Scientia splendet et conscientia

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GEOMORPHOLOGY
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Vulnerability mapping for sustainable hazard mitigation in the city of Bukavu, South Kivu DRCongo

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Presentation outline

I. INTRODUCTION

I.1Geographic setting

I.2 Objectives

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II. CAUSES OF THE LAND DEGRADATION

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III. DIACHRONIC ANALYSIS OF THE DEVELOPMENT OF BUKAVU & HAZARD MAPPING

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I. INTRODUCTION

I.1 Geographic setting

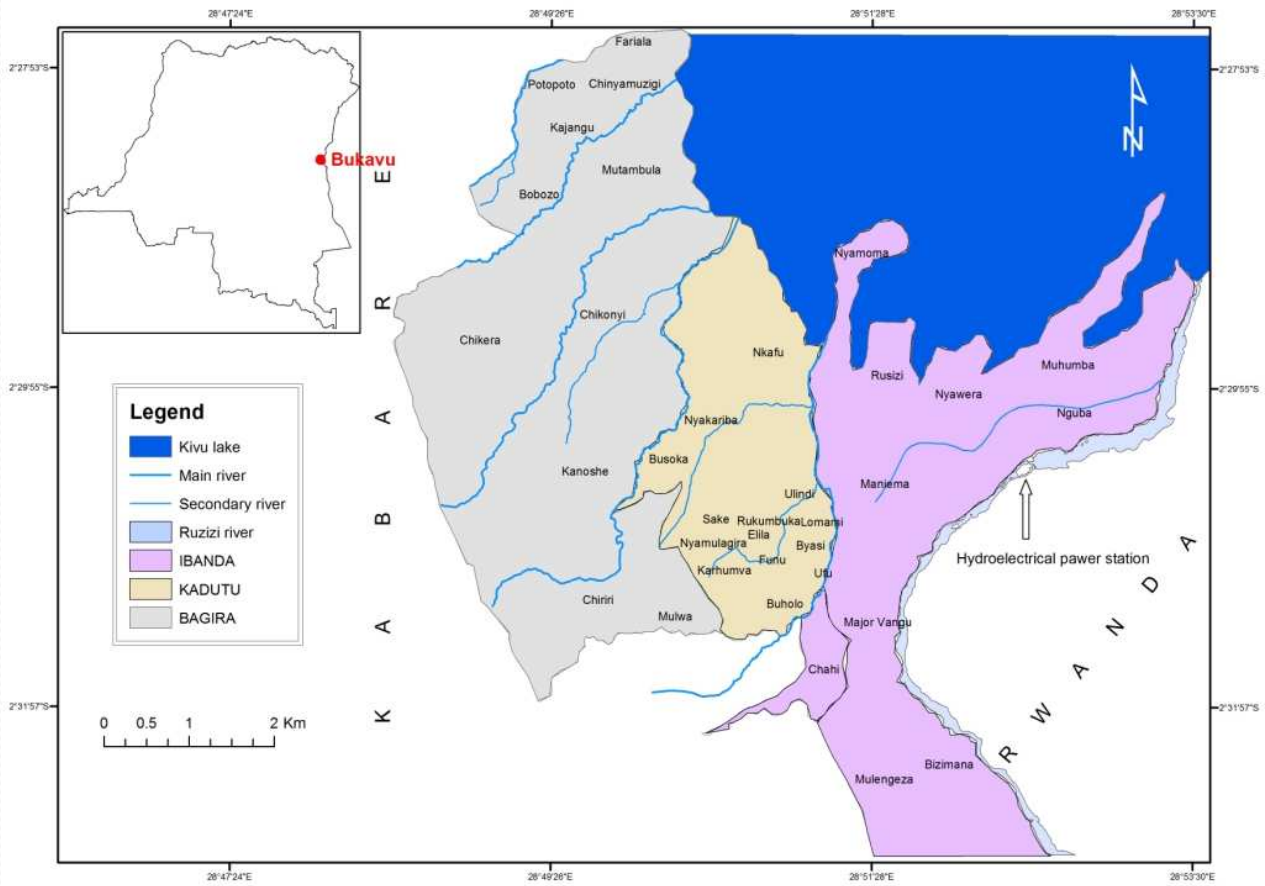


Figure 1: Bukavu city location

Bukavu city is: 2°31.1' and 2°33,1' southern latitude and 28°48.4' and 28°53.6' eastern longitude (Fig. 1).

The town is separated from Rwanda by the Lake Kivu (1460m of altitude) and the Ruzizi River.

Administratively:Ibanda, Kadutu and Bagira) with an area of 60km^2.

I.2 Objectives

This study presents the natural as well as human factors which are responsible for the land degradation and the increasing vulnerability of the population of Bukavu to natural hazards.

I.3 Methodology

1) Review of existing studies was undertaken

2) Make an inventory of natural hazards in the region in a way to allow the comparison of different causal factors and the occurrence of events

3) Analyze existing climatic data and Make a diachronic analysis of the development of the city by showing interactions between the rapid urbanization and the landscape stability using GIS and Remote Sensing

