Mapping of natural hazards in Cameroon

Tchindjang Mesmin
The University of Yaoundé I. PO BOX 30464 Yaoundé mtchind@yahoo.fr

Abstract

With its wide extension in latitude (2-13 ° N, over 1500km) and longitude (9-16 ° E, over 800km), Cameroon by its triangular shape, occupies a unique position in Africa. It appears as a true topomorphologic hinge which recorded all geodynamic events which have marked the African continent (since the breakup of Gondwana until the Present), and summarizes in its main features, African reliefs and morphology. This country, from the Mandara Mountains to Cameroon Mountains, overlap the main tropical bioclimatic and morphoclimatic domains. Cups and pediplains bristling with inselbergs and dominated by the concave massive slopes observed in the Sahelian regions of the North, contrasted at the south with large polyconvex flattening and degradation surfaces of south Cameroon forest plateau that surrounded the Atlantic coastal plain. Between these two entities, arise imposing mountain ranges covered by volcanism, which far from being erased human and cultural footprints, have caused and organized the dense human occupation of these mountains while making its become the area of sacrality . These reliefs constrained by lithological and tectonic scarps, cut essentially in the Precambrian basement rocks, are the result of a long evolution marked by the staging surface flattening.

This geographical and geological configuration exposed Cameroon at several types of naturals hazards occurring in all regions, following the climate regime and the morphological shape. Among the natural hazards observed in Cameroon, one can include: earthquakes, volcanoes, floods, landslides and drought. In the detail, the hazard aspect gives the preponderance to earthquakes, although in vulnerability appearance, volcanism appears more important. However, landslides, floods and drought hazards become more recurrent and this paper attempted to illustrate it by maps. For each type of hazard, the author has used the statistical data collected from various oral sources (collective memory) which he associate existing hazards observed in Cameroon since the 19th century. These risks were then crossed through GIS to the population density (fig 2) of the whole of Cameroon. This mapping gives a general idea of the types of hazards by type of region in Cameroon. It allows establishing a database of different types of natural hazards at the same time it is a starting point for understanding, analyzing and taking into account the risks that may occur in Cameroon. At this level, it can help to organize and compute exposure scenarios of the Cameroon regions to natural hazards

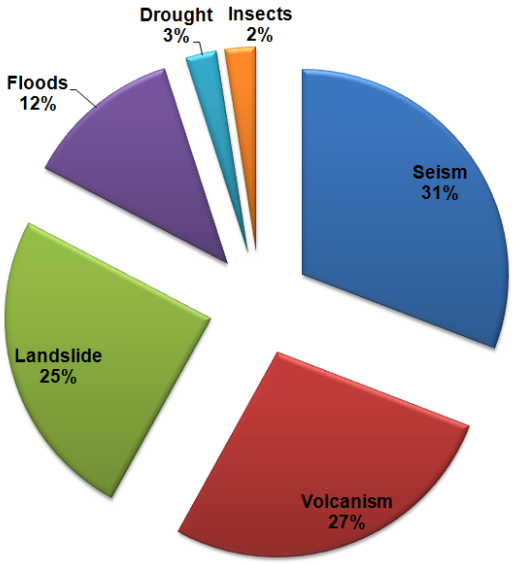
1.Introduction

Regarding Cameroon and until the past 30 years, natural hazards faced by, companies or individuals did little party preferred fields of historical basic or applied research. However, by anchoring it in the long term, a specific approach to questioning, criticism, analysis of sources, but also perspectives and new problems, the research provides a better understanding of the responses of societies to hazards incurred and disasters suffered. If the disaster is defined by the extent of damage to persons and property, there is not necessarily a correlation between the size of a hazard and the extent of the damages.

Since the early 1980s, the Cameroonian mountains inspire interest in the events that occur. It is the case of Mount Cameroon eruptions in 1982 (and repeated in 1999 & 2000), the limnic gaseous eruption of the Monoun Lake in 1984 and Lake Nyos in 1986. Over the past decade, mountain environments have recorded other events such as landslides and floods. Unfortunately, there is no data or studies that have structured the point of the question. This paper focus on performing a history and typology of natural hazards in the mountains of Cameroon before turning to specific cases observed. This contribution will try as much as possible to raise the paradox of these environments to high population densities and the dangers that people who live there face.

2. Natural hazards and disasters in Cameroon

Cameroon, through its territorial configuration and types of media is exposed to many types of hazards it experiences in all regions following the climate regime and the morphological configuration. Among the natural hazards experienced by Cameroon, one can take into consideration 5 types: earthquakes, volcanism, floods, landslides drought and insect infestations. In detail, the random appearance gives preponderance to earthquakes while in appearance vulnerability, volcanism is more important. Figures 1 a, b & c realized from statistics gathered from various sources observed hazards in Cameroon since the 19th century illustrate these remarks.



