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Risks Prevention Plans (RPP) and the vulnerability of peoples around volcanoes: Case study of Mt. Cameroon

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Abstract

Located at the bottom of the Gulf of Guinea, Cameroon is exposed to a large variety of natural hazards, some of which are linked to volcanic activity. These are concentrated around the active volcano Mt. Cameroon which combines effusive and explosive types of activity. The threatened stakes are numerous and diversely exposed. They include people, habitat, industrial plantations, a petrol refinery complex and many other industries, equipments and infrastructures.

In order to understand and strengthen civil protection measures, for the security of the population faced with natural hazards, the French Embassy in Cameroon, within the framework of a financial convention between Cameroon and France, put in place the GRINP (Management of Natural Risks and Civil Protection) project whose objective was to reinforce the capacity of Cameroon's civil protection department and thus, contribute to the improvement of the security of the population faced with catastrophes.

At the end of the 2 years working program focused on the "Elaboration of the risk zoning map of the Mount Cameroon", which corresponds to the 1st phase of the 1st component of the GRINP project, some key recommendations were made to Cameroonian authorities. In the framework of the implementation of recommendation n°1, it was deemed necessary to carry on a risk prevention plan (RPP) project, which was the 2nd phase of the 1st component, with the aim of reducing the vulnerability of the stakes.

The objective was to realize a Risk Prevention Plan at a local council scale, and taking into consideration the specific natural risks of each zone.

The general objective of the RPP was to clearly draw land use maps for risks zones, showing the overlay of stakes with risk of different intensities. This then led to the setting up of regulations that can reduce the impact of natural catastrophes on human lives and properties.

1. Introduction

Located at the bottom of the Gulf of Guinea, Mt Cameroon is the most active volcano of the West and Central Africa region (Figure 1). It belongs to the Cameroon Volcanic Line, a SW-NE volcano-tectonic trend which straddles the continental margin. With a height of 4095 metres and an area of about 3000 km², it is formed at the intersection zone of fractures from different directions. Mt. Cameroon is a stratovolcano-tectonic massive dominantly basaltic composition above a basement of Precambrian metamorphic rocks covered with Cretaceous to Quaternary sediments. Several hundreds of cinder cones occurred on the flanks of the volcano. Mt. Cameroon is quite active, with large lava flows often erupting from fissures in the summit region and in flanks.

The earliest reported eruption dates back to 2.500 BP, witnessed by the Carthaginian explorer Hanno. It is only from the early 19th Century that eruptive activities were listed. In the course of that century, a total of seven eruptions have been dated: 1815, 1835, 1838, 1839 (probable eruption), 1852, 1865-66 and 1868. Seven other occurred in the 20th Century: 1909, 1922, 1954, 1959, 1982, 1999 and 2000.

