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Impact of Mbujimayi Airport on Groundfill Cavities in Bipemba Community

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--***ABSTRACT***--
The aim of this survey is to show how the collapse of the underground cavities in the municipality of Bipemba in Mbujimayi is one of the consequences of the evolution of airport facilities which, by disrupting the circulation of runoff water, accelerated the dissolution of the underlying limestone rocks following the intensification of infiltration in depressions where water had accumulated. To prevent and reduce geohazards, the article identifies their different characteristics and suggests some remedies.
***Key words**: subsidence, underground cavities, geohazards, air transport, Mbujimayi airport.*

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I. INTRODUCTION

Verluise F (1974), in the town planning master plan of the city of Mbujimayi, with a view to avoiding and / or delaying the onset of collapse of underground cavities, resulting in the vulnerability of the population and infrastructure, had made many recommendations to prevent and / or reduce probable geohazards. One of these recommendations was to promote the infiltration of rainwater on the ground, to avoid their concentration in the lower areas and to channel the runoff into the thalwegs of the watercourses.

For several reasons, all these recommendations were not taken into account and applied in particular in the development of Mbujimayi airport. No infrastructure for onsite infiltration of stormwater has been developed. On the other hand, runoff from airport facilities freely flows through the various thalwegs and ends either in the valleys of the Kanshi (south) and Muya (north) rivers, or in the depressions where they are concentrated. infiltrate on the spot. While the two main talwegs have become the two major ravines that directly threaten Mbujimayi airport, the various depressed areas around the airport are the seats of actual and potential subsurface cavities.

This situation, whose consequences cover physical, social and economic aspects, raises many questions. The most important of them and which constitute the problematic of this survey concern (1) the efficient documentation of the collapses and the damages which they generate, (2) the existence of a correlation between their appearance and the development of the Mbujimayi Airport, and (3) remedies to prevent, avoid and / or reduce risks.

The general purpose of this paper is to contribute to the knowledge and assessment of geohazards associated with an air transport infrastructure in Mbujimayi. Specifically, it will be a question of, on the one hand, to inventory and describe the collapses of the underground cavities, on the other hand, to put in relation their appearance with the stages of the development of the airport of Mbujimayi.

The interest of this study is to provide decision support for the prevention of natural risks of cryptokarstic environments. Our hypothesis, on the other hand, is to think (1) that a good knowledge and a good documentation of the geohazards would make it possible to prevent them and to reduce their dangerousness and (2) that the different phases of appearance of the collapses of the underground cavities would correspond, after a few years lag, with the stages of development of Mbujimayi airport.

The collapses in the city of Mbujimayi have already been surveyed and reported by Morelli (1965), Verluise (1974), Mumba Kasongo (1977), Kakule Kasereka (2016), Mbayo Kabunda (2016), Muya Cinkeleshi (2016), Kalombo B. (2016) ... It should be noted that, not only did most of this work not cover neighborhoods around Mbujimayi airport in Bipemba commune (uninhabited at the time), but also and above all, did not look for the correlation between the appearance of the collapses of the underground cavities with the stages of the development of the airport of Mbujimayi.

Tackling the cryptokarstic forms related to the impact of the Mbujimayi airport on its environment, we will limit ourselves to the municipality of Bipemba where it is located. Taking into account the time aspect, the study covers the entire period from 1970 to June 30, 2016.

In this paper we mean by collapses "gravitational movements with essentially vertical components, which occur more or less brutally. They result from the breaking of the supports or the roof of a pre-existing underground cavity. This initial break propagates vertically to the surface, determining the opening of a roughly cylindrical excavation, the dimensions of which depend on the volume of the void, its depth, the geological nature of the soil and the mode of failure. According to this mode, the surface collapse can be punctual or generalized if it concerns important surfaces (several hectares). In the first case, it is the phenomenon of “fontis” whose diameter is generally less than 50 m, and which widens with time by successive landslides of the walls ". (Ministry of Spatial Planning and Environment, Ministry of Infrastructure, Transport and Housing: 1999)

The collapse is different from the subsidence. The latter, according to Wikipedia (2016), "is a flexible, non-breaking and progressive deformation of the soil surface which results in a topographic depression in the shape of a bowl generally with a flat bottom and bent edges".