Figures 1a: of natural hazards in Cameroon

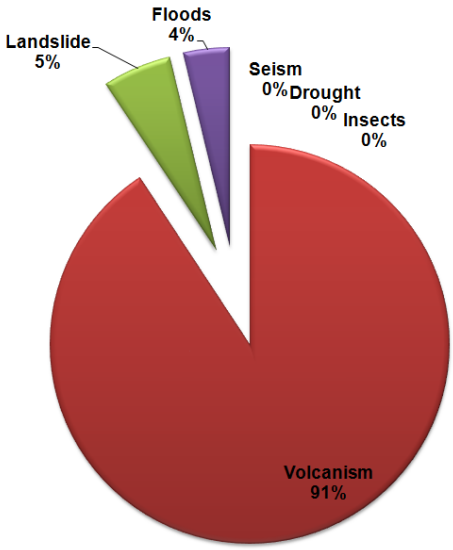


Figure 1b: distribution of the victims of natural disasters

Figures 1 a & b show that volcanism is more deadly than the earthquake in Cameroon while paradoxically in the world, earthquakes are more deadly. All events recorded in Cameroon, volcanism totalized 1883 deaths against 0 for the earthquake, 122 for landslides and 77 for flooding. (Source: surveys supplemented by data from CRED 2007).

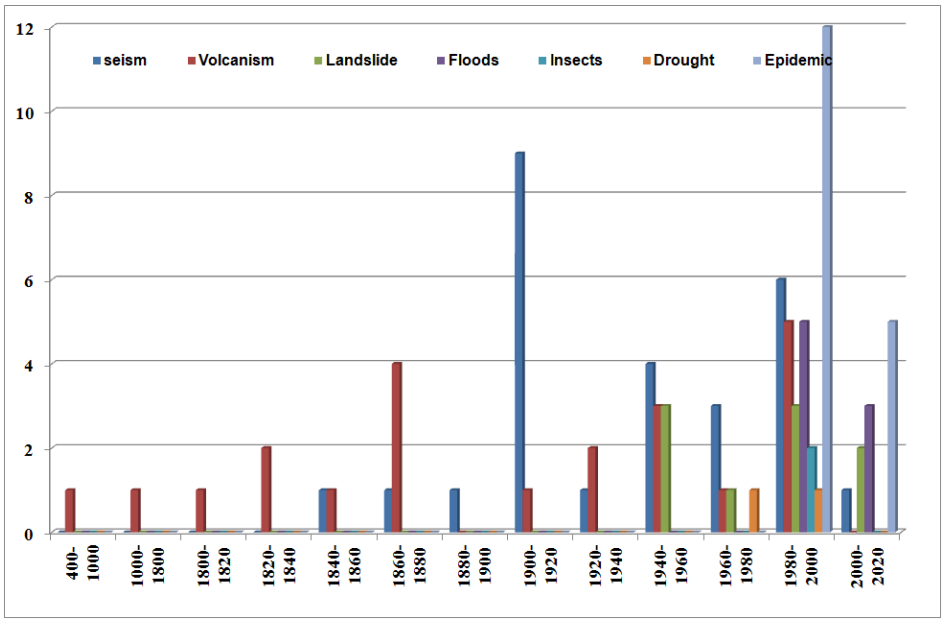


Figure 1c: Some hazards identified in Cameroon since 1900.

This graph shows floods as phenomena of 1980-2000 decades; earthquakes and volcanism occurred since the 19th century, landslides are recorded in the collective memory since 1940 and tend to grow. (Source: Tchindjang, 2012; surveys supplemented by data from CRED 2007).

Overall, the most common disasters observed can be divided in three broad categories:

- geological risks that qualify for any of lithospheric hazards including earthquakes and volcanism
- hydrometeorological hazards in which one can classify geomorphological hazards including landslides (landslides, mudflows, rockfalls) which are of various size and scope in the mountainous regions. The severe drought in the northern part of the country and floods must be added;
- biological hazards with cholera and meningitis due to drought and water pollution. It is the same with the locusts' invasion (dry mountains north of the Adamawa).

Figure 4 shows the distribution of these damaging events throughout Cameroon. It allows to understand the fringe vulnerable populations of Cameroon prone to disasters. It was made from the collection of scattered information in order to establish a database for Cameroon in this area.