4) Propose ways to reduce the vulnerability of people and consequently the risk

I.2 Observations

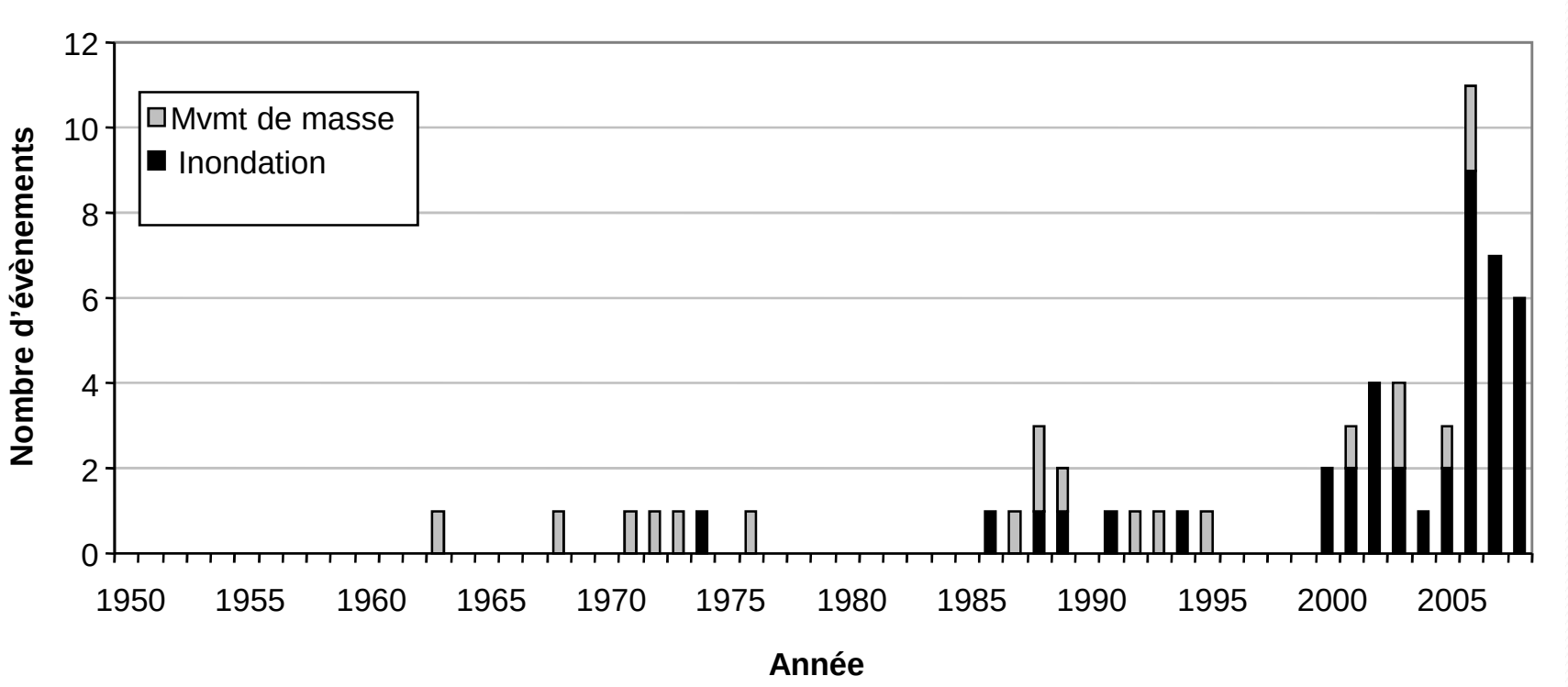


Figure 2: Number of Natural Hazards recorded in the great lakes region from 1950 to 2010 (Ine Vandecasteele *at al*., 2009)

It has been noticed these last few decades an increase in natural disasters(mass movements and flooding) in the region of Kivu-Rwanda-Burundi) in general (Fig. 2) and particularly in the province of South Kivu (Fig. 3).

