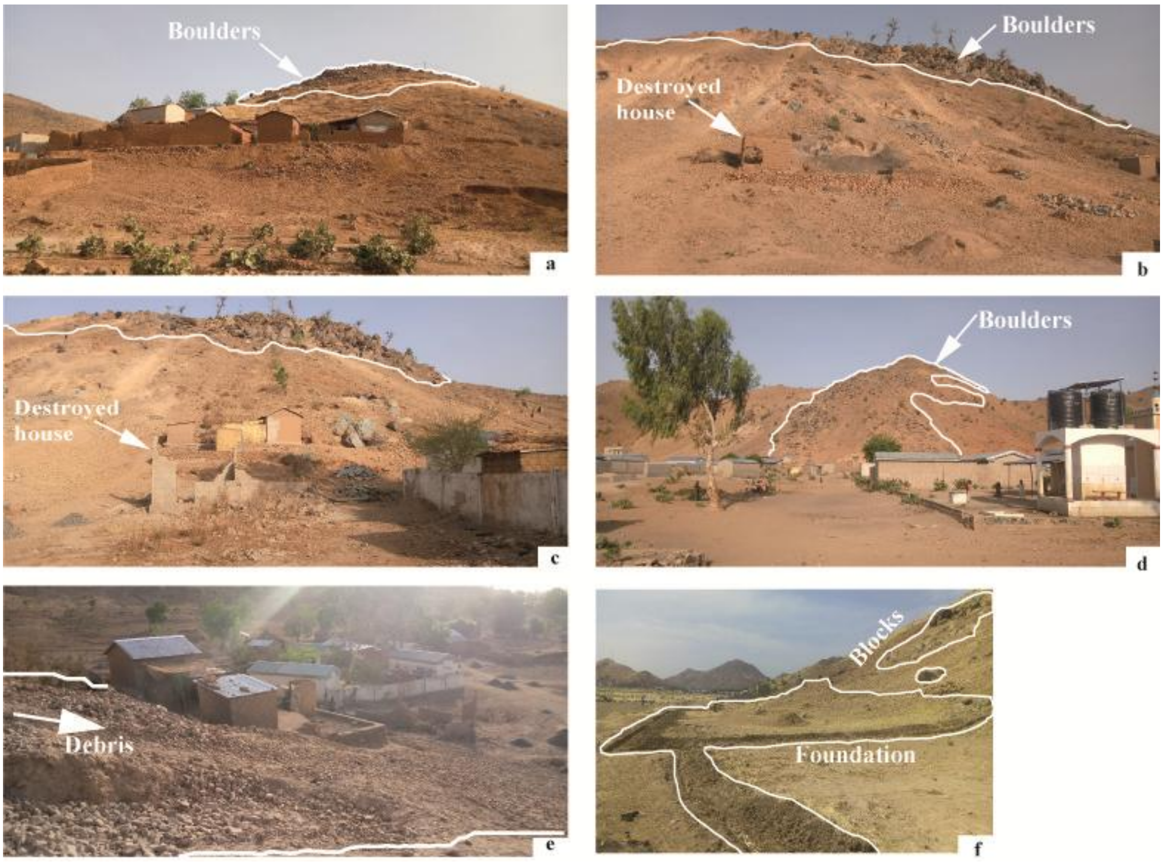

Figure 6: Pictures of different vulnerability in DV: **a, b, c** an **d)** houses exposed to rock fall; **e)** houses exposed to debris falls; **f)** foundations exposed to the rock fall.

Risk assessment of mass movements in DV

The assessment of risks provides an overview of the economic figures for the DV. It takes into account the annual income from agricultural and pastoral activities on the one hand, and the investment costs of the population on the other.

Risk on lives tock

As far as livestock is concerned, there are poultry and cattle. In the case of cattle, they are classified by category of sheep, goat, and cow. In the case of poultry, they are domestic birds such as hens, roosters (Table. 4).

Calculations were made according to the general formula:

C= V x v

-Number of head of cattle, sleep, goats and poultry (V)

-Average cost of a head of cattle, sheep, goat and poultry (v)

-Total cost of cattle, sheep, goats and poultry (C):

Table 4: Risk results on lives stock

Categories	*Number of Head (V)*	*Average cost of head (v) in XAF*	*Total cost (C) in XAF*
Cow	450	150,000	67,500 000
Sheep	200	25,000	5,000,000
Goats	350	15,000	5,250,000
Poultry	300	2,000	600,000
Total			**78,350,000**

Risk on farming

The production is divided into categories such as corn, peas, peanuts, beans and millet. The low number of bags of beans and peas is related to the nature of the soil which is not favourable to this type of production. The results are expressed in table 5 and figure 7.