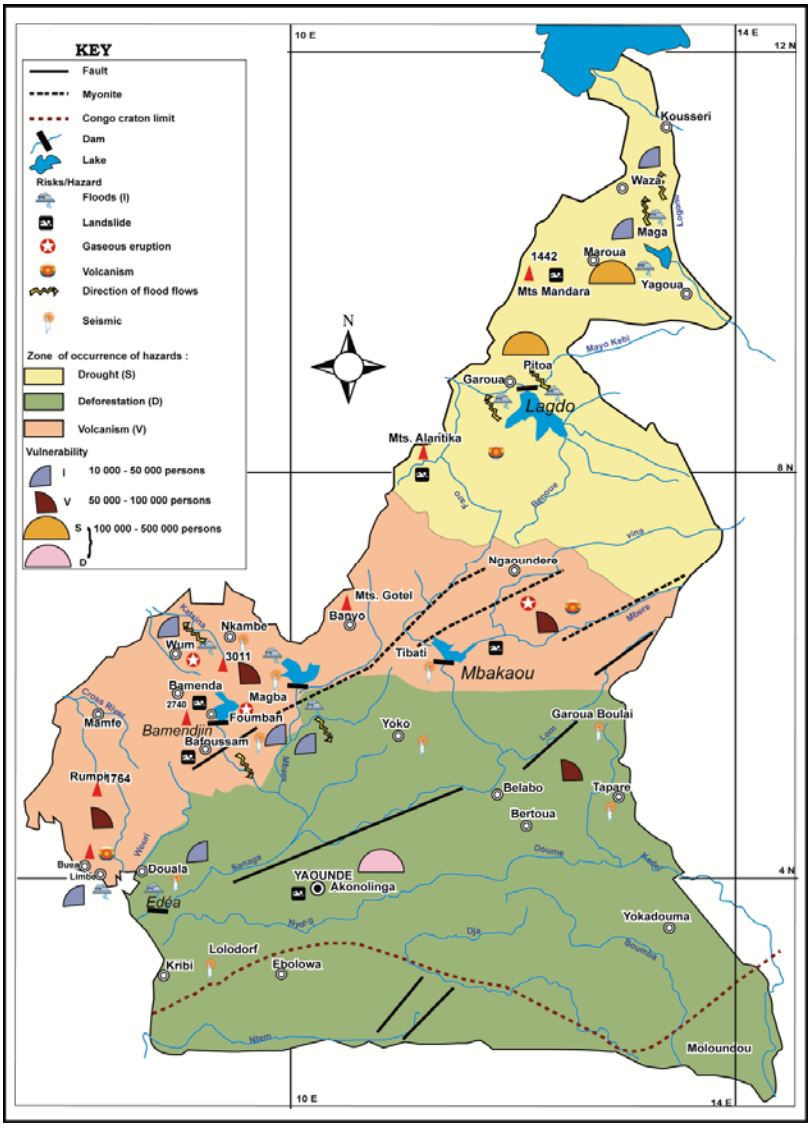


Figure 4 : main hazards recognized in Cameroon (after Tchindjang, 2012, Tchindjang & al., 2012).

From this figure and map of population distribution, one can identify that natural events occur in densely populated mountainous regions (with densities 100-200hts/km ²). These are the mts Mandara, the Bamileke plateau, the Grassfields and the Cameroon Mountains. The vulnerable population range from 10,000 to 100,000 people for the flood hazard, 100 000 to 500 000 for volcanic hazards. This map, which delivers a synthesis overview, is a tool that will guide future investigations in each area and the mountain environment by hazard type. Hazards are generally aggravated by population pressure and arrangements imposed on the natural environment by human societies regardless of their risk perception.

On the Western highlands of Cameroon (mainly Bamileke and Grassfields areas) the major hazards that have been identified are earthquakes, volcanism (limnic eruption of lakes Nyos and Monoun) and flood risk related to the presence of the Nyos natural dam and artificial dam of Mape located near a fault line. For this tropical mountainous region, one can add that heavy rainfall also increase the annual rate of change of scenery as well as the occurrence of landslides. The following paragraphs will focus on the four types of hazards observed in Cameroon namely: earthquakes, volcanoes, landslides and floods.

2 Types of Hazards in Cameroon

2.1. Seismic hazard

Cameroon is a mountainous country (mountains account is 63%) whose implementation by tertiary dome after the formation of Adamawa, was accompanied by large geodynamic movements linked to active faults. These induce natural hazards are not without effect on the lives of people and the whole country. Geologically, Krenkel (1900) had mapped the earthquake (Figure) in Africa. According to this map, the Cameroon line saves 11 to 20 earthquakes per year. Within this area, the Mount Cameroon in stores at least 21-50 earthquakes annually (figure 5).

Nevertheless, the Great Lakes region of East Africa totalized more than double of the earthquakes recorded in the Gulf of Guinea. Perhaps this explains why Cameroon as well as Central and West Africa have always been considered less exposed to danger. The fact is that the occurrence of phenomena and hazards related to geodynamics is common. Thus, the Cameroon Volcanic Line, which is still active is one of the major past and current volcanism. The figure 7 emphasizes in the main sites where most focused earthquakes are felt in Cameroon as shown by the work of Ambraseys (1986), Ntepe & Ateba (1998) and Zogning (1988). However, as can be seen, other locations are also affected and there are usually two main areas:

- SW-NE axis which is the Cameroon Volcanic Line, the main axis of the ridge of highlands and mountains of Adamawa that focuses at least 80% of Earthquakes;
- West-East axis located at the edge of where the Congo Craton lists some historical earthquakes recorded since 1800.