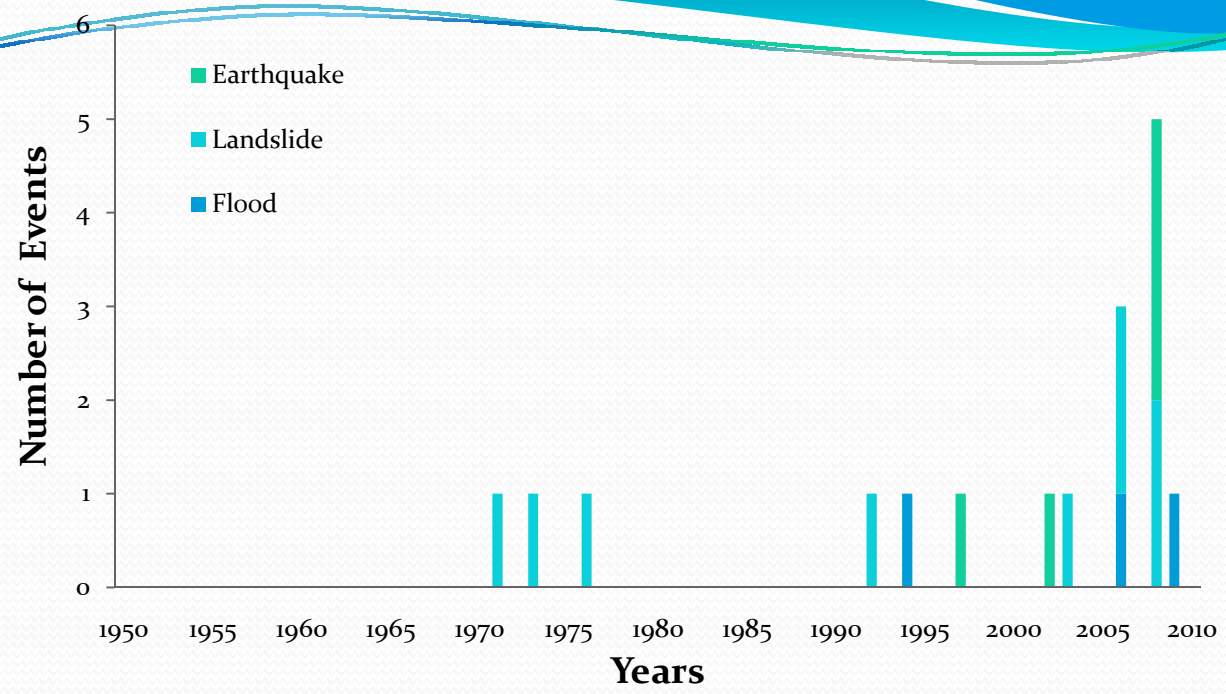


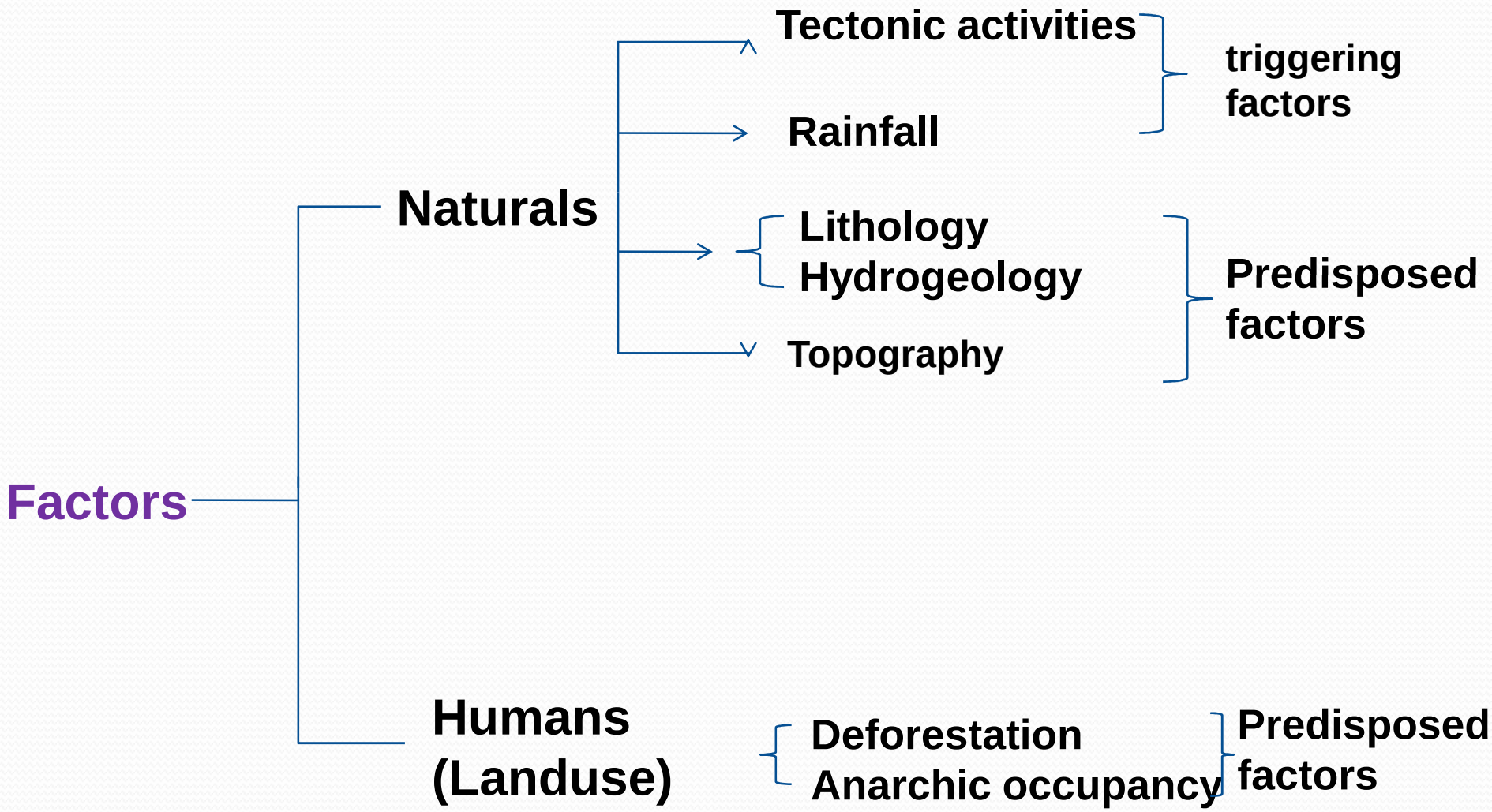
Figure 3: Number of Natural Hazards recorded in South Kivu from 1950 to 2010 (Data source: RMCA)

In Bukavu from 1950 to 2010 (table 1): fragmentary data

Table 1: Hazards tracking in Bukavu from 1950 to 2010 (Data source: RMCA Natural Hazards data base)

	Landslide	Earthquake	Flood	Total
Events	9	4	3	16
People killed	10	9	49	68
People affected	0	13 100	50	13 150

II. CAUSES OF THE LAND DEGRADATION



II.1 Natural factors

➢Seismic Hazard

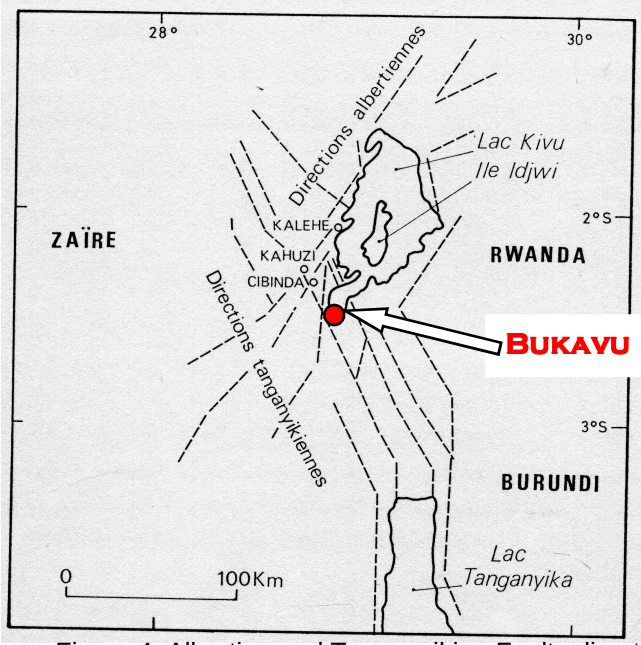


Figure 4: Albertian and Tanganyikian Faults directions (Boutakoff, *in* Ilunga 1991)