There are two natural phenomena that can create cavities: karstification and suffocation. Karstification is the phenomenon of dissolution of limestones, gypsum or salt by water loaded with carbon dioxide. The intensity of this phenomenon increases with the amount of water, its carbon dioxide content and its low temperature. This phenomenon allows the establishment of special facies that are found in the underground part (endokarst) in the form of chasms, caves or galleries, and on the surface (exokarst) in the form of sinkholes, aven (chasm) or lapiez (Wikipedia, 2016).

Suffocation is the mechanical phenomenon. It corresponds to the internal erosion generated by underground water circulation. (Wikipedia, 2016).

II. FIELD OF STUDY, MATERIAL AND METHODS

2.1. Field of study

2.1.1 The Municipality of Bipemba

Created by the ordinance-law n ° 67/221 of May 3rd, 1967, the municipality of Bipemba (Figure 1) is subdivided into 41 districts and 438 cells. With an area of 61 km², it is the largest of five municipalities in the city of Mbujimayi. Its geographical coordinates are: 23 ° 27 'Longitude East, 6 ° 08' Latitude South (Municipality of Bipemba: 2015).

Located west of the city of Mbujimayi, this urban entity is bounded on the north by the Muya River, on the south by Kanshi River; in the East, the limit is formed, on the one hand, by the Salongo avenue separating it from the commune of Kanshi in the South-East, and on the other hand, by the avenue MgrNkongolo which separates it from the commune from Diulu. . In the West, on the other hand, the municipality of Bipemba that extends to the Tshibombo site is limited by the Lupatapata Territory (Karuhije M.: 1980).

Its relief is a plateau consisting of more or less elongated hills, almost all culminating at the same altitude and separated by depressed areas. The general slope is inclined mainly towards the East and secondarily towards the thalwegs of Kanshi in the South and Muya in the North. Indeed, the highest point of the town of Mbujimayi (740 m) is in this town which is crossed by a line of main ridge of east-west orientation. The latter constitutes the watershed between the two watersheds of the commune: that of Kanshi and the other of Muya (Verluise F. 1974).

The municipality of Bipemba, by its situation (6 ° 8'latitude South,) between the equator and the tropic of Capricorn, enjoys the wet tropical climate called "subequatorial". The average annual rainfall is 1,476 mm. Its natural vegetation - the wooded savannah - hardly exists anymore. It has been replaced by ornamental and / or useful, local and / or imported plants.

Its soil is sandy-clay (85% sand and 15% clay) and several meters thick. Its subsoil, on the other hand, consists of calcareous rocks, easily dissolved by the rains, which favors the formation of the underground cavities which are at the base of the collapses and ravines in the commune of Bipemba (Kambi D.: 1984).

In 2015, Bipemba township had, as a whole, 918,972 inhabitants distributed unequally by sex and by neighborhoods as shown in Table1 in Appendix II (Commune of Bipemba: 2015).

2.1.2 Mbujimayi Airport

Built in 1958 by the Forminière (now MIBA company), transferred to the Ministry of Transport and Communication in 1960 (Ordinance-Law No. 0162/12 of Nov. 18, 1960), the national airport of Mbujimayi (FZWA according to the ICAO code and MJM according to the IATA code) is, since 1972, one of the 54 airports of the DRC managed by the RVA. It is one of the top five in the country. It is located in the RVA district in the municipality of Bipemba. Its coordinates are: 6 ° 07'16 " S, 23 ° 34'08"E and 677 m altitude. Its territorial extent theoretically covers 300 hectares, but practically it does not remain more 169 hectares (1.69 km²) for a perimeter of 6.54 km because of the invasion of its site by the houses.

Its runway, 2000 km long and 45 meters wide, and oriented S-E-N-O, is known as Runway 17/35 (Figure 2). By its altitude (677m), the Mbujimayi Airport, located on the top of an elongated hill, is a center of dispersal of runoff water particularly towards the northeast and the east on the catchment of the Muya river.