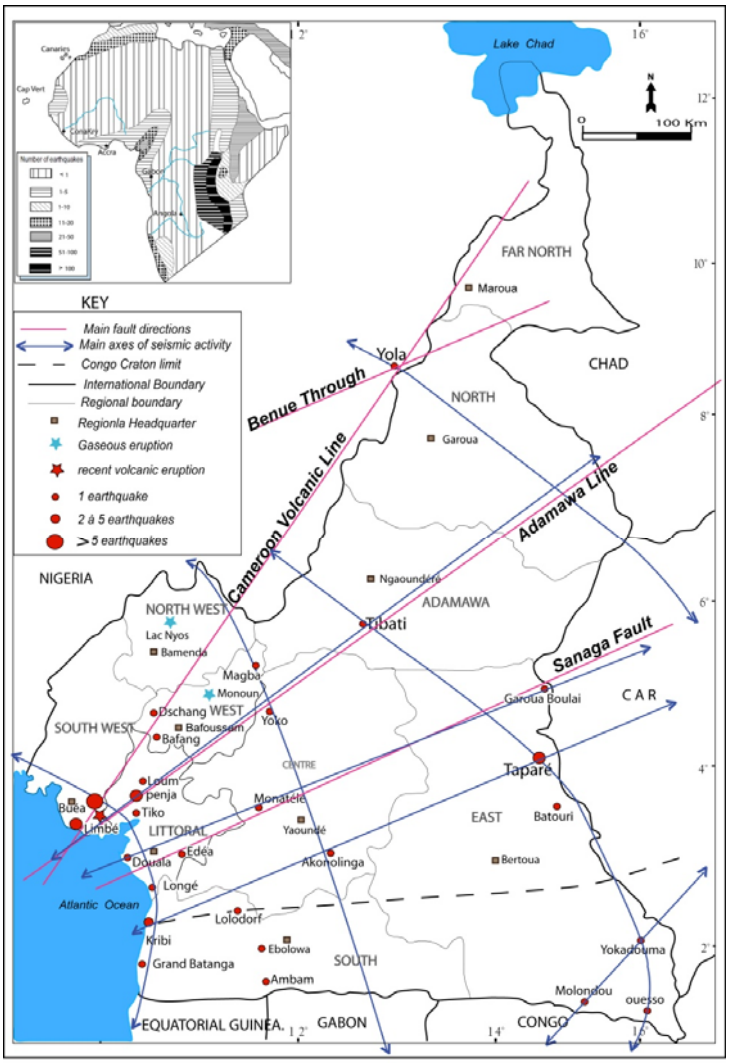


Figure 5: dissemination of seismic activity in Cameroon and Africa (source : data compiled from Krenkel, 1900, Rothé (1976), d'Ambaseys et Adams (1986), Ambeys et al. (1987), Zogning (1988), Tchindjang (2012)

Throughout Cameroon, seismic hazards rarely exceed the Modified Mercalli scale VI. The newest earthquake felt in Cameroon at the 2005 Monatélé. Paradoxically, there is a lack of seismograph network in Cameroon (apart from those on the flanks of Mt Fako). Yet the position of Cameroon sliding intraplate area (zone transform faults Atlantic), which is feeling the effects, and even replicas of events occurring elsewhere. This was the case in 1986, when the earthquake in Colombia, the replica had been felt by seismographs installed at Foumbot on an experimental basis (Tchindjang, 1996). Nevertheless, it must be recognized that earthquakes, frequent in Cameroon are often subtle and it may be where the difficulty lies. The below figure coming from a variety of sources (Ntepe and Ateba, 1998; Ambey 1989; Ambraseys & Adams, 1986), suggests that the seismic hazard, though little known, is recurrent in Cameroon since the 19th century.

Tchindjang (2012), shows that the earthquakes phenomenon will keep on boosting, the 2005 Monatélé earthquake constituting evidence. In 144 years, there were 50 seismic events recorded or felt, with an average frequency of 01 earthquake every 6 years. Based on it, figure 6, using the same sources, attempted to spatialize and show the occurrence of seismic hazard across the Cameroonian territory, then put them in parallel with the distribution of exposed populations. Earthquakes have never caused any casualties in Cameroon. But, in the case of major human concentrations at the foot of Mount Cameroon, it is not excluded that the

future event could cause death, that is the most obvious aspect of the exposure of people to risks. It is also possible that some mass movements have a close relationship with earthquakes.

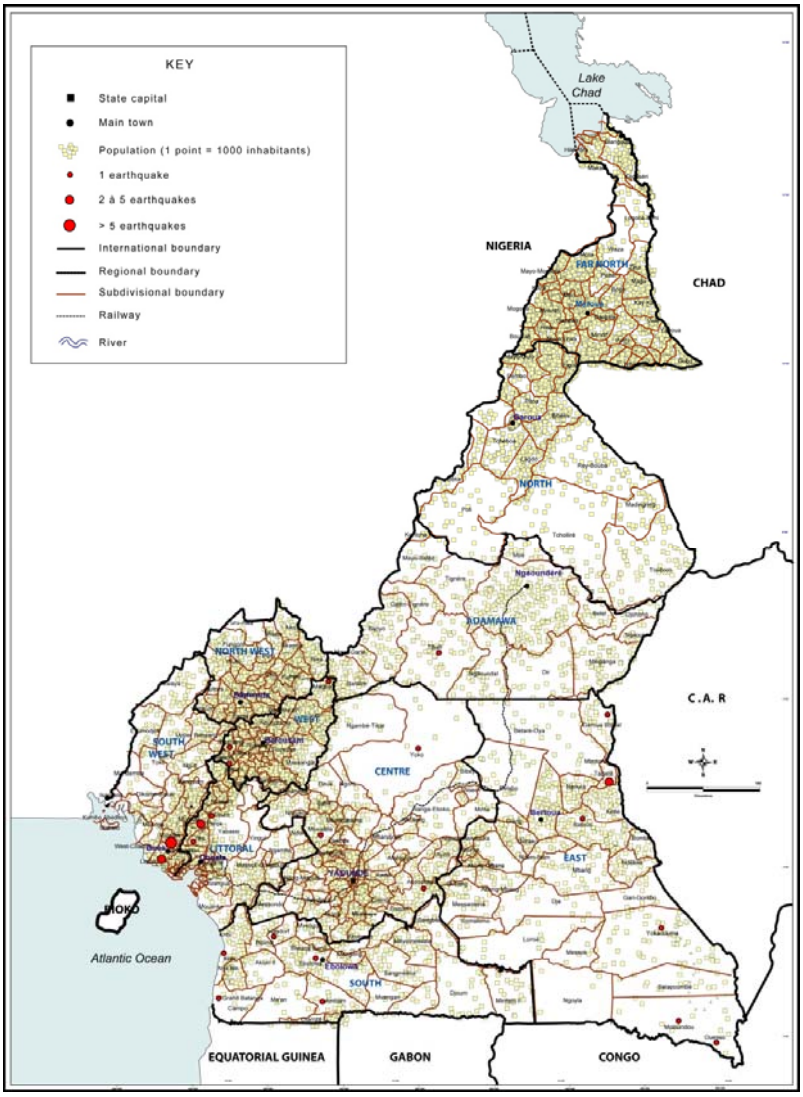


Figure 6 : seismic dissemination and population distribution in Cameroon (Tchindjang, 2012).