Calculations were made according to the general formula:

C= M x n

-Number of bags of millet, beans, peanuts, peas, corn (M)
-Cost of a bag of millet, beans, peanuts, peas, corn (m)
-Total cost of bags of millet, beans, peanuts, peas, corn (C)

Table 5: Risk results on farming

Risk on the production of	*Number of bag (M)*	*Cost of a bag (m) in XAF*	*Cost of total (C) in XAF*
Mil	10	25,000	250,000
Bean	2	40,000	80,000
Peanuts	25	60,000	1,500,000
Peas	2	20,000	40,000
But	10	20, 000	200, 000
Total			**2,070,000**

The results show that the risks associated with mass movements with regard to agricultural production are high.

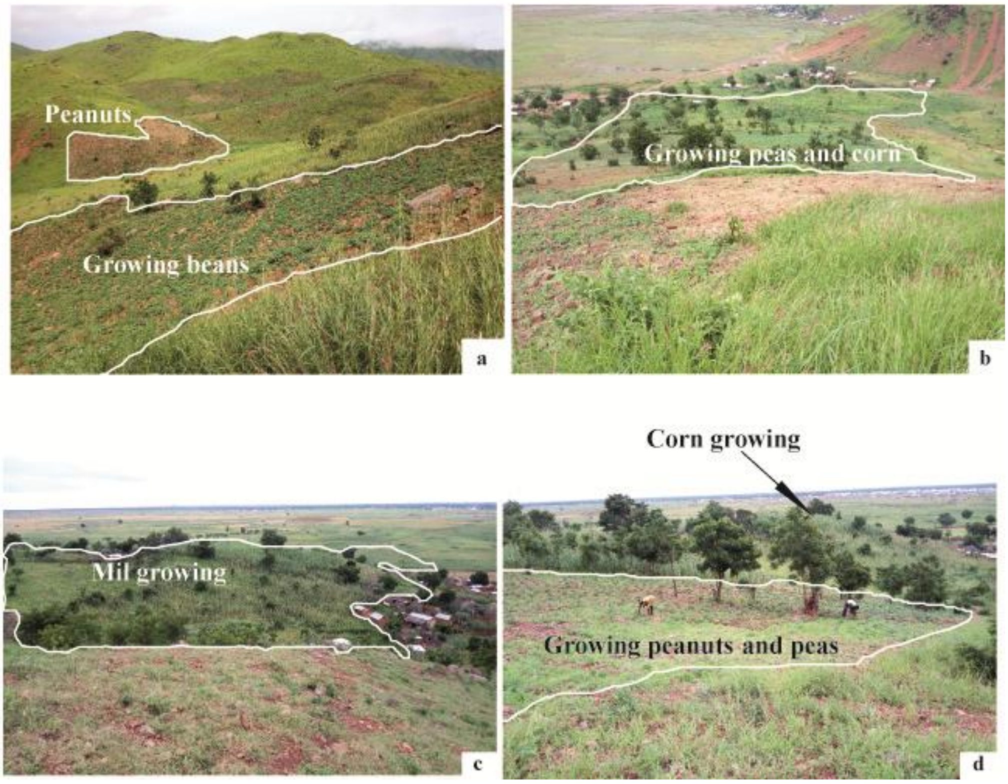

Figure 7: Pictures of growing in DV: a) peanuts and beans; b) Peas and corn; c) Mil and d) corn, peanuts and peas.

Risk on human investment

Clay houses throughout the study area

In this case, there are bedrooms and living room. The results are expressed in table 6.

Calculations were made according to the general formula:

C= B x b

With:

-Number of bedrooms and total living-room in clay (B)
-Cost of a room and total living room in clay (b)
- Total cost of bedroom and total living room in clay (C)

Table 6: Risk results on clay houses

Categories	*Total Number (B)*	*Average cost (b) in XAF*	*Total cost (C) in XAF*
Bedrooms	284	150, 000	42, 600,000
Room lounge	72	300, 000	21, 600,000
Total			**64,200,000**

These results show that the risks associated with mass movements in these clay houses are high.

Breeze-block houses throughout the study area

These houses are divided into bedrooms, living room and 2 to 3 bedrooms. The results are expressed in table 7.

Calculations were made according to the general formula:

CT= P x p

With:

-Number of rooms and rooms-total living room in block (P)

-Cost of a room and rooms-living room in block (p)

- Total cost of room and total living room in breeze block (CT)

Table 7: Risk results on blocked homes

Categories	*Total number (P)*	*average cost (p) in XAF*	*Total cost (C) in XAF*
bedrooms	229	200,000	45,800,000
Rooms-lounge	83	500,000	41, 500,000
≥ 2 bedrooms-living room	26	3, 000,000	78,000,000
Total			**165,300,000**

These results show that the risk associated with mass movement in the case of breeze-blocks houses is high. The risks map of the DV (Figure 8) shows that crops and dwellings on steep slopes are exposed. In addition, plantations and houses in an area with a high probability of mass movement are at high risk. On the other hand, houses and crops on slopes with a medium probability of mass movements are at medium risk. Houses that are not on a slope and/or in an area of medium probability and facing boulders are also at high risk. Issues located below a quarry opening are also at high risk. In case of major events, the financial losses in the DV could be nearly 309,920,000 XAF (472,469.994 Euros).