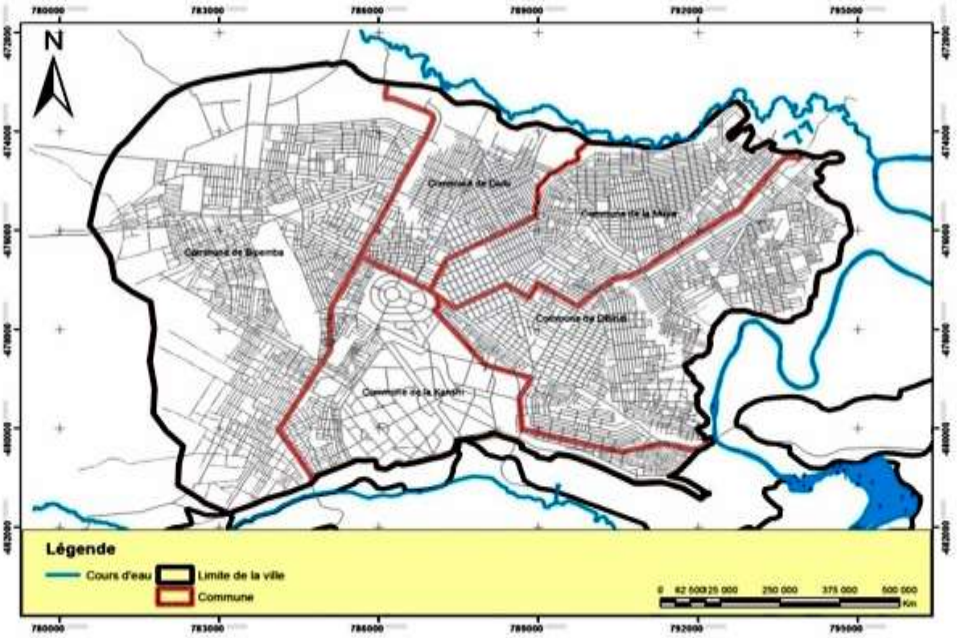

Figure 1 The municipality of Bipemba in the city of Mbujimayi

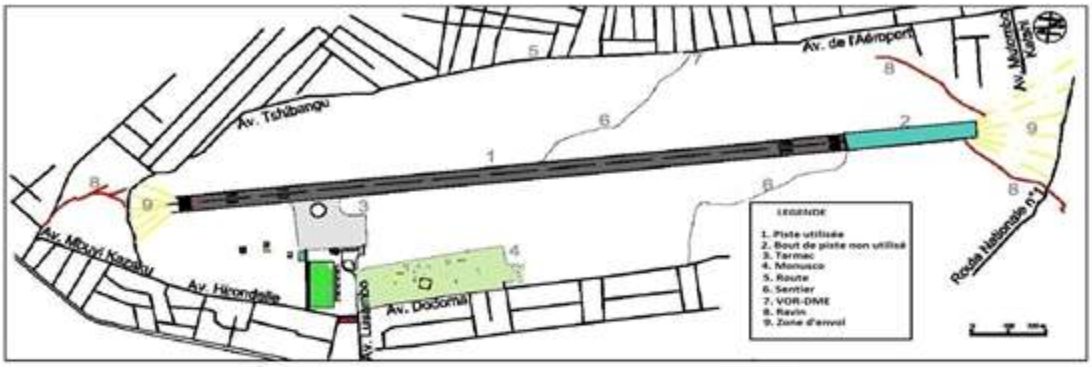

Figure 2 Mbujimayi Airport: Facilities diagram

2.2. Equipment

To carry out this survey, we used the following equipment: GPS, computer tools, software (QGIS, ENVI 4.2) a rope, a decameter, the field book and aerial photos (aerial cover of Mbujimayi, 1970).

2.3 Methodology

The study of geohazards or natural hazards belongs to the geo-cindynic or geo-science of risk (Faugères L,: 1991). As a working method, cindynic combines aspects of natural sciences (geology and meteorology for natural disasters, chemistry and physics for industrial disasters), aspects of human sciences (psychology, urbanism, economy). It knows downstream possible applications in IT (disaster continuation plan) or in the management of complex strategic projects.

Risks are analyzed as carrying a probability of binary realization ("realizes" or "does not happen"). It is thus possible to predict possible downstream chains of risks and thus to quantify the financial allocation required to remedy them. This is called a risk tree (Faugères L,: 1991).

To study the collapse of underground caverns in Mbujimayi, we mainly used the working methods used in geomorphology and urban planning. These are direct observation, field investigation, remote sensing, aerial photo reading and mapping.