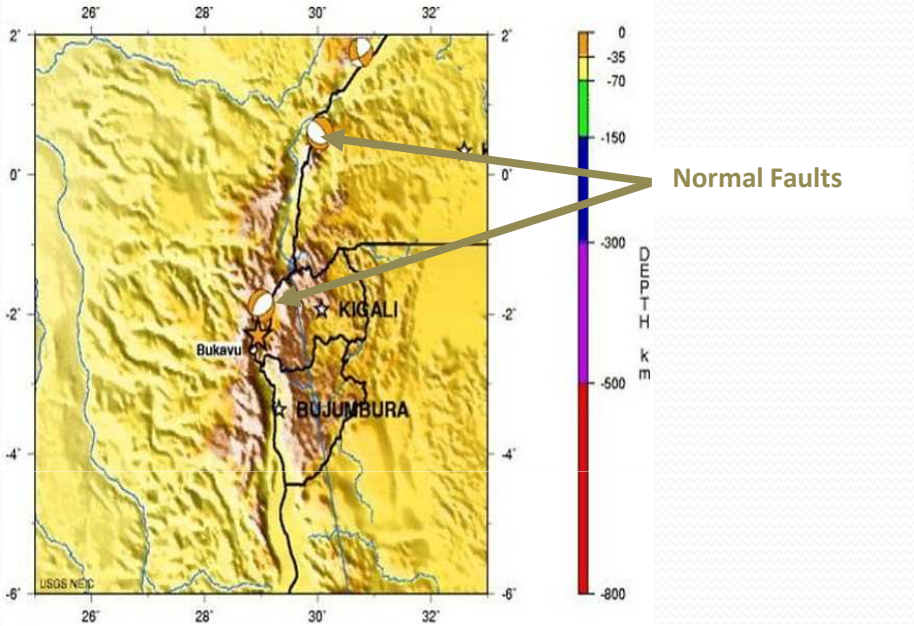


Figure 5: Magnitude 5.9 of earthquake 3 February 2008 around Bukavu

(Source : USGS NEIC, 2008)

Brittle deformations in the kivu lake basin are usually normal faults (Fig. 4 and 6) and joints witch testify the extension of the albertine rift.

➢Geomorphologic factor

Geological formations in the Lake Kivu basin have been intensely tectonized generating folds and fractures

Figure 6: Bukavu view from Rwanda (source: Jan Moeyersons 2005)

The topography has an impact on several events recorded in the region: landslide, gully erosion, rocks fall, flooding, etc.

➢Lithologic factor

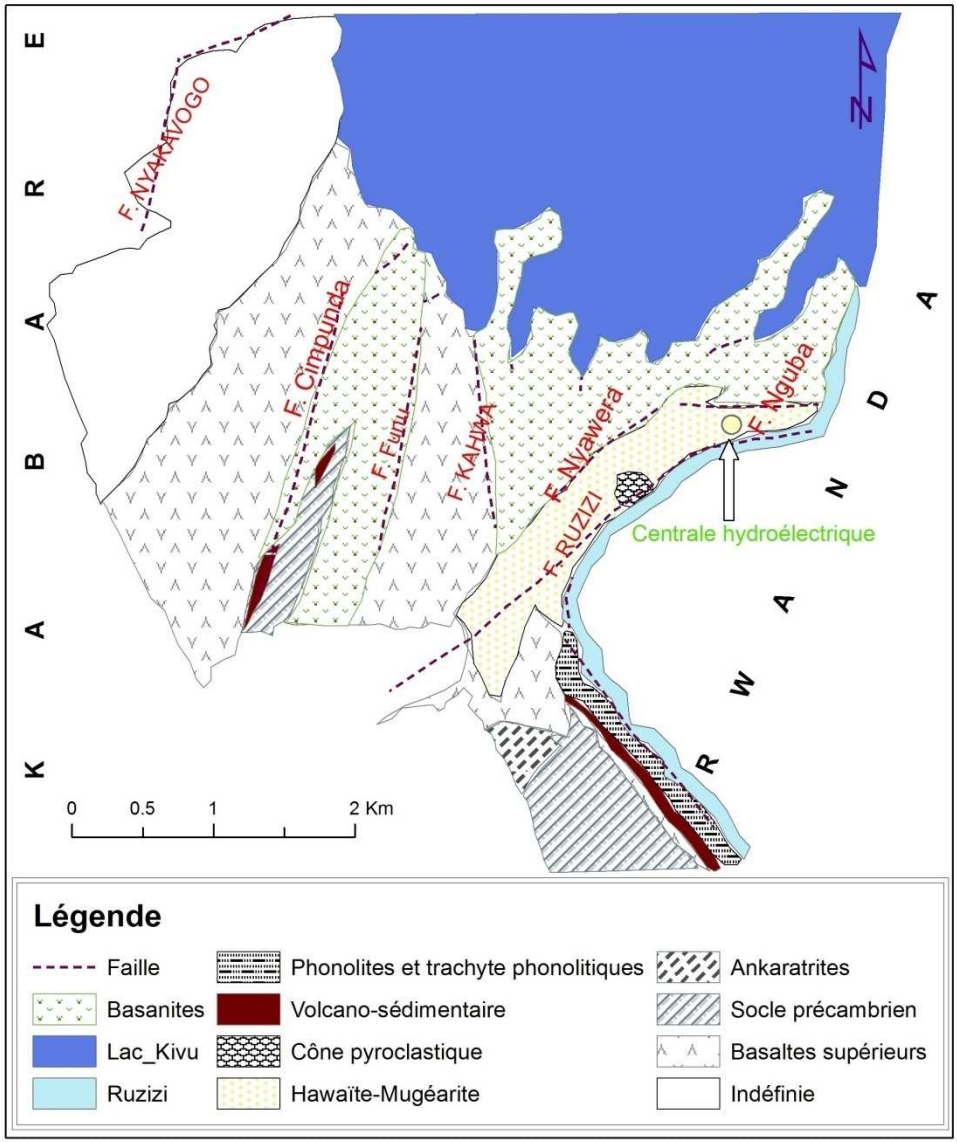


Figure 8: Geologic map of Bukavu (Kanika et all, 1981 modified)