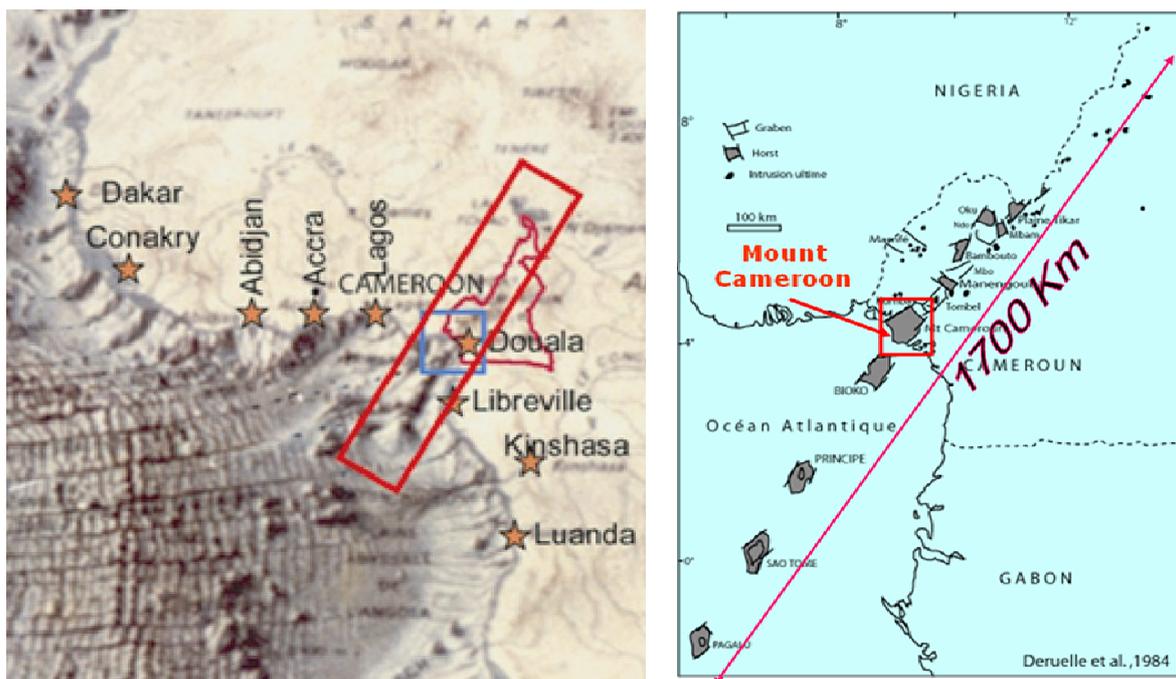


Figure 1. Mt. Cameroon location maps. a) geographical location: red rectangle indicate the Cameroon volcanic line, blue rectangle indicate the Mount Cameroon area, the red line indicate the Cameroon state border. b) Structural location. 1700 km is the length of the Cameroon volcanic line (Source Deruelle et al., 1984).

Generally, eruptions are accompanied by more or less strong earthquakes and sometimes by tectonic movements. Some of these eruptions really threatened the population living around the volcano. This is the case of the 1922 and 1999 eruptions, which destroyed several hundred hectares of farmlands, houses and infrastructures. The 1999 eruption was characterized by voluminous 'a'a flow emitted by the vent at about 1400 m a.s.l.. This flow moved in south-southwest direction through dense rainforest toward the village of Bakingili and people were evacuated. The 10-12 m thick 'a'a flow cut about 80 m of the important Limbe-Idenau road and ceased about 200 m from the Atlantic Coast.

2. Risks and threats around Mt. Cameroon

From the bibliographical studies (Zogning 1989, 1991, 1994, 1999; Zogning et al., 2007) and complementary field work, four main types of risks were identified, to which the population around Mt. Cameroon are more or less directly exposed. These are risks linked to volcanic eruption, earthquakes, land movements and floods.

2.1 Volcanic risk

Risks linked to volcanic eruptions vary according to the eruptive dynamism and external factors, such as atmospheric and topographic conditions. The eruptive dynamics of Mt. Cameroon is relatively complex and varies from explosive dynamics, close to the volcanic type, to effusive dynamics of the Hawaiian type, and moderately explosive dynamics of the Strombolian type (Tchoua, 1971).

All the flanks of the volcano can be considered exposed to two direct threats: aerial fallout and lava flow.

In addition to these threats, there are two others hazards which are indirect and more or less local. These are:

- The risk of lahar flow,

- Partial collapse of the flank of the volcano.

2.2 Earthquake and soil movement risks

Risks related to earthquakes extend on all the mountain flanks. Earthquakes are from both of the two origins: volcanic and tectonic.

Risks linked to soil movements can be classified into two main categories:

- Risks linked to slow or rapid landslides
- Risks linked to rock fall or block fall of all dimensions

The first risk consist in landslides, which can occur with different ground velocity. Landslides occur constantly in geologic formations dominated by clay rich soils, such as that of weathered basalts or old volcanic cones, and sedimentary tertiary formations. During the last decade, about 30 people were killed in Limbe and Buea cities (Zogning, 2007).