For field investigations, we had a GeoorisCAgeorisks fact sheet, (Georisks in Central Africa) initiated by the Royal Museum for Central Africa (RMCA), in partnership with the University of Liege and University

of Brussels (GEORISKA.fr), which we have adapted to our problematic and our theme (see Appendix I). This sheet consisted of three parts. The first one describes in a detailed way the current situation of the collapses, the second part tries to reconstitute the history of each collapse and its initial morphology and finally the third inventories the material as well as human damages by distinguishing the effective damages and the damages potential. For this study, we limited ourselves to the first two parts that identify and characterize the collapses.
Assisted by three investigators, we traveled from 5 January to 10 July 2016, the different neighborhoods around the Mbujimayi airport in Bipemba township, first, to identify, observe, describe the collapses and their damage, on the other hand, to question the privileged witnesses of their appearance to complete our observations. An investigation sheet was completed for each collapse. The main results of the counting have been recorded in a general table (Appendix III) and in the small sectoral tables which are commented on and interpreted throughout this paper.

III. PRESENTATION AND INTERPRETATION OF THE RESULTS

3.1. Number and distribution by quarter

Table 3.1 and Figure 3 show that the municipality of Bipemba has recorded until 30 June 2016 twenty five collapses of underground cavities. The sinkholes thus engendered are located in only six of the 41 neighborhoods in the commune. These are the following quarters and in descending order: From the Mission (15 i.e. 60%), Ciombela (5 or 20%), Kalundu (2 or 8%) and the last three (Kabuacia, Kankelenge and Tshintunta) each has a collapse of 4%.

Table 3.1. Number and occurrence by quarter

Quarters	Superficy	Number	Percentage
Ciombela	2 km²	5	20%
De la mission	1 km²	15	60%
Kabuacia	1 km²	1	4%
Kalundu	1 km²	2	8%
Kankelenge	1 km²	1	4%
Tshintunta	1,5 km²	1	4%
Total	7,5km²	**25**	**100%**

Source: personal survey, 2016

The six affected quarters are on the Muya watershed due to two east of Mbujimayi Airport (Mission and Kalundu districts), two in the Northeast (Ciombela and Kankelenge) and the last two (Tshintunta and Kabwacia) in the North. Most of the runoff from the Mbujimayi airport facilities flows east and northeast.

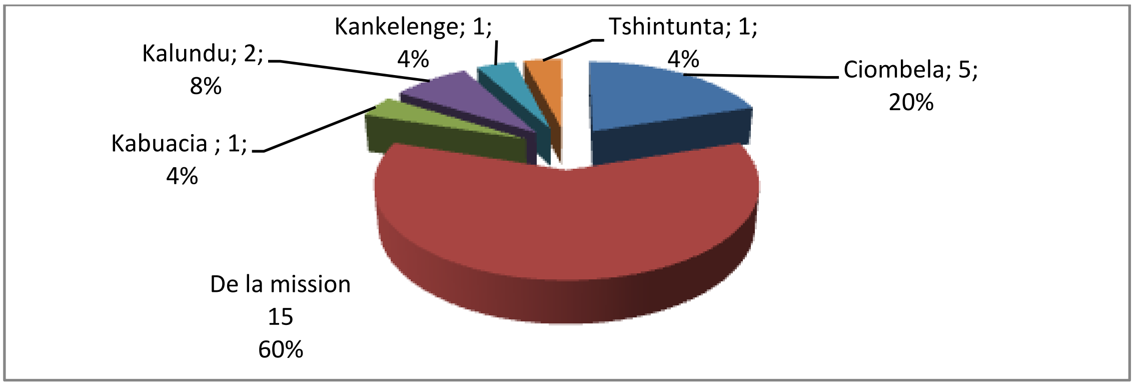

Figure 3 Distribution of collapses by quarter in the municipality of Bipemba

As shown in the map below, the actual collapses appear to be aligned on a diagonal that would connect the north end of the airstrip with the animated (currently destroyed) roundabout at the intersection of MgrNkongolo Avenue and the Kalonji Avenue. They are in fact situated in the SO-NE directional trough that connects the Mbujimayi airport hill to the Muya river (see Figure 4 in Annexes I and II). But this thalweg does not succeed directly. It passes through some depressed areas located in Kalundu neighborhoods, Mission, etc. But the most important is in Ciombela (598 m), at the junction of MgrNkongolo and Kalonji avenues. It is a vast depression that overflows the town of Diulu in Masanka and Nkuluse neighborhoods where is its lowest point. It was here that runoff from the MIBA town and those along the MgrNkongolo and Kalonji avenues were dumped before the excavation channel (between 1977 and 1980) was dumped into the Muya River. Unmapped and stabilized, this channel became the famous Mbala wa Tshitolo ravine through which most of the Bipemba and Diulu runoff flows.