Figure 7: Rocks fall at Kasheke-Kadutu after the earthquake of 03/02/2008

➢Climatic Factor

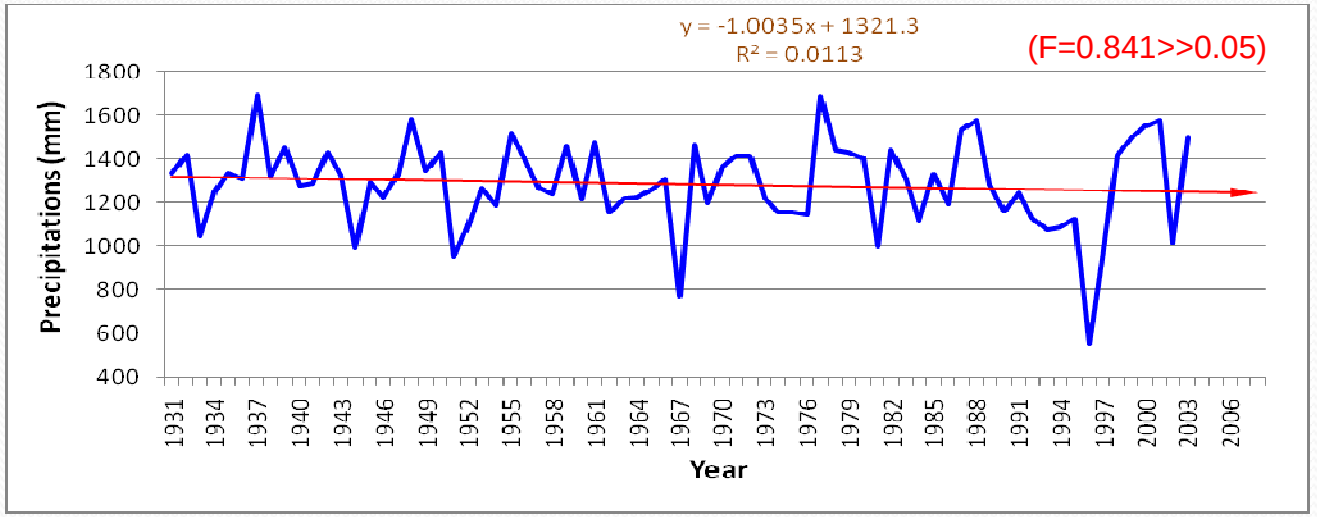


Figure 7: Annual Precipitation for Bukavu 1931 to 2003 (Source: Bukavu Station, N° 64180 (N° indicatif de l'OMM))

Precipitation data recorded at the meteorological station of Bukavu were analysed for the period of 1931 to 2003.

There is no significant increase or decrease in annual total precipitation for the period of 1931 to 2003 (fig. 7).

➢Climatic Factor

However, there has been a change in the monthly distribution of rainfall (Fig. 8), with significant increases in rainfall from October to January, and a decrease from February to July.

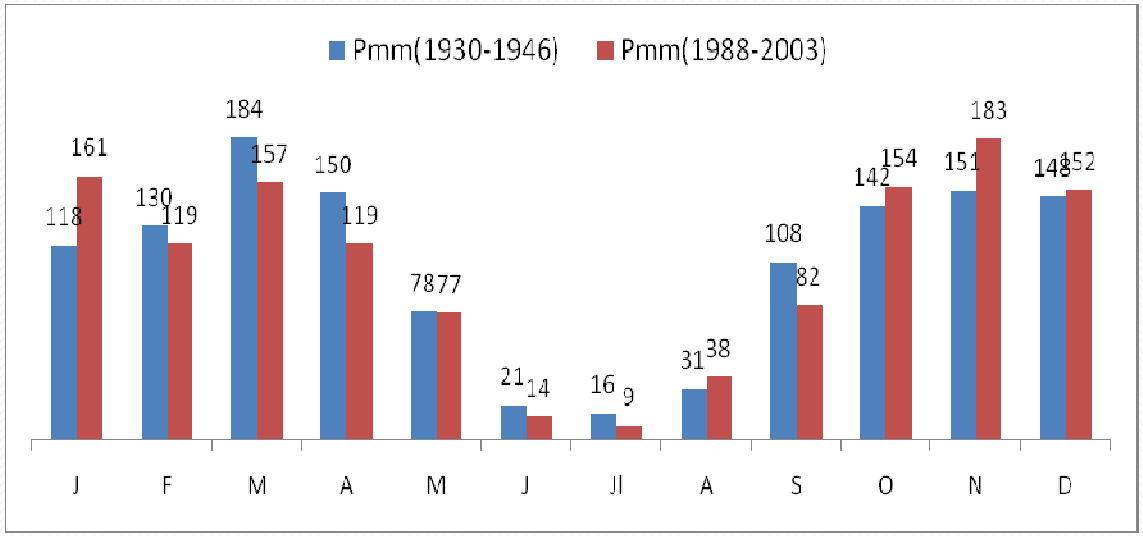


Figure 9 Monthly average precipitation for Bukavu, DRC, for the periods1930-1946 and 1988-2003 (Ndyanabo at al. 2009)

This shows a trend of increasing seasonal variability in rainfall in the city . It has been noted by Muhigwa (1999) in the surroundings of Bukavu.