A second risk consists in block fall. Blocks of all dimensions, observable in the cliff areas, are susceptible of falling in the mountain's more abrupt relief, along river banks, road sides or seashore.

2.3 Flooding risk

Flooding can also occur (Zogning, 1991). They concern three principal types that can be produced:

- floods caused by volcanic eruptions, particularly by the effusion of lava;
- floods caused by tsunamis, as a result of serious seismic events that occur in the sea or serious landslides;
- floods resulting from torrential rainfall phenomena.

3. Risks zoning plans

According to their geographic distribution on the Mt. Cameroon area (Cruz Mermey 2006; Thierry et al., 2006), the different risks have been grouped into two main categories:

- Large scale risks,
- Localised risks.

3.1 Large scale risks

Concerning the risk at regional scale, these are considered large scale risks. The first step of the work consisted in updating cartographic documents integrating new data collected during the field campaigns.

The second step of the work concerned the creation of GIS (Geographical Information System) data of GRINP (Management of Natural Risks and Civil Protection) project related to the risks already studied and their organization in conformity with already existed one. The first series of these data relied on the different hazards and their intensity. In the following figure the example of lava flow hazard cartographic representation is shown (Figure 2).

3.2 Localized risks

Concerning the risk at local scale, as cities, these are considered localised risks. The GRINP GIS database obtained from the 1st component of the GRINP project was elaborated at a small scale (1:200000) from 15m resolution satellite images. During the RPP working program, the contour lines were drawn accurately from a 2.5 m resolution satellite images, and a slope classification was done (Figure 3).

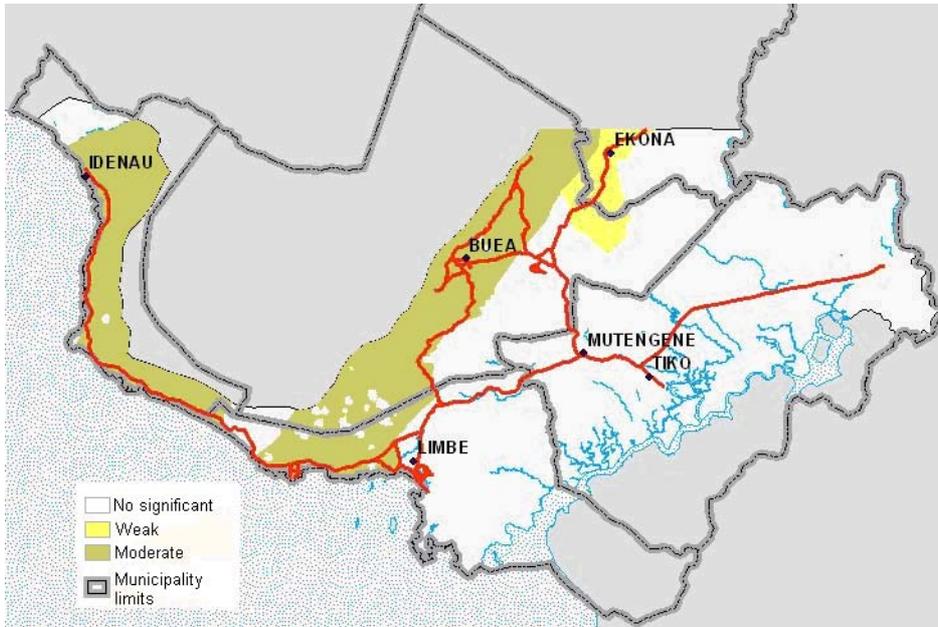


Figure 2: Spatial distribution of lava flow hazard in the study area of Mt. Cameroon.