Paradoxically, there are no building obeying seismic standards around Mount Cameroon, or in places where earthquakes were felt at least once. Therefore, in case of occurrence of an event of intensity 7, it will be a disaster, and the number of victims is not so much related to the strength of the earthquake, but to the population exposure and the complete absence of land use policy and risk policies more than 200 years after the first recording earthquakes and 50 years after independence. In fact, around Mount Cameroon, Buea and Limbe cities with over than 100, 000hts have felt the effects of earthquakes in 1999 with slight damage, but so far, nothing has been implementing, neither the zoning of Mount Fako , nor the land use planning. The lack of insurance system is the second paradox, in areas prone to seismic events.

It is therefore necessary to provide possible clues of these movements on the worsening of landslides and even damage to infrastructure as part generally observed on the road to Bamenda. While earthquakes do not occur necessarily always with volcanism, the correlation between earthquake and volcanic activity is very high in Cameroon.

2.2. Volcanic hazards

The first hazard to be recognized since the 19th century on the territory of Cameroon are seismic and volcanic. If earthquakes occurred less deadly, volcanism on the contrary is more. To realize this paper, my approach was essentially to identify any literature on volcanism in Cameroon in order to constitute the database and to compare it with the map of population density. It appears that if one ignores the historical eruptions of the sixth century evoked by Hannon the explorer (who evokes the eruption of Mount Cameroon in speaking of the Chariot of the Gods), until 1982, was the only Mt Fako volcano asset recognized in Cameroon. Events Monoun Nyos in 1984 and 1986 revealed that only the Chariot of the Gods cannot alone be the evocation of volcanic hazards in the country. Although the only event of Lake Nyos killed 20 times more than 15 eruptions of Mount Fako (the only deadly eruption, that of 1922, had 100 deaths). This is because it exploded in 1986 releasing an estimated 3 million m 3 of magmatic CO that swept down its lower valleys asphyxiating 1750 people and over 3000 cattle (Le Guern and Sigvaldason, 1989). Tchindjang (2012), succeed in depicting the historical evolution of volcanism at Mount Fako and throughout Cameroon. From fragmentary data collected from various sources (including the Smithsonian Observatory, oral sources and based CRED), The author shows that the volcanic hazard is best followed on Mount Cameroon (telemetric seismographs equipped) elsewhere. In addition, the Mt Cameroon kept pace eruption predictable now well know in the literature, 01 eruptions on average every 17 years. Finally, historical and recent volcanic hazards have been insert in a map in relation to population density (figure 7).

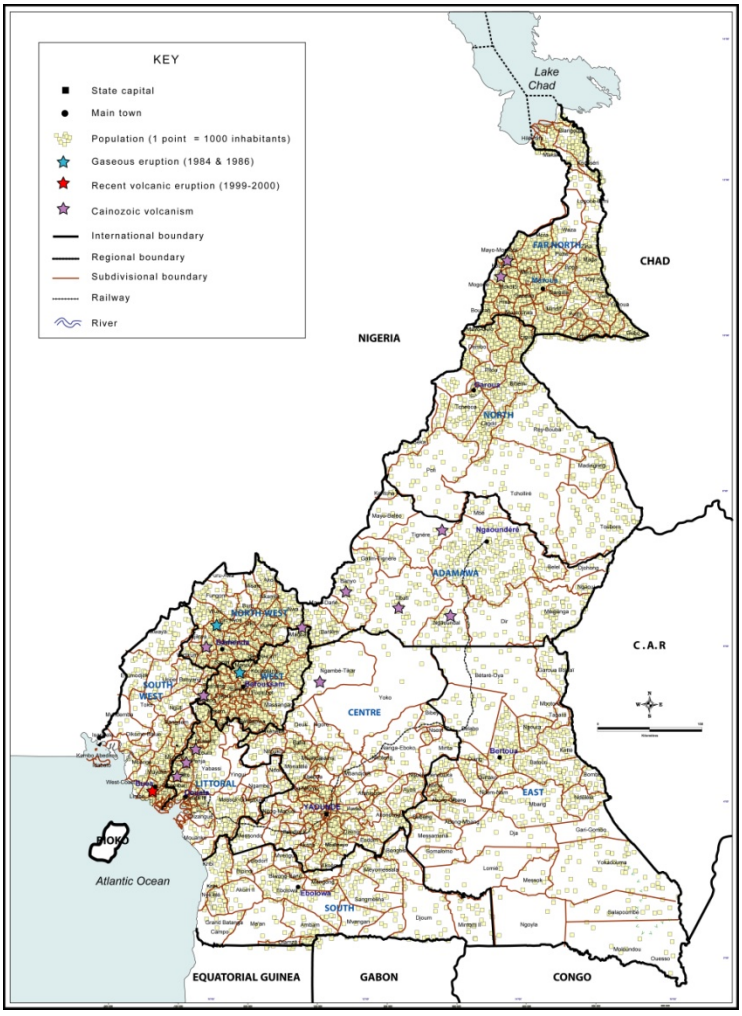


Figure 7: Volcanic hazards in Cameroun (Tchindjang, 2012).