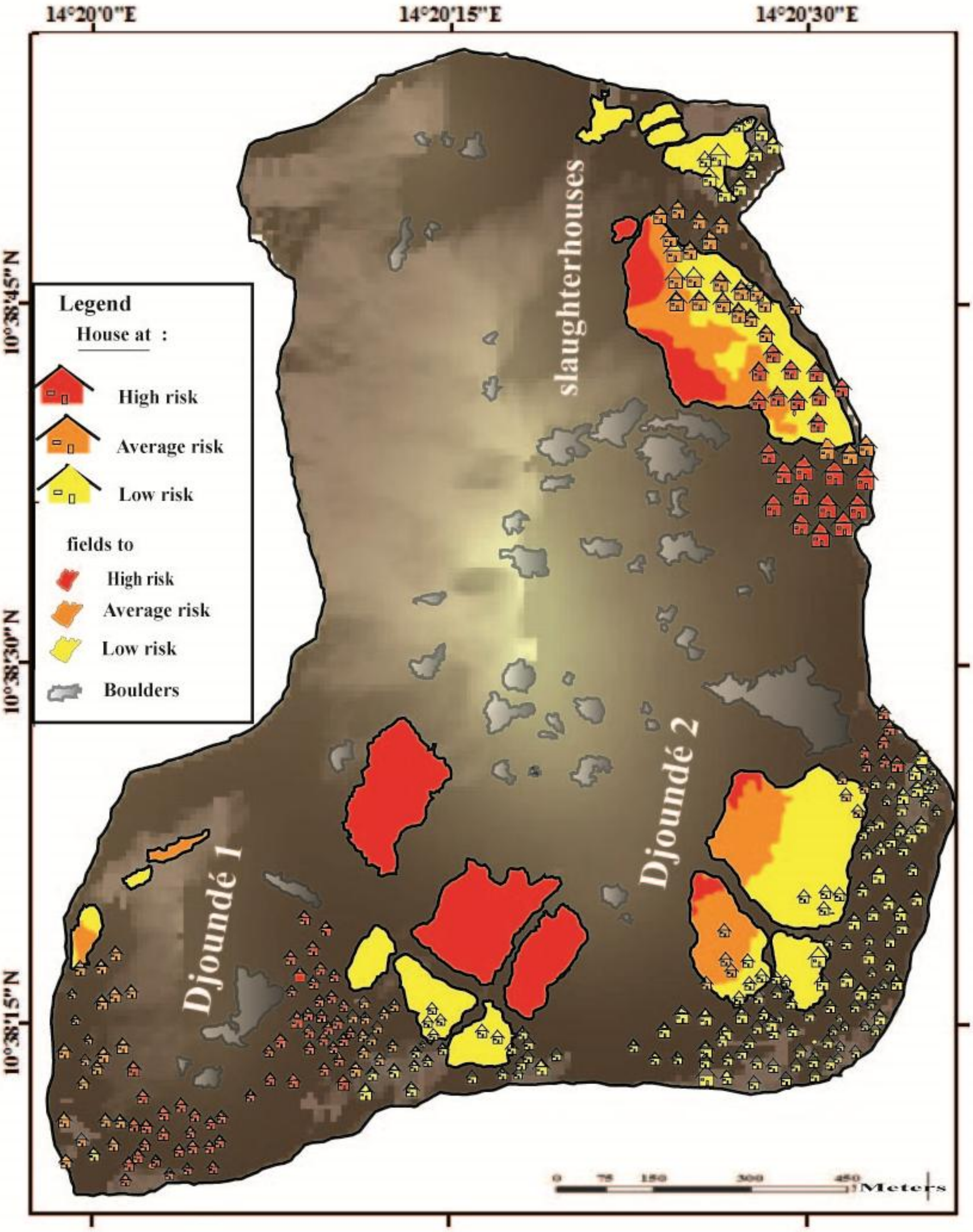

Figure 8: Map of risk associated with mass movements in DV

IV. Discussion

Volcanic environments in the Cameroon are the seat of several detrimental natural hazards[4,3,12,13]. DV present a series of mountain ranges which are animated by mass movements such as rocks and debris falls which are often accompanied by gully[10]. Due to its assets this locality attracts a significant population more or less diverse (around 840 inhabitants) despite the occurrence of mass movements. The risk could be important in case of the occurrence of mass movement hazards in DV. In 2017, the house of the chief of Djoundé district was hit by a detached block from upper slopes. Moreover, through the testimony of the population, several historical lethal events in DV's neighbouring localities have been recorded. In March 1993 in Doualaré, rock falls killed two (02) people who were sleeping. In 2005 the same event kills an entire family of six (06) members including a new-born baby (six (06) months of age). In December 2013 in Kosselbé neighbourhood, the same phenomenon led to the death of one child who was asleep and fractured his grandmother's foot. Mass movement hazards are frequent in other region in Cameroon. The most recent murderous cases are those of: - Limbe (South-West Region), in June 27th, 2001, that killed 24 people, destroyed nearly 120 homes and left nearly 2,800 people homeless[5]; - Mag'haa (Mount Bambouto) in July 21st, 2003, that caused the death of about 20 people and 50 cows and, the destruction of houses and plantations[2,14,3,15]; - Kekem (between Littoral and West Regions), in

October 20th, 2007, which caused the death of one person and destroyed several houses, plantations and roads[6];- Bafoussam (West Region), in October 28th, 2019, which killed about 43 people, made nearly 11 wounded and 150 homeless and destroyed around 15 homes[16]; - Ngousso (Centre Region), in November 4th, 2019, which caused the death of one person and the destruction of homes[17]. These phenomena occurred in several countries in Africa and beyond with a significant damage recorded on the population and goods: in Kenya[18], in Ethiopia[19], in Romania[20], in Democratic Republic of Congo[21], in Tunisia[22], in Alpine valley of Bagne, Switzerland[23], at the level of the western face of small mountain (Dru) of Mont Blanc in France[24,25], in Yosemite Valley of California[26,27]. It emerges from these examples, that populations are not aware about the dangerousness of mass movement hazards. In DV the main reasons of the population growth is the poverty and the weight of the history of the Islamic colonization of the Fulani on the natives of the Far North region. Indeed, according to the local populations, the settlement of these populations on the mountains allowed them to have a panoramic view of nature and its different components.