This alignment of subsurface cavities along the thalweg, from Mbujimayi Airport via a few depressed areas to the Muya River, suggests that subaerial traffic would correspond to an underground circulation.

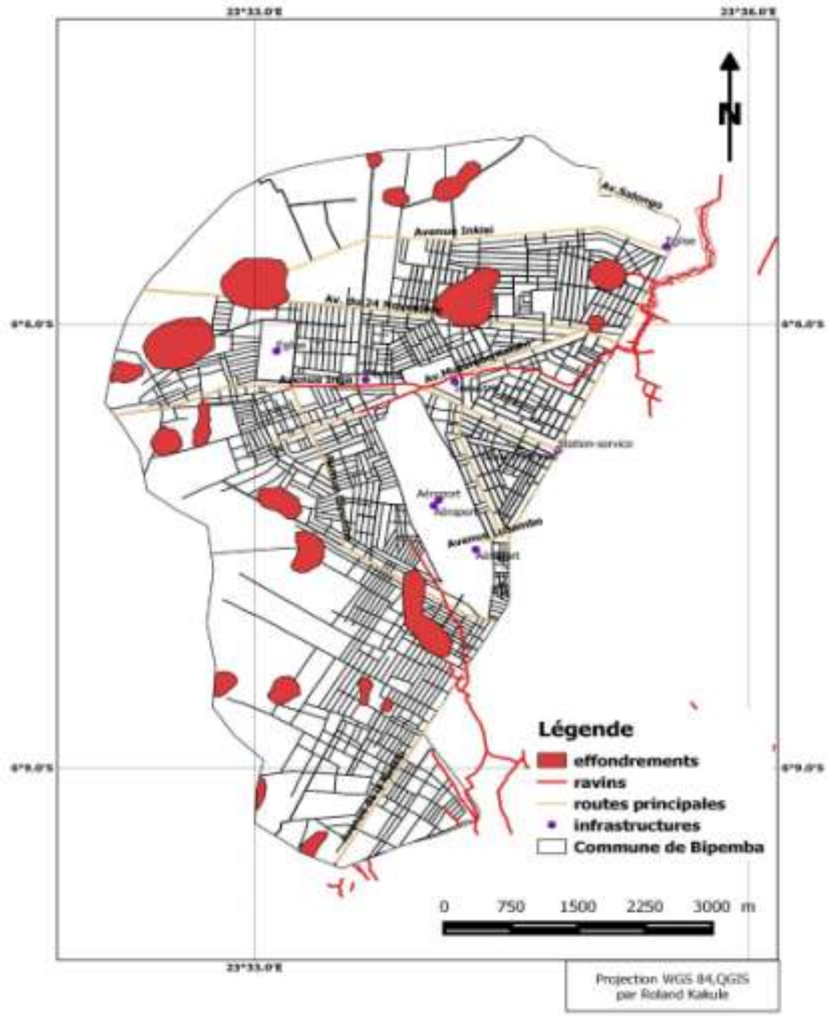

Figure 3: the collapses in Bipemba township

3.2. Background of collapses of underground cavities in Bipemba

The genesis of downfalls of the underground cavities describes a curve in bell (Picture 3.2 and face 4) shows that before 1990, Bipemba township had not recorded any downfall. It is from the decade 1991-2000 that appear the first five downfalls, that is 20%. The biggest number, 14 cases represent 56%, reached during the decade 2001 - 2010. The decade 2011 - 2016 recorded only six downfalls, that is 24%.

Table 3.2. Distribution of collapses by date of occurrence

Quarters	**Before 1990**	**From1991 to 2000**	**From2001 to 2010**	**From2011 to 2016**	**Total**	**%**
Ciombela	0	3	1	1	5	20
De la mission	0	0	10	5	15	60
Kabuacia	0	0	1	0	1	4
Kalundu	0	1	1	0	2	8
Kankelenge	0	0	1	0	1	4
Tshintunta	0	1	0	0	1	4
Total	0	**5**	**14**	**6**	**25**	**100**
%	0	**20**	**56**	**24**	**100**	