The same paradox noticed above for seismic events can be applied to volcanic hazards. Since the eruptions of Mount Cameroon in 1999-2000, Monoun in 1984 and Nyos in 1986, it quietly waits for the next clock volcanoes, during this time, people fall into a sleep of heedlessness. Since politically speaking, nothing has been put in place outside the alarm placed around the lakes Nyos and Monoun. There is even or awareness session for the simulation to sensitize and prepare population as do the Japanese. A revival of a crater lake cause more casualties than the Nyos event in 1986 due to the crowding of people and in the absence of land use and land cover planning around these volcanoes. Therefore, one focus of future research and work would supervise the zoning of volcanoes and potentially dangerous lakes.

Among the seven primary volcanic hazards identified in the literature (Bardintzeff 1998), Cameroon experiments five namely : lava flows (Mount Fako eruptions in 1982, 1999 and 2000), projections and impacts (eruption of 1999), clouds burning (eruptions of 2000), the gaseous eruption (Monoun in 1984 and Nyos in 1986) and lahars (Mount Cameroon eruptions of 1923). The gaseous meromitic lakes are the latest volcanic hazards manifested in Cameroon. Its raised up the question of the research to be drived on the string of volcanic or volcano-tectonic lakes of the Cameroon highlands.
Five volcanic hazards, lahars have been reported historically as to justify large crevasse accident that the western flank of Mt Cameroon (figure 8) and assumes that heavy rains fell on the slope during this historic eruption. Similarly, the abundance of rain, humidity and gravity largely explain the occurrence of landslides in Cameroon.

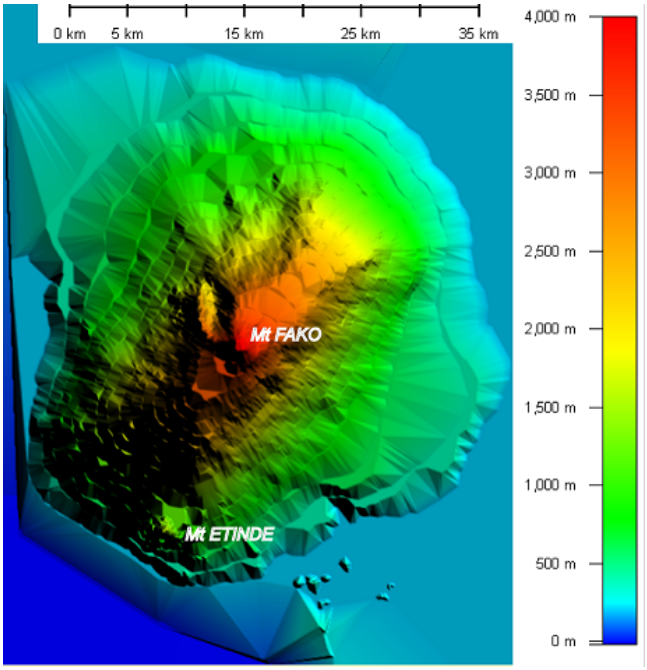


Figure 8: DEM of the Mount Cameroon. The crevasse is lying between 4000 and 2000m of altitude. (Tchindjang, 2012)

2.3 The landslide hazards

The world scientific literature on landslides is abundant with the research of Hewitt (1971); Caine (1974); Dikau (1993); Varnes, (1978), Cruden and Varnes, (1991). Their more rigorous terminology give an understanding basic knowledge on the landslide which is a generic term describing geomorphic processes of mass displacement of a volume of material along a slope. The style of displacement of the material may be a fall, topple, slide, spread (expansion) or flow. Differentiation of landslides is related to the type and volume of material moved and mode of travel.

Landslides appear as a recent phenomenon in Cameroon. Indeed, most studies focused on geomorphological slope dynamics tried to evoke the occurrence and dominance of landslides in the evolution of slopes. These phenomena were observed random spot in favor of a heavy rain or within the trenches of major roadworks. Still, the term dynamic slopes had a broader and included as landslides themselves, rockfalls, subsidence, creeping etc.. Nowadays, with the enrichment of scientific literature and modeling, this typology is best understood and has been refined (Malet & al., (2006), Van Western (2000), Maquaire & al. (2004). Regarding Cameroon, geomorphologists and geologists have very little interest in the phenomenon and it is this which explains the total absence of specific studies. In this work, from the reconstruction of historical sources, I identified some observed landslides. Subsequently, I will describe three recent phenomena observed in Cameroon (landslides, debris flows, rock falls). It seems to me that this hazard will be later a main focus in research planning supported by the systematic use of Geomatics tools.

Landslides, originally associated with mountainous regions can occur even in the lowlands. They are usually caused by a combination of three factors including geology (regolith water-soaked, discontinuity, schistosity and fault contrast in permeability and rigidity of the material, earthquake), geomorphological (tectonics and volcanism, subsidence, erosion and groundwater extraction , freezing and thawing, etc..) and human (deforestation, agricultural activities, mining, urbanization, slopes excavation etc.).