II.2 Human factors

Human factors can be related to the rapid urbanization

- Deforestation: natural soil protection removal

Figure 10: Triggering of mass mouvements (source: 3 tamis 2006)

- Slope destabilisation by anarchique occupancy

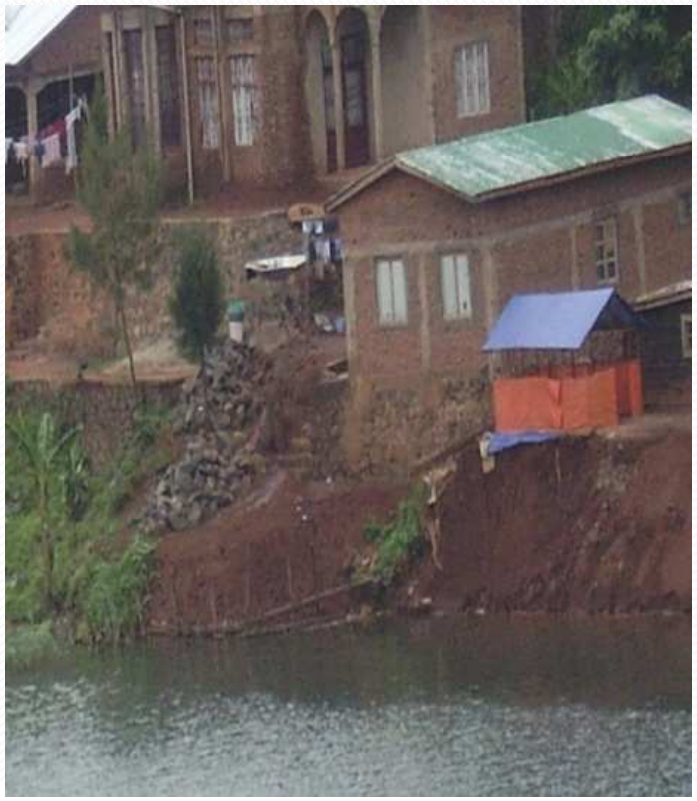


Figure 11: Landslide after the earthquake of 03/02/2008

Anarchic Occupancy

Figure 12: View of la Roche Hotel from the lake

Figure 14: Subsidence at La roche Hotel after the earthquake of 03/02/2008

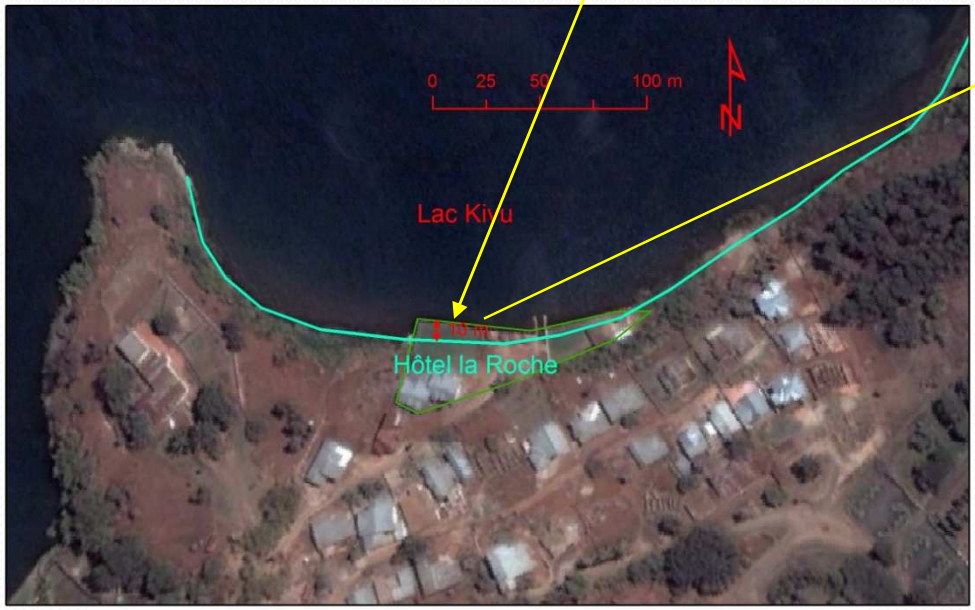


Figure 13: La Roche Hotel on Google Earth image in 2009

III. DIACHRONIC ANALYSIS OF THE DEVELOPMENT OF BUKAVU & HAZARD MAPPING

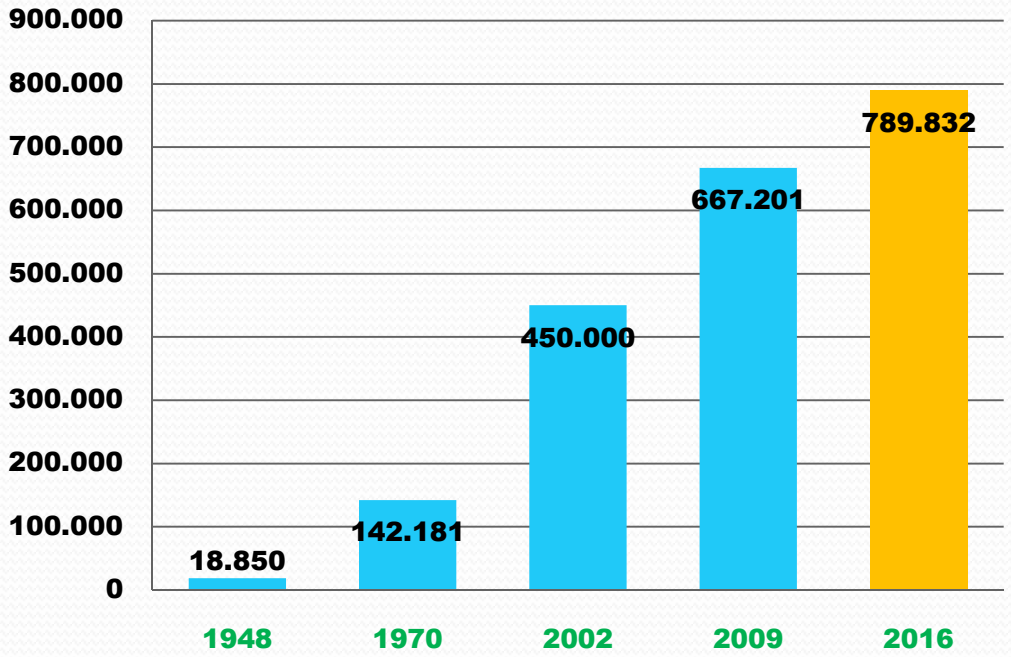


Figure 17: Evolution of people in the Bukavu city

Between 1970 and 2008 the population increased more than four times within a constant area of about 60 km^2

