



Dynamics of landslides and their impact on the Lake Kivu coastline for the period 2018 to 2020 (Nyabibwe, Kalehe Territory, South Kivu, DRC)

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Abstract

The North-Western zone of Lake Kivu in general and more particularly the site of the French of Nyabibwe, in the territory of Kalehe has always been the object of natural phenomena such as land movements (landslides, erosion, mudflows, landslides). These phenomena are often linked to natural causes such as: tectonics (the presence of active faults and earthquakes linked to the Rift), gravity (the important relief), the alteration of rocks in a tropical climate due to tropical rains and anthropic causes such as: embankments, excavations, mining quarries, deforestation, bad cultivation practices on the slopes.

At the Nyabibwe site, landslides have been observed for decades, accompanied by subsidence, particularly at the site known as "chez les Français", where these phenomena cause the cutting of the N2 national road. Their causes are essentially tectonic because it is located on the intersection of two faults, one of which is oriented North-South and the other West-North West. In addition to this, there is the slope of more than 20°, the orographic rains, the lithology (alteration of schistose rocks); the deforestation and the cultures on strong slopes.

The dynamism of these ground movements was studied from the analysis of data obtained by measuring the distances (spacing) between the various points located around and in the selected disaster area that surround this site. Data of distances are obtained using a tachometer or laser beam distance meter brand Leica TCRM 1102 Plus.

Keywords: Dynamics, sliding, distance meter, coastline

Introduction

In recent decades, the number of disasters reported each year has increased dramatically from less than 100 in 1975 to more than 400 in 2010 (CRED, 2011) ^[4]. At the same time, the number of people affected by disasters and their economic impacts has increased (YOSHI S., 2011) ^[16]. Major incidents can be caused by seismic movements (earthquakes) and heavy rainfall (Moeyersons and Trefois, 2004) ^[10]. Numerous medium-sized incidents around the world are reported annually and these are more significant in terms of national impact due to lack of risk assessment, inability of local government to respond, and lack of community awareness and preparedness.

Rural areas with large populations face landslides established on known floodplains, mud and debris slides combined with flooding continue to take lives and devastate property (Walpole, 2007) ^[15]. Many human lives are destroyed due to earthquakes, and landslides at the onset of heavy rains; The study area has a rainy climate ranging from 1500 mm to 1800 mm per year and two seasons where the dry season runs from June to August and the rest is rainy (NSIMBA *et al.* 2014) ^[12].

Moeyersons and Trefois (2004) ^[10] suggest that the most obvious geomorphic change taking place in Central Africa is the changing hydrological regime of rivers and other streams in areas with similar morphological characteristics to these ecosystems. This phenomenon is growing and generating related problems, including water shortages, subsidence and other types of mass movements. Physical and human aspects that concern us find their place in a book that reproduces the proceedings of a symposium on the Great African Rift (De Dapper and De Lame, 2006) ^[3].



Fig 1: Landslides feeding debris into the river

Generally, topographic factors play an important role in explaining the occurrence of landslides (Corominas *et al.* 2014) ^[1]. Maki and Dewitte (2014) ^[7] show, in a preliminary regional analysis of landslide predisposing factors on mountainous slopes in western Lake Kivu, that altitude, slope, slope orientation, and distance to the drainage network are favorable to landslide susceptibility. Depending on the type of process, the vegetation cover is more or less affected (CRUDEN & VARNES, 1996) ^[2]. In general, in the presence of a deep movement, i.e. where the rupture surface is at least 3 m deep (KEEFER, 1984), the vegetation of the displaced mass can remain almost intact at the level of the homogeneous blocks; at this depth, the rupture affects little the rooting zone. In contrast, in the case of a sunken landslide, much of the vegetation cover may disappear as a result of displacement.

Predisposition factors

The predisposing factors (topography, geology, soils...) are natural factors in the landscape that contribute to the formation of landslides, which are among others heavy rainfall or a major earthquake allow the movement of materials under the pull of gravity. These mountainous reliefs are constantly being rejuvenated by the tectonics of the Rift since the Tertiary and Quaternary to this day (Villeneuve, 1980) ^[14].