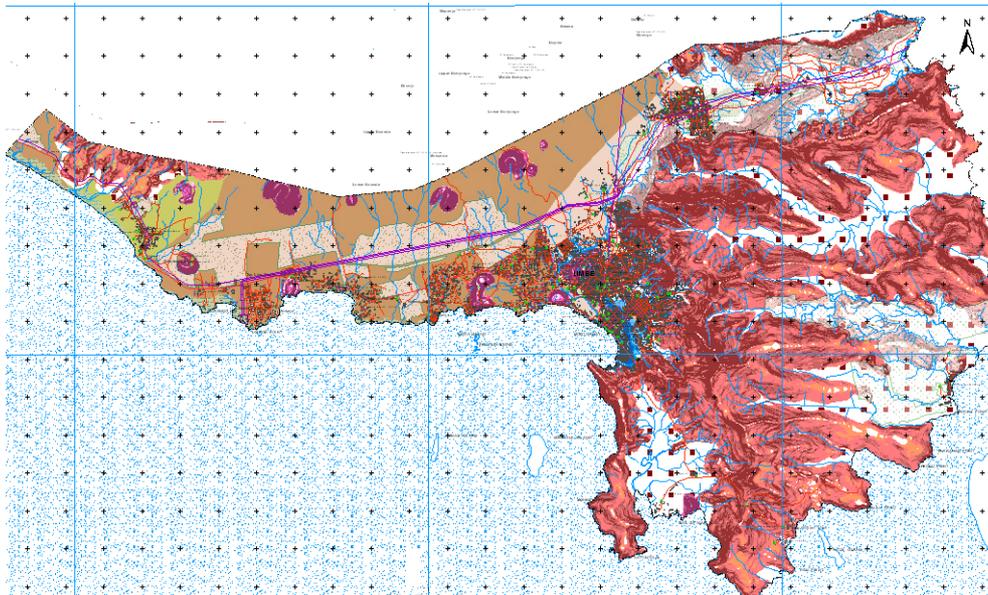


Figure 3: Land use and risk zoning map of Limbe Council.

As concerns landslides which were grossly defined in the first component of the GRINP project, we did not only draw with greater precision the boundaries of the massifs and cones concerning with landslides and rock fall, but we equally defined their intensity which varies according to slopes. The slopes map, drawn during the first phase, enabled to define five classes corresponding to different levels of hazards according to the GRINP nomenclature. These are:

- slopes of less than 3% (insignificant risk);
- slopes of 3-10% (low risk);
- slopes of 10-20% (moderate risk);
- slopes of 20-30% (high risk);
- slopes of more than 30 % (very high risk).

The same procedure was followed for flood risks which were not taken into account by the GRINP project. Three parameters were taken into consideration for their evaluation and classification. These are: altitude, slope and frequency of phenomena.

The altitude and slope were extracted from the DTM elaborated from the topographic base map of 1/25000, with an equidistance of 2 m. This DTM was earlier updated while integrating topographical data collected with a geodesic GPS. The frequency of floods resulted from the exploitation of a questionnaire proposed to the population.

As concerns the risks of tidal waves, its classification was essentially based on altitude in relation to the sea level. The zone extending from the coastline up to 5 m of altitude was extracted from the DTM, and it showed that the degree of risk reduced as the altitude increased from level zero.

In the following table (Table 1) the example of lava flow hazard information on the city area involved.

Table 1: Distribution per council of Lava flow hazard.

Council	Hazard	Area in km ²
Buea	Weak	13.77
Buea	Moderate	120.09
TOTAL BUEA		133.86
Limbe (UC)	Moderate	37.28
Muyuka	Weak	16.37
Muyuka	Moderate	2.73
TOTAL MUYUKA		19.10
West Coast	Moderate	84.47
TOTAL		274.71

3.2 Land use map: the stakes

The second set of data extracted from the GRINP GIS concerned the recorded stakes. We started by crossing the different hazards by intensity and by council with the stakes brought out by GRINP to which we added data from other sources (individual cases extracted from Spot image and the data bank of AZOMARC), including industrial plantations.