Source: personal survey, 2016

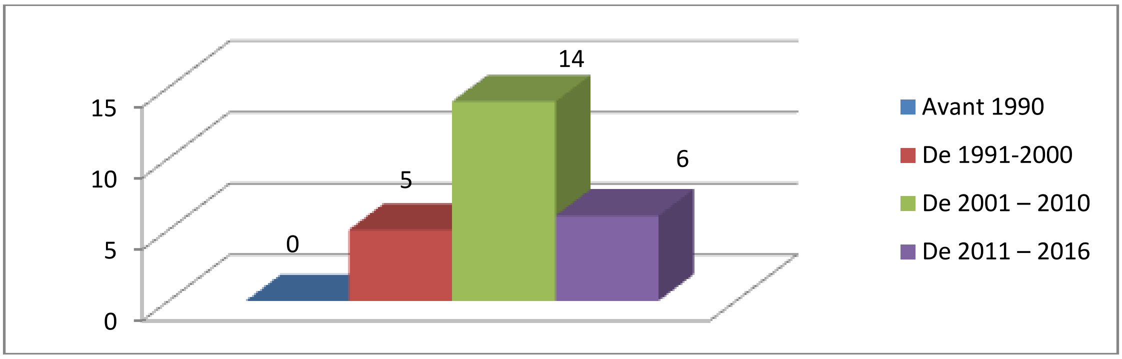

Figure 4 Distribution of collapses by date of occurrence

Throughout the story of the collapse of the underground cavities, it is necessary to glimpse the different stages of the evolution of the Mbujimayi airport. Indeed, the various works of development, extension of buildings and sheds, strengthening and lengthening of the runway, carried out without respect of the recommendations of the urban master plan (1974), have not only disorganized the infiltration of water and the circulation of runoff water, but also and above all, favored their concentration and infiltration in the depressed areas, located more or less far from the airport. It followed the acceleration of the dissolution of limestone, the formation of underground cavities and later its collapse and / or itssubsidence.

With regard to the acceleration of the dissolution of limestones, Verluise F. (1974) notes that "if we consider an area of one hectare having undergone this transformation on which only 1/3 of the rainwater would no longer be absorbed at even at the point of the fall and in a system of gutters or ravines, one realizes that the quantity of water flowing annually at the low point of the main collector over a surface of one square meter is finally 300 times greater to that received and absorbed before urbanization ".

Before 1990, Bipemba township had recorded no collapse (Table 3.2 and Figure 4) whose origin could be related to airport facilities. Indeed, before 1974 -1975, the Mbujimayi airport runway measured less than 2000 meters, the facilities were rudimentary, the immediate area of the airfield was uninhabited and invaded by the bush. As a result, the rate of dissolution of limestones by rainwater infiltrating mainly at the site of their fall was low.

After 1975, following the extension works, lengthening of the runway (to reach 2000 meters in length) and construction of the control tower and various buildings, the subdivision of the east face of the airport, the waters rains falling on the east face do not infiltrate more on the spot. They flow eastward along Lusambo Avenue. Part of it slips north-east into the neighboring Kalundu neighborhood where part of it will stagnate in the Dijiba cell while the other will cross the national road No. 1 to the Mission area in the Nkatshia and Kanzewu cells. Another part continues to the Salongo roundabout and then goes north along Salongo Avenue and then to MgrNkongolo Avenue and ends in the depressed area at the junction of MgrNkongolo and Kalonji avenues in the Ciombela district. Lumière,Bialushiku and Lubi cells. This situation must have accelerated the dissolution of the limestone in the cells where the infiltration was concentrated, resulting in the collapse of the underground cavities 15 years later (in the decade 1991-2000 and the beginning of the decade 2001-2010).

The 400-meter surface course, erosion control and runway rehabilitation works carried out between 2000-2001 also contributed to the increase in the amount of runoff. While the subaerial circulation gave rise to a large ravine that connects the north of the airport to the Mbala wa Tshitolo ravine (north-east of the airport), the underground circulation continued and led to further collapse of the cavities. underground in the same neighborhoods after 2011.

3.3 Installation altitude

Table 3.3 indicates that seventeen or 68% collapses are between 601 and 610 meters above sea level, compared to 7 or 28% between 591 and 600 meters above sea level. Below 590 meters above sea level, there is only one case, ie 4%. Indeed, the collapses did not occur at the lowest points of the city, that is, in the bottoms of the Kanshi, Muya and Mbujimayi valleys, but in the depressed areas between the plateau hills. sandy-clayey of the municipality of Bipemba. These are located within a radius of more or less one kilometer from Mbujimayi Airport, which rises to 677 meters above sea level. According to Lukusa M. (2014), Mbujimayi Airport is a dispersal center for runoff to the North - Northeast, East and Southeast. But these waters pass through a few depressions where they concentrate and infiltrate on the spot. Appendix III and Table 3.3 provide information on the names of neighborhoods and cells where these depressions are located.