The geological nature of the terrain is one of the main factors in the appearance of these phenomena, as are water and slope. The materials affected are very varied (marly or schistose rocks, altered tertiary formations, fine colluviums, clayey moraines, etc.) but globally the presence of clay in high proportion is always an unfavorable element considering its bad mechanical characteristics. The saturation of the ground in water (presence of springs, heavy precipitations,) also plays a driving role in the triggering of these phenomena.

Soils

The dominant soils are sandy-clay in the valleys and along

the shores of Lake Kivu (Figure 2), but on the hills and slopes of certain plateaus, the soils are thinner because they are generally degraded by erosion. In the highlands, where erosive action is less intense, the soils are fertile and are more suitable for agro-pastoral use as a whole. The conquest of new arable land and the supply of woody resources are pushing the population of the region to destroy more and more of the forest, of which only a few relics remain (Mudinga *et al.* 2013) ^[11].



Fig 2: Sites of the measurements in Nyabibwe at the French - source Google Earth

In conclusion, during this period there was less rainfall and the area was more or less stable compared to the previous quarter.

Methodologies

To carry out this study, three types of data were basically used:

- Field surveys and direct observations complemented by indirect observations from Google Earth satellite images;
- Analytical data based on semi-structured interviews;
- The reading of various available reports.

These field observations were completed by the interpretation of Google Earth satellite images, which are freely available and easy to use. Indeed, Google Earth is a powerful tool facilitating observation over a large area, especially the less accessible one, for geomorphological observations such as landslide inventory, anthropogenic activities... (Fisher *et al.* 2012). In our study area, Google Earth images from before the landslide was triggered allowed for landscape recognition on the mountain slopes, the river's path from upstream to downstream,

... On the other hand, the images taken after the passage of the flow inform on the identification of landslides, the presence of stone blocks and the enlargement of the valley, the extent of damage on the national road No. 2; In addition, the geographical coordinates were taken on the Google Earth images for the identification of sites of interest to our study

3. Results and Data Processing

a. Data processing

The literature review was done around the themes of geomorphological processes of landslides leading to debris flow, disaster management of the kind.

In addition, the cartographic data were processed using the cartographic software Quatum GIS

2.14 For the realization of thematic maps. Some diagrams were established to delimit the disaster sites and the graphic data were realized by the Excel software.

Results

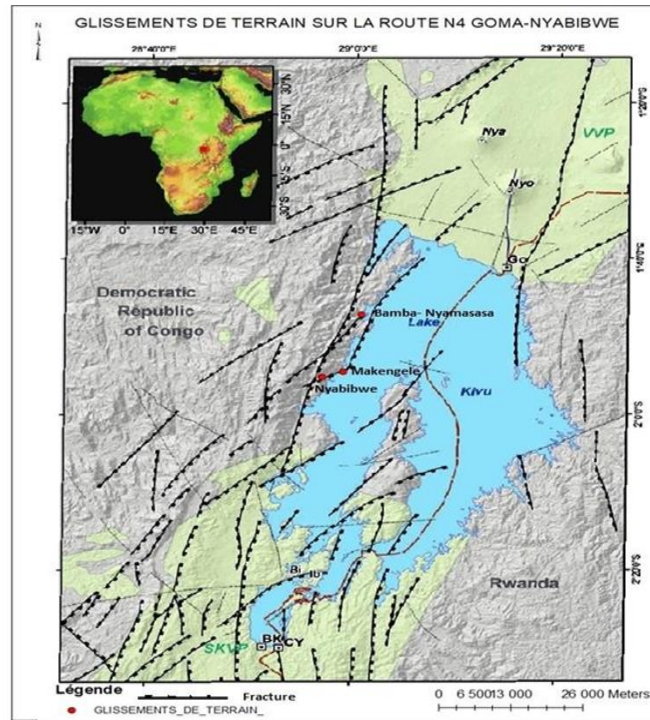


Fig 3: Illustration of landslides on the national road number 4 GOMA NYABIBWE

A. EDM measures

From the hydrant to the plank house

Table 1

Date	Distances	Variations in meters	Variations
Tuesday, July 31, 2018	341,8837085	Initial measurement	0
Thursday, August 30, 2018	342,0587524	0,1750439	0,175m
Friday, December 22, 2019	343,678932	1,7952235	1.795m
Thursday, January 28, 2020	343,768956	1,8852475	1.885m
Friday, February 21, 2020	343,956421	2,0727125	2,072m
Friday, March 27, 2020	343,994963	2,1112545	2,111m