In Cameroon, the growing concern and interest granted to landslides date from 1950s in the collective memory of the western highlands and 1990s among policymakers. In the highlands, the extroversion of the economy that is accompanied by the expansion of cash crops has resulted in deforestation, reduction of land available for food crops and slope instability and bare. Therefore, hilltops and mountain once denied access began to be cultivated. Moreover, the descent of the Mbororos pastors from northern dry regions in search of pastures and their settlement at the heart of the highlands have been accompanied by overgrazing and degradation of watersheds. Degradations drived by farming and overgrazing have led to large movements of landslides, washouts generalized on some slopes of high mountains (Oku, Bangou, Sabga mountains, etc..). Unfortunately, these movements have not been recorded, not only because of the remoteness of the lands in relationship to research centers (600km from Yaoundé), but also the means and the willingness of the researchers. It is the reason why the CRED database (CRED have no information on events occurred in Cameroon since 1980) does only identify a single landslide in the 2003 at Wabane village that killed 22 persons. According to Ayonghe & al. (2002), Lambi (2001), Tsou (2007), Tchindjang & al. (2012), more than 300 landslides have been felts (historical and oral memory) or recorded in Cameroun since 1954 with more than 122 killed and many damages (devastation of farmlands, excavation, destruction of houses, of road infrastructure and water tower etc.).

Although it should be noted that it is difficult to quantify the number of landslides in the highlands of Cameroon. Sometimes it is only people who attend and later can inform scientists or authorities. For the record, Fogwe Nji (1999), recorded on the Ring Road, 75 slides (from June to August as from 1991 to 1996) for sites ranging from 1240 to 1900m and slopes measured between 15 ° and 27°. Under such conditions, it will raise the question of tools for quantification and spatialization of the phenomenon. In this paper, a general map (figure 9) of occurrence of landslide hazard in Cameroon and exposed populations have be drawn. The Cameroon volcanic Line and the mountain ridge appear to be the preferred site of this phenomenon. Roughly the wet Cameroon highlands is a favorite site for this hazard.

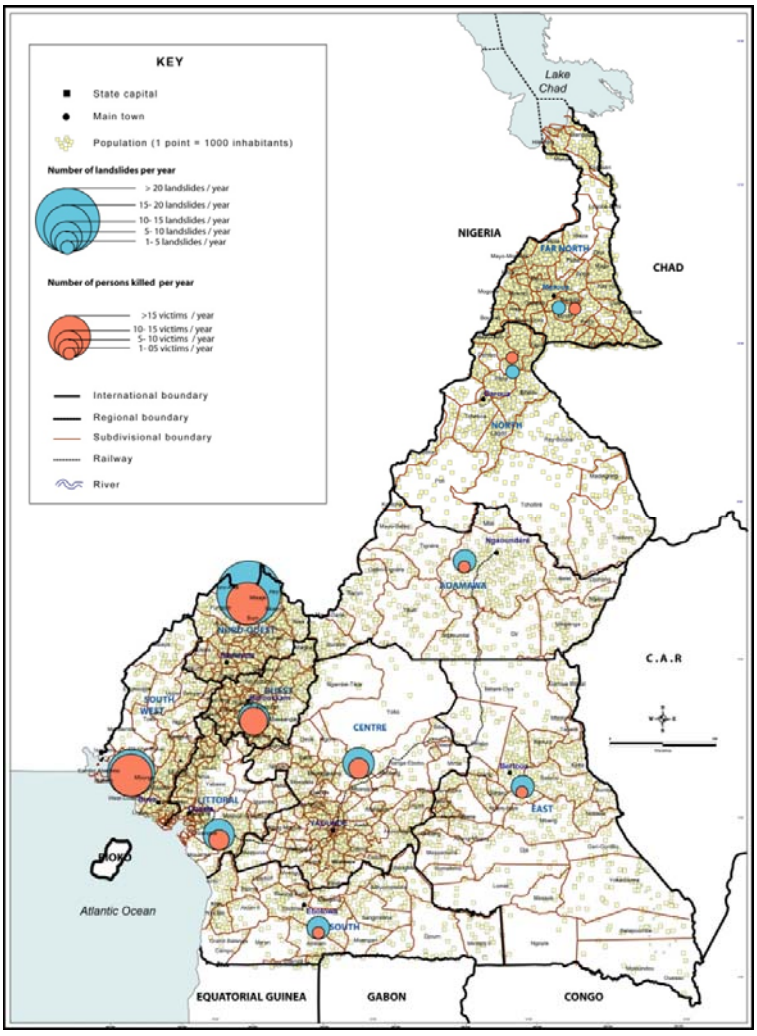


Figure 9: landslide occurrence in Cameroon region (after Tchindjang, 2012).

If in the past, such phenomena seemed limited, today's high population densities on these fertile lands, intensification of agricultural activities coupled with the unbridled exploitation of land, construction of major roads, the abandonment of ancestral cultivation methods which stabilize land, are factors that aggravate these hazards, making it susceptible to recurrent movements. Even if the same hazards were recorded in the history, magnitude and frequency are not those known today.

Regarding the highlands of Cameroon, the data in the literature require me to take to the starting point the year 1954. From 1954 to 2012, there were more than 50 deadly landslide for 122 deaths. The evolution curves and the linear trend shows that we can expect an increase in the number of events and victims in the future. Most murderers from Table 21 are landslides from 2001 to Limbe (24 deaths) and those of Magha 2003 (22 dead). Although, the Magha event appears as the most lethal of all (22 victims for a single and complex mudflow). Landslides generally destroy, crops, buildings, residential homes, loss of lifes.