NDVI Evolution between 1984 et 2000

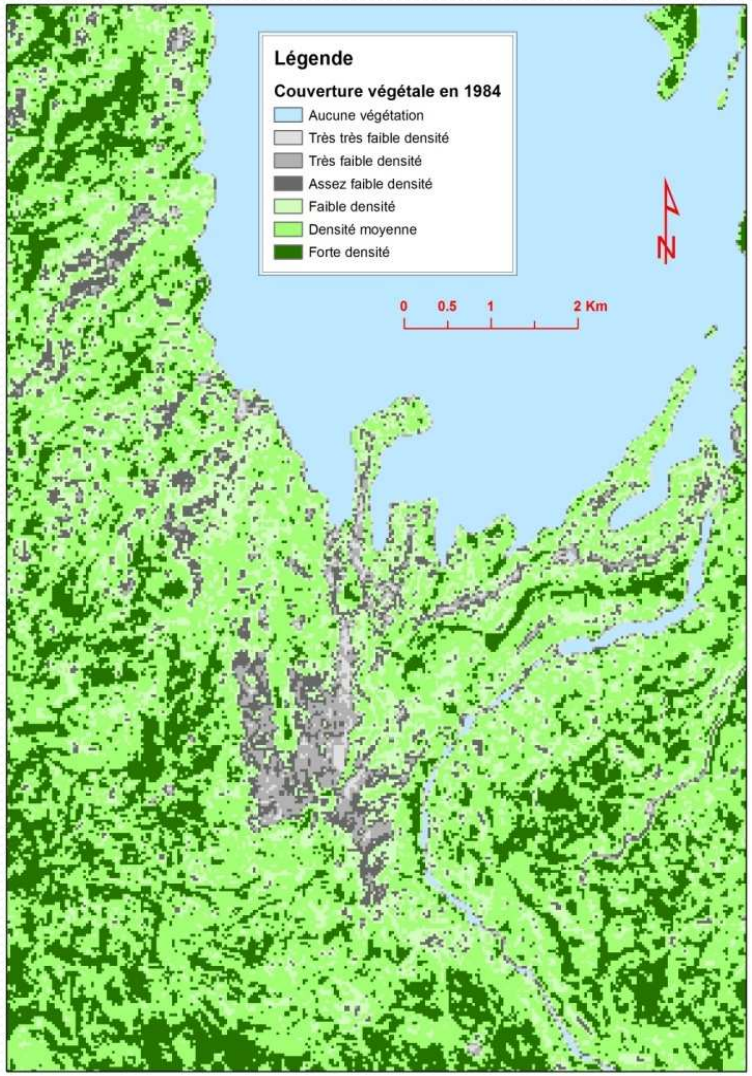


Figure 18: Vegetal cover in 1984

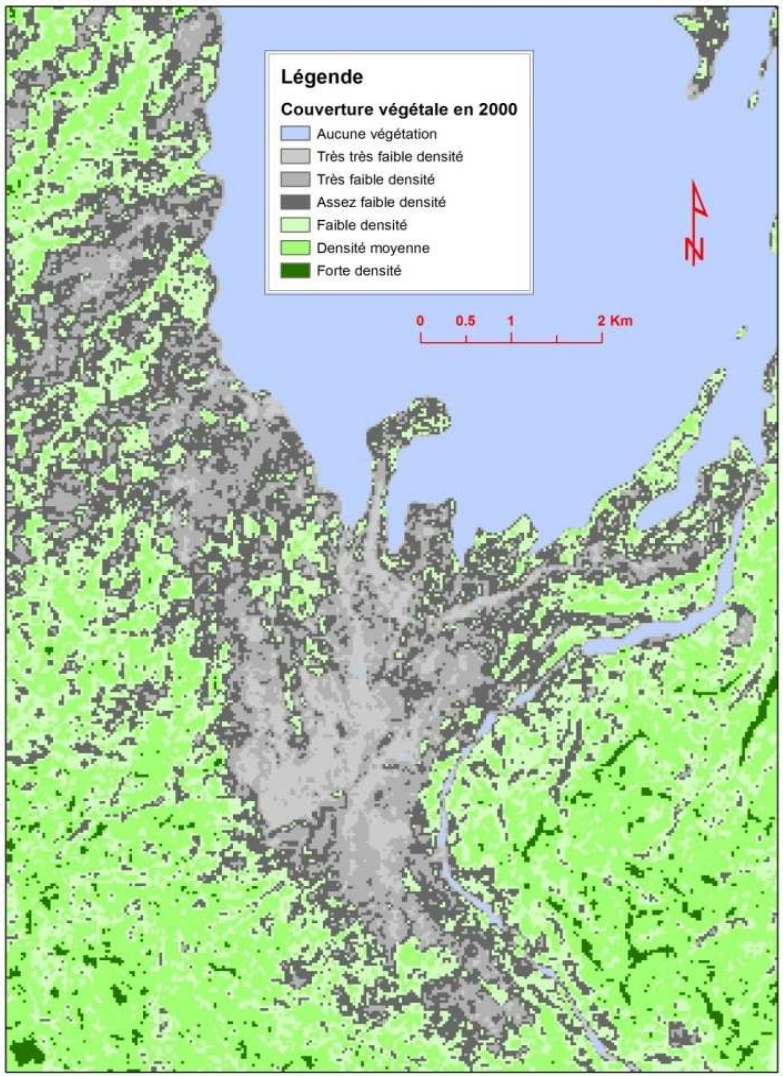


Figure 19 Vegetal cover in 2000