Number of EDM measurements made per year during our study

2. Variation of the distances by putting

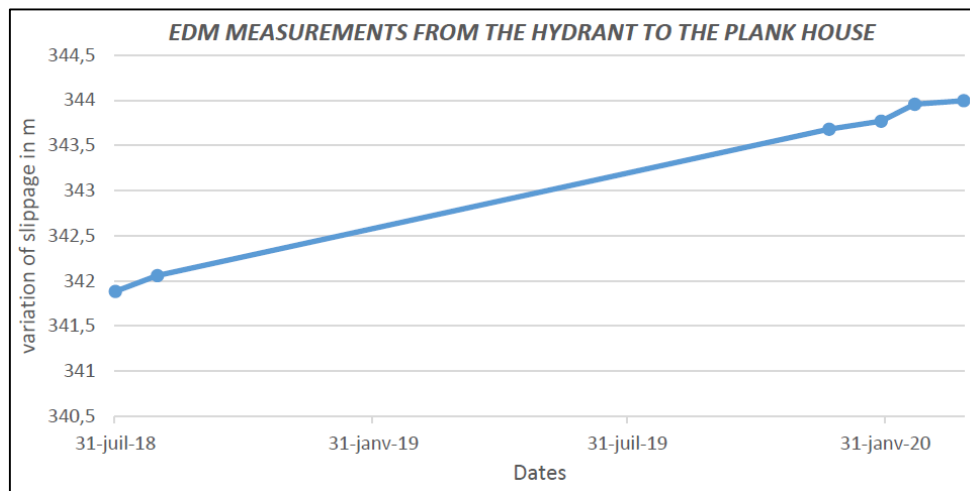


Fig 1

The change in gauges went from 341.8837085m on July 31, 2018 to 343.994963m on March 27, 2020, that is a change of 2.11m in one year and 9 months

All the landslides are located on the fractures along Lake Kivu (see map below), they are on the National Road N°4 see pictures N°4



Fig 4: Bamba Nyamasasa landslide on the N2 road -source Google Earth

The landslide that threatened to cut off the Goma-Bukavu road at Bamba in Nyamasasa at coordinates 01.78714°South, 029.00676°East at an altitude of 1529m is evolving in the sense that the road at this site has already subsided by 30cm

and the nozzles are already broken. If measures are not taken in time, the road traffic will also be interrupted for a while at this location (cfr fig. 2).

Road collapses



Fig 5: Subsidence and sliding of the road at Bamba-Nyamasasa



Fig 6: Landslide at Makengele Chez les Français -source Google Earth

On Thursday, April 30, another landslide occurred at Makengele at the bridges at $1^{\circ} 54' 33.17''$ S and $28^{\circ} 58' 38.07''$ E and traffic on the road was interrupted for ten days. During the night of May 14 to 15, the earth slipped again at the same place cutting again the road and the traffic interrupted (Cfr fig. N°3et 4).

Recall that a landslide occurred at this site in 2018 and interrupted traffic on this stretch for about ten days.



Fig 7: Landslide at makengele on the Goma-Bukavu road

C. From the Nyabibwe landslide



Fig 8: Landslide area at Nyabibwe Chez les Français -source Google Earth

Routine measurements were carried out in the landslide area in Nyabibwe where subsidence continues on the National Road N°2 at the level of the French.



Fig 9: Subsidence zone at Nyabibwe Chez les Français

Conclusion

The study of EDM measurements from July 31, 2018, to March 27, 2020, shows a total distance change of 2.11 meters. The increasing variation highlights ongoing geotechnical issues, particularly around Lake Kivu's fractures. Notable landslides, such as those at Bamba Nyamasasa and Makengele, have resulted in significant road subsidence and interruptions, emphasizing the critical need for timely intervention. The repeated disruptions, including the subsidence of roads and damage to infrastructure, underscore the urgency for continuous monitoring and preventive measures to mitigate further impact on road traffic and infrastructure stability.

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