Table 3.3 Distribution of collapses by implantation altitude

Quarters	Altitude in meters				Total	%
	From 581- 590	From 591-600	From 601 – 610	From 611 – 620		
Ciombela	0	4	1	0	5	20
De la mission	0	2	13	0	15	60
Kabuacia	1	0	1	0	1	4
Kalundu	0	0	2	0	2	8
Kankelenge	0	0	1	0	1	4
Tshintunta	0	1	0	0	1	4
Total	1	**7**	**17**	**0**	**25**	**100**
%	4	**28**	**68**	**0**	**100**	

Source: Personal Survey, 2016

3.4 Location and conditions of occurrence of collapses

A checking of Table 3.4 reveals that the cave cavern collapses in Bipemba township occurred only in inhabited areas during the rainy season and after rainfall. In fact, residential houses, as well as road construction, contribute to the waterproofing of the soil, favoring the runoff and the concentration of water in the depressed areas where they will infiltrate. The consequence is the important and rapid dissolution of the limestone and formation of the underground cavities.

Table 3.4 Location and condition of occurrence

Quarters	Implantation site		AppearanceConditions	
	Inhabited zone	Uninhabited zone	Afterone rain	Othermoment
Ciombela	5	0	5	0
De la mission	15	0	15	0
Kabuacia	1	0	1	0
Kalundu	2	0	2	0
Kankelenge	1	0	1	0
Tshintunta	1	0	1	0
Total	**25**	0	**25**	0
%	**100**	0	**100**	0

Source: Personal Survey, 2016

3.5. Other features of the collapses in the municipality of Bipemba

3.5.1. Form

The direct observation of the phenomena on ground allowed us to note that the collapses present two main forms: circular, elongated or irregular.

Table 3.5 shows that circular collapses (15) are by far the most numerous. They represent 60% of the total. The elongated and / or irregular sinkholes constitute 40% of the total population.

Table 3.5. The forms of collapse in the municipality of Bipemba

Quarter	Circular	elongated/ Irregular	Total	
	Number	Number	Number	%
De la mission	10	5	15	60
Kabuatshia	0	1	1	4
Kalundu	0	2	2	8
Kankelenge	0	1	1	4
Tshintunta	1	0	1	4
Ciombela	4	1	5	20
Total	**15**	**10**	**25**	**100**
%	**60**	**40**	**100**	

Source: Personal Survey, 2016

The circular form often characterizes young collapses and / or who have not yet experienced some external actions. The shape of the old collapses, having already experienced the action of erosion (gully, landslide, coalescence with neighboring sinkholes, etc.), is more or less elongated and / or irregular. Table 3.5 gives their breakdown by neighborhood.

3.5.2 The dimensions of the collapses

The table in Annex III provides information on the main dimensions (diameter, depth, area and perimeter) of the 25 collapses encountered in the municipality of Bipemba. But Table 3.6 gives the average, the minimum and the maximum. The following observations stem from his examination: - The average diameter of the collapses is 33.64 m, with a maximum of 200 m and a minimum of 12 m; - The average depth of the collapses is 3.42 m, the maximum being 7 m against a minimum of 2 m. - Their average surface is 1766 m², for a maximum of 21000 m² and a minimum of 96 m² - The average perimeter is 136.56 m against a maximum of 1140 m and a minimum of 40 m.

Table 3.6. The dimensions of the collapses in the municipality of Bipemba

	Minimum	**Maximum**	**Average**
Diameter in m	12	200	33,64
Depth in m	2	7	3,42
Surface in m²	96	21000	1766
Périmeter in m	40	1140	136,56

Source: Personal Survey, 2016

The dimensions of subsurface cavities collapse as they age. The diameter increases with the evolution of the collapse. Thus the young collapses have a smaller diameter than the old collapses having experienced many erosive events: landslide, bank erosion, coalescence with neighboring sinkholes, etc. This variation of the diameter also causes that of the surface and the perimeter. As for the depth, it decreases with aging. The recent collapses are deeper than the old ones, which are gradually filling up with the help of the erosive and anthropogenic activities taking place there.