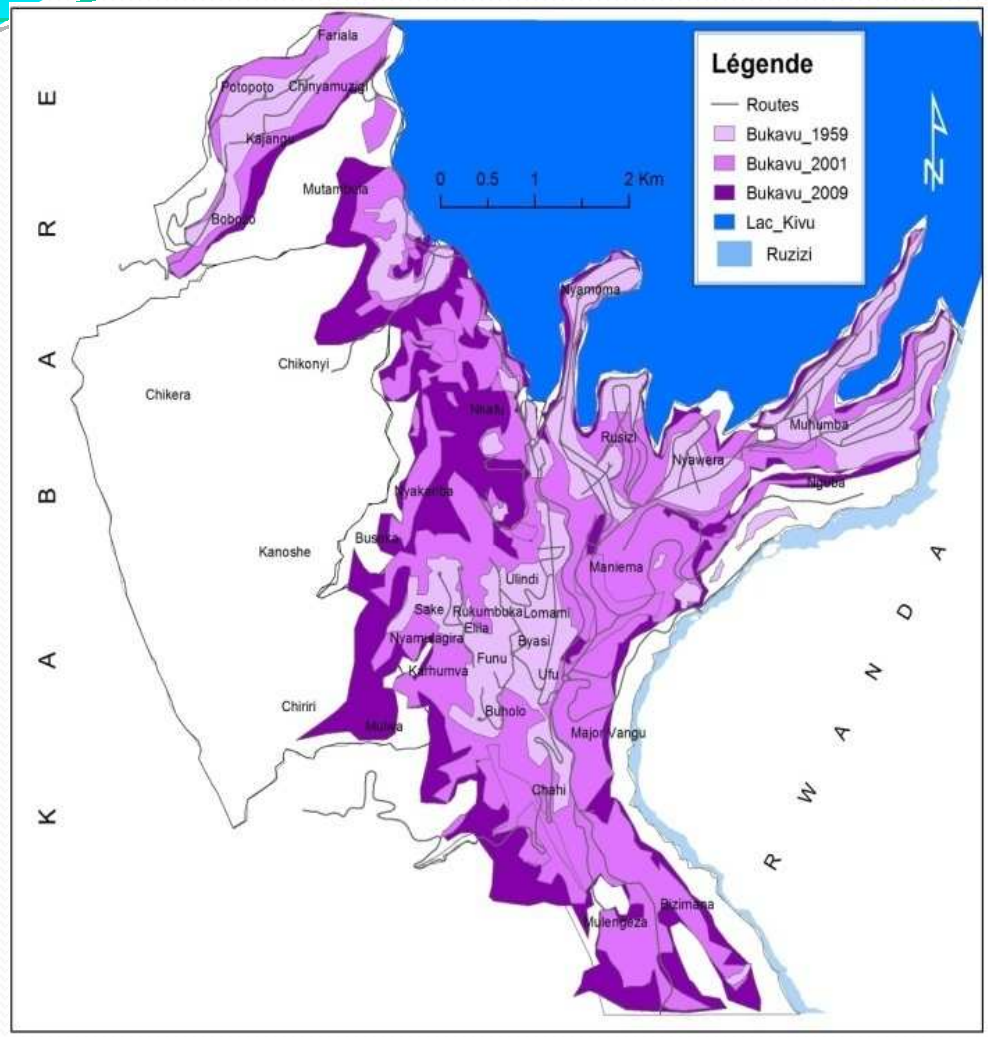


Figure 20: Bukavu between 1959 et 2009

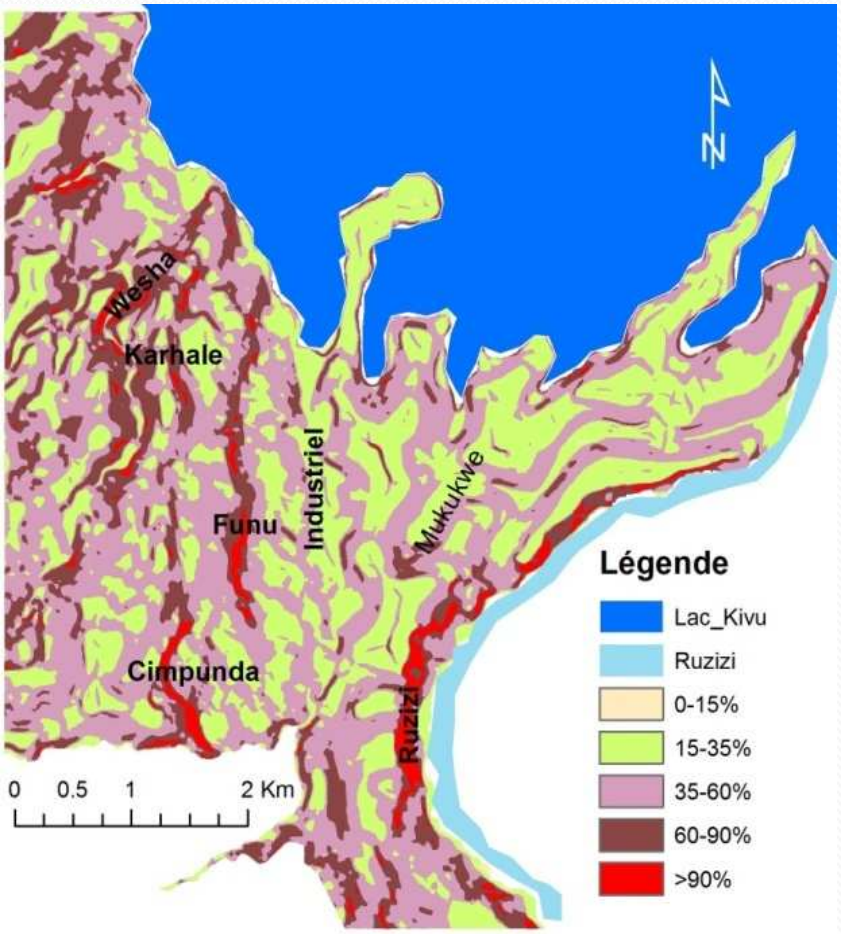


Figure 21: Slope map of Bukavu