In total, more than 10 risk maps were produced by the GRINP project, where 4 were on large scale risks, 4 related to localised risks and 1 on the stakes. Based on specific criteria, each risk was evaluated on a scale of five values to which is associated a set of recommendations (Table 2).

Table 2: Threat index qualification and recommendation
(Source: GRINP project, Final report page 79).

Index class of threat	Qualification of the hazard (threat)	Global recommendations
$Im \leq 1$	Not significant	no recommendation for construction of houses for permanent use;
$1 < Im \leq 10$	Weak	no specific recommendations but a certain degree of vigilance is needed, particularly for serious or primordial stakes;
$10 < Im \leq 50$	Moderate	permanent human settlement is possible, but specific precautions are recommended;
$50 < Im \leq 100$	High	permanent human settlement is not recommended, except serious precautions are taken;
$Im > 100$	Very high	permanent human settlement should be avoided

4. Spatial distribution of stakes and threats

Within the framework of the first component of the GRINP project, a total of about 810 serious stakes (equipment and infrastructure) were counted in the study zone. These are classified into 8 categories: potable water supply equipment (30), economic centres (101), communication and telecommunication structures (38), educational and scientific research structures (213), energy supply equipment (216), governance and safety structures (94),

population and housing (25), public service structures(PSS: 25), transport(parks and works of art: 90).

To these, should be added built-up structures extracted from satellite images and completed by data from the AZOMARC database. A total of 49,923 houses where 18,122 were found in the Buea council, 18,508 in Limbe, 10,436 in Tiko, 2,129 in Muyuka and 728 in the West Coast.

The crossing of the stakes map with that of the risks clearly shows the threat that weighs on a certain number of major stakes. Within the framework of the GRINP project, a counting and an evaluation of stakes were undertaken. The inventory and localisation of exposed elements, followed by an analysis of their different values (human, social, monetary, economic, strategic, environmental) was done using information extracted from the questionnaire carried out on public services or the concerned organisms, completed by field study. The elements that were seen to be important by the Technical Follow-up Committee of the project were retained and drawn. These were:

- The population (urbanised zones and periodic points of population concentration such as schools, principal areas of church services, markets, stadia etc.);
- Strategic buildings for the management of crisis (governance, security, health centres, etc.);
- Buildings, infrastructures and lifelines (habitats, water network, energy; roads, work of arts, telecommunication relays etc.);
- Natural and cultivated milieus (vegetation and hydrography, subsidence crop agriculture and industrial plantations, etc.);
- Principal centres of economic and financial importance (banks, factories, etc.).

The different stake values were quantified, such that the number of inhabitants per locality, the level of importance relative to the management of crisis, the evaluation of the unit cost of different infrastructures, the values of agricultural production etc, could enable to establish a hierarchy as a function of the different periods of crisis (out of crisis, pre-crisis, crisis and recuperation phase).

In the following table example for the Limbe council area.

Table 3: Intensity of threats in the Limbe council (area in km²).

Hazard	INTENSITY OF THREAT				Total
	weak	Moderate	High	Very High	
Lava		37.28			37.28
Fallback	170.41				170.41
Gas	170.41				170.41
Seismic		170.41			170.41
Lahar			6.29		6.29
Tidal wave	1.14	0.84	0.91	0.76	3.65
Inundation	8.31	1.17	10.11	9.53	29.12
Landslide	4.15	10.79	11.53	9.40	35.87
Deposit			22.43		22.43
Rockfall	4.26	7.24	8.40	8.22	28.12
Total	358.68	227.73	59.67	27.91	673.99

5. Threats associated with human installation and the natural milieu

From this study, an order of dimension was taken note of in the evaluation of risk. This order were regrouped under human risks, risks on strategic buildings for the management of crisis, risks on infrastructures and constructions, risks on agricultural production and the natural milieu (Zogning, 2002).

Table 4: Stakes and threats in the Limbe council.

<i>STAKES AND THREATS IN THE LIMBE COUNCIL</i>					
CATEGORY	TYPE	QTY	CATEGORY	TYPE	QTY
Potable water supply	Water supply	10	Energy	Fuel	4
Economic Centers	Trade	4		Gas	1
	Finance	8	Governance and Safety	Electrical posts	78
	Industry	9		Decision	4
	Tourism	17		Justice	1
Communication and telecommunication	Post office	1	Health	7	
	Radios et televisions	3	Safety	2	
	Telecommunication	6	Population and Housing	Worship	5
Education and Scientific Research	Research centre	2		Entertainment Halls	1
	Education	63		Stadia	1
TOTAL			Transport	Motor Parks	1
				Works of arts	28
				Sea port	2

5.1 Human risks

About 12000 people are installed in very high hazard zones principally in Limbe and to a lesser extend in Buea. They are threatened by landslides, mud flows and floods.

Close to 20000 people live in high hazards zones (old volcanic cones, thalweg, clayey slopes). About 450000 people live with a moderate threat (lava flow, fall back of ashes and seismicity).

A nursery school, 9 primary schools, 2 secondary schools are situated in very high hazard zones. In high hazard, we counted 4 primary schools and 2 secondary schools.

For all these structures, rapid sliding and mud flow constitute a principal threat.

5.2 Risks on strategic buildings and crisis management

A tenth of strategic buildings for the management of crisis are situated within or at the proximity of very high hazards zones. They are mostly situated at the centre of Buea. The other 106 important strategic buildings are situated within moderate hazard zones (101) or weak hazard (05).

Six telephone relays (where we have the CRTV relay at the proximity of Bimbria and the 3 “ELF” relay situated on the volcano) are situated in very high hazard. Four telephone relays are found in high hazard zones. Elsewhere, 30 radio-TV centres or telephone relays are situated in average or weak hazard zones.

5.3 Risks on buildings and infrastructure

Of the 50000 buildings of the study zone, 1800 are implanted in very high hazard zones and 1600 in high hazard areas. They are threatened by landslide. All the houses are threatened by a moderate seismic hazard, where about 5% are 1 storey buildings and 1% with two storeys buildings or more. In this respect, 50000 houses, that is about half, constructed with bricks/concrete, present a very high vulnerability to seismic activities. With about 10 to 50% of damages on the latter, about 1000 to 5000 houses risk to be seriously damage in case there is a destructive seismic activity in this region like that of 1999. We can envisage that in such a case, in addition to deaths and injuries about 25000 might be rendered homeless.

Out of the 550 km of principal roads (tarred or not), 19 km of main road (where 9 km are tarred) are found in very high hazard zones. 17 km (where 4 km are tarred) are situated in high hazard zones. These are principally areas of thalweg crossing, corresponding to 29 bridges.

Concerning lifelines (water supply networks and electricity), 9 km of the above-mentioned out of the 170 km installed, as well as 2.5 km of High Tension line(90 Kv) and 5.7 km line of

MT(30Kv) are threatened by a very high hazard (for a total of 100 km of MT line and 90 km of HT line respectively).

The SONARA refinery and the Limbe power plant are situated in a geologically moderate risk zone. The threat is associated to seismic activities and the flow of lava to this area, while other hazards are considered as being weak or non significant.

5.4 Risks on agricultural production

As concerns foodstuff cultivation, 30 km² are situated in very high hazard zones (Limbe-Mabeta essentially) and 50 km² in high hazard zones (slopes of Tamben-Misellele). Elsewhere, about 250 km² are situated in moderate hazard (falling back of ashes) and 650 km² in weak hazard. 2/3 of foodstuff productions (including cocoa production) are only slightly concerned with natural risks.

For industrial plantations, conclusions are equally contrasting, with 17 and 22 km² of plantations situated in very high and high hazards, while moderate hazard (falling back of ashes) concerns 78 km² located mostly on the Atlantic coast (oil palms) and the sector of Tole (tea). Equally, 360 km² of industrial plantations are situated in weak or in significant hazards, representing about ¾ of the industrial cultivable surface area.