The expected results are by family, for the entire study area. Farming, investment costs are almost similar we will therefore have close to 840 dead, a destruction of nearly 251 homes and crops. The estimated risks are almost similar to those of Amalfi road in terms of distance and possible damage. It is estimated at around 33.9 Km/Year subdivided into 164 sections, each characterized by different values[28]. The total probability of death for people at high risk due to the direct impact is 3.43/year. Moreover, risk reduction in DV implies the combined cartographic proposal of risk areas. This is explained by the vulnerability and risk maps. This model will be developed on a regional scale as in other countries worldwide[29,30,31,32,33].

The population growth worldwide leads to the conquest of green space by some families that migrate settle down and practice their activities, even in the areas with very steep slopes because of assets that these environments offer. We can mention the villages developed on steep slopes in the Bambouto, Manengouba and Lefo calderas[4,3,34]. The progressive migration of the population in DV contribute to diversify the vulnerability (human, animal and material) that could increase the level of risk in case of the occurrence of major mass movement hazards.

V. Conclusion

The assessment of risks related to mass movements in DV highlights the issues likely to be damaged as these phenomena become preponderant. The proposed working method is based on observations, the inventory of risk areas, the study the different types of vulnerabilities and the assessment of the risk. The evaluation procedure was focused on field surveys, calculations through EXCEL 2007 as well as mapping through ArcGIS 10.4.1 in the laboratory. It turns out that, the forms of vulnerabilities and the risk highlighted are Human vulnerability which stands out in the number of men, women and children, namely 840 people in total. Added to this is animal vulnerability, which highlights 1,300 animals and material vulnerability that could be damaged. In this study, we carried out a risk assessment which focused on the overview of the figure with regard to the economy in DV and slaughterhouse. In case of the occurrence of important mass movement hazards there will be losses of human and animal beings, and destruction of houses and equipment estimated at about 309,920,000 XAF (472,469.994 Euros).

To reduce or avoid the losses in DV, the following recommendations are provided:

- Educate the population about the mass movements hazards;
- Build protection structures at the slopes, such as the double-twist fence, as it helps to reduce falls of blocks and stones;
- Avoid construction on risk zones;
- Establish farms to stabilize cattle that affect the soil during overgrazing.

Moreover, this study can be extended to other regions of the Far North region and beyond that are prone to mass movements hazards. This will be helpful in the reduction/prohibition of human and animal lives and, material losses in those part of the country.

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Mfossi Amza, et al. "Assessment of risk related to mass movement in Djoundé locality and vicinity (Far North-Cameroon)."*IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG),* 8(2), (2020): pp 01-11.