3.5.3 Types of funds and use of collapses

The shape of the bottom and the use of the collapses also make it possible to distinguish them and to characterize them. The information in Table 3.7 shows the existence of three types of bottoms: flat, dissymmetrical and funneled. The flat bottom collapses (12) are the most numerous. They represent 48% of all. The collapses with funnel bottom (8 cases) constitute 32% of the total against 20% or 5 cases for those holding an asymmetrical bottom.

Table 3.7. Types of funds collapses in the municipality of Bipemba

Quarter	flat bottom	asymmetrical bottom	funnel bottom	**Total**	
	Number	**Number**	**Number**	**Number**	**%**
De la mission	4	5	6	15	60
Kabuatshia	1	0	0	1	4
Kalundu	2	0	0	2	8
Kankelenge	1	0	0	1	4
Tshintunta	1	0	0	1	4
Ciombela	3	0	**2**	5	20
Total	**12**	**5**	**8**	**25**	**100**
%	**48**	**20**	**32**	**100**	

Source: Personal Survey, 2016

Morphology explanatory factors of the bottoms of collapses in Bipemba consist of the following:the position of the absorption point in the center or on the periphery of the collapse, the sedimentation, the direction of surface water flow, the age, etc. Table 3.8 provides information on the use of collapses. It shows that 64% of the collapses are cultivated. It is in fact the old collapses, in process of filling and whose bottom, following the sedimentation, lined with clay, retains moisture. The surrounding population takes the opportunity to cultivate, depending on the area of the collapse, vegetables, banana, corn, fruit trees, etc. The permanent presence of water (2 cases), sand (5 cases or 20%) and the great depth (2 cases or 8%) explain the non-development of other collapses. The bamboos have been planted in the deepest of them, in order to stabilize the slopes.

Table 3.8.Use of funds from collapses in the municipality of Bipemba

Quarter	**Culture**	**Water**	**Dry**	**Vegetation**	**Total**	
	Number	**Number**	**Number**	**Number**	**Number**	**%**
De la mission	8	1	5	0	15	60
Kabuatshia	0	0	0	1	1	4
Kalundu	2	0	0	0	2	8
Kankelenge	1	0	0	0	1	4
Tshintunta	1	0	0	0	1	4
Ciombela	4	1	**0**	1	5	20
Total	**16**	**2**	**5**	**2**	**25**	**100**
%	**64**	**8**	**20**	**8**	**100**	

Source: Personal Survey, 2016

IV. CONCLUSION

At the end of this survey, we recall that our objective was to contribute to the knowledge and evaluation of geohazards related to an air transport infrastructure in the municipality of Bipemba in Mbujimayi. In order to achieve this, we first have inventoried and described the characteristics of the collapses in this township. Then, we have sought the correlation between the location of the collapses, the dates of their appearance and the successive phases of the development. from Mbujimayi airport.

The town of Bipemba has 25 collapses of underground cavities or sinkholes located in only six quarters to the east and northeast of Mbujimayi airport. The district of "De la Mission", with 15 sinkholes or 60% of all, is the most collapsed of the municipality, following its location in a depressed area located in the thalweg connecting the airport to the roundabout facilitators. They all occurred in the middle of houses, during the rainy season, after heavy rain, and in depressed areas within a radius of about one kilometer northeast of Mbujimayi airport. Their shape is essentially circular (60% of cases) while the flat bottom (48%) and funnel bottom (32%) are the most widespread. Their average diameter is 33.64 meters. The average depth is 3.42 meters; the average surface area is 1766 m^2 against an average perimeter of 136.56 m^2. Finally, the oldest of them, being filled and the bottom is lined with clay are cultured (64%) against 20% used as a dump and 8% filled with stagnant water.

The story of the occurrence of collapses and their location have shown some correlation with the development phases of Mbujimayi Airport. In fact, the non-respect of the recommendations of the master plan of urban planning during different phases of development of this air transport infrastructure increased the quantity of water infiltrating in the depressions located downstream and accelerated the dissolution of the limestone under underlying. Thus, the collapses that could have occurred in natural conditions a century or more before (Nicod J: 1972, Verluise F.: 1974) occurred fifteen to twenty years after the different periods of development of this infrastructure.The other depressions located upstream of the airport, that is to say to the west of the latter, have not yet recorded collapses of the underground cavities.

To prevent the occurrence of collapses or geohazards and reduce their dangerousness, we invite all stakeholders in urban development to respect the recommendations of the master plan for urban planning, in particular: to encourage the infiltration of rainwater at their point of fall avoid concentration in low areas, channel runoff into the water troughs and do not subdivide depressed areas.

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