5.5 Risks on the natural milieu

About 80 km² of dense forest are threatened by landslide on the Limbe-Mabeta massif, with a very high hazard. On the flanks of the volcano and in the sector of the Mokoko River, 380 km² of forest, dense or degraded, are situated in a high hazard zone and about 500 km² in average hazard. Close to 400 km² and 200 km², i.e. less than half of the natural milieu, are situated in weak and in significant hazard, respectively.

A greater part of the permanent hydrographic network is situated in weak hazard zone (308 km) or average hazard (36 km). Meanwhile 120 km, of rugged relief zones are concerned with landslide or mud flow.

A total of 7 maps were thus realized. These are:

- 5 maps at a scale of 1/25000 for each of the five councils of the Mt. Cameroon region;
- 1 map at a scale of 1/10000 for the urban zone of Buea;
- 1 map at a scale of 1/5000 for the centre of Limbe town, exposed to flood and soil movements hazards.

6. The RPP regulatory measures

The regulatory measures are intended to enable the different concerned authorities to take appropriate measures to safeguard the population and their resources for each council area, especially since land use is directly involved.

It will thus be conceived with the tasks of making its regulatory content rigorous but with a simple elaboration and by council area.

As a document to be used by the public and susceptible to be annexed on future urban planning documents, the document opens up with:

- an introductory note indicating clearly the reasons for the prescription of the RPP;
- the geographic sector concerned, the nature of the phenomena taken into consideration and their possible consequences;
- the mode of hazard qualification;
- the human, socio-economic and environmental stakes;
- the determination of risk zoning and rules.

Special attention will be laid on legibility of this note and its pedagogic content and more particularly on the clarity and argumentation highlighted in the description of the natural phenomena that are at the origin of the procedure and then on its regulatory transcription (zoning but equally prescriptions).

The dispositions of the regulation have to be simple, clear, precise, efficient and realistic, in order to delimit zones without any ambiguity, understood by the users of the RPP and by people and institutions consulted during the process and easily applicable.

The strategy adopted focused on reducing urbanization and construction works in the most risky sections, as well as putting in place preventive measures to protect and safeguard any resistance to council decisions forbidding these activities, not excluding incentive measures and laws, as well as sensitization.

For each zone defined by the zoning plan, it will be established:

- What is forbidden, what is allowed under certain conditions;
- Urban prescriptions and the measures for construction, development and exploitation applicable to new projects as well as resources and existing activities;
- For prevention, protection and safeguarding reasons, expulsion measures will be taken or prescribed, with a catalogue of the above-mentioned at the annex (Zogning, 1989).

The RPP is a public utility and its provisions are against third party transfer during examination of applications for occupation and/or the use of land by the competent public authorities.

The RPP regulations, if available, are a constraint on urban and/or regional planning documents and should be incorporated into previous documents. The non respect of the RPP regulations is liable to the same punishment as that provided in the Town Planning and Housing Code.

7. Conclusions

The Risk Prevention Plan has been realized at a local council scale taking into consideration the specific natural risks of each zone, with the aim of clearly drawing land use maps for risks zones, showing the overlay of stakes with risk of different intensities. This then led to the setting up of regulations that reduce the impact of natural catastrophes on human lives and properties.

For the efficiency of the Risk Prevention Plan some key recommendations were addressed to the government and municipal authorities. These mainly include dissemination and training of the results of the study.

The dissemination of the work done and the awareness of the stakeholders is one of the objectives of a new project called MIA-VITA “Mitigating and Assessing Volcanic Impacts on Terrain and human Activities”. The aim of the project is to improve the crisis management capabilities based on monitoring and early warning systems and secure communications; reduction of people's vulnerability and development of recovering capabilities after an event occurs for both local communities and ecological systems. These objectives will be achieved design of an integrated information system which comprises data organisation and transfers.

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