2.4 The flood hazards

Flood risk is the combination of two factors, hazard and vulnerability. The flood hazard defines itself as vulnerability determines the land and its use. Thus, the consequences of this hazard will be less important in uninhabited and urban areas. Flood hazards are perceived better in urban than rural areas. It's the case of Nkolbisson floods (a neighborhood in the city of Yaoundé) twice in April 2008. Its occurrence was related to heavy rainfall that hit the mountainous part of the city, drained by the Mefou River. The causes are related to the anarchic occupation in prohibited areas by building and also deforestation in mountainous areas (850-1200m) devoted to green spaces.

In urban areas, the functional damages prone to flooding are buildings, equipment, houses, roads and tracks. In rural areas, it takes with the habitat, cultures and protected areas. In Cameroon, the first record of this phenomenon is dated 1980. Figure 10 try to spatialize this hazard throughout Cameroon. It will give way to further detailed and more systematic and better targeted work.

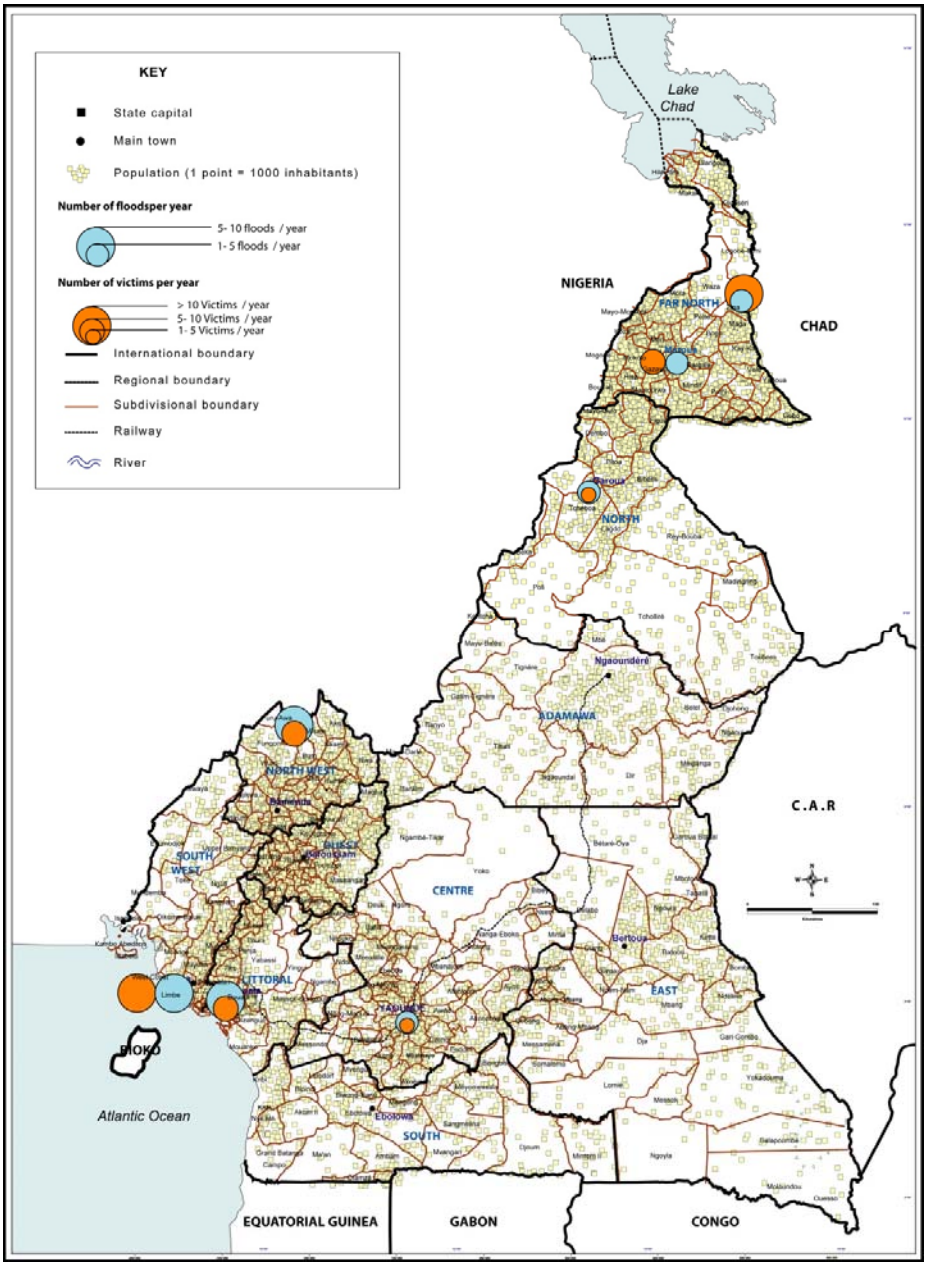


Figure 10: Floods occurrence in Cameroon region (Tchindjang, 2012)

3. Conclusion

These paragraphs focused on natural hazards in mountains were primarily designed to identify and describe the types of observed hazards. Whenever possible, this contribution was essential to establish a database of risks in Cameroon (prelude to a scientific risk observatory), then a mapping of this general phenomenon across Cameroon. It is worth mentioning that such a document does not exist in the literature. It will give access to analyze in the near future specific cases coupled with population density. Indeed, I am convinced with Hewitt (1997) as the most serious risks in the mountains depend largely on external influences to it (p. 253-254), in the sense that economic and social upheavals of the cities rise an increase and intensification of activities in rural mountain (deforestation, overgrazing etc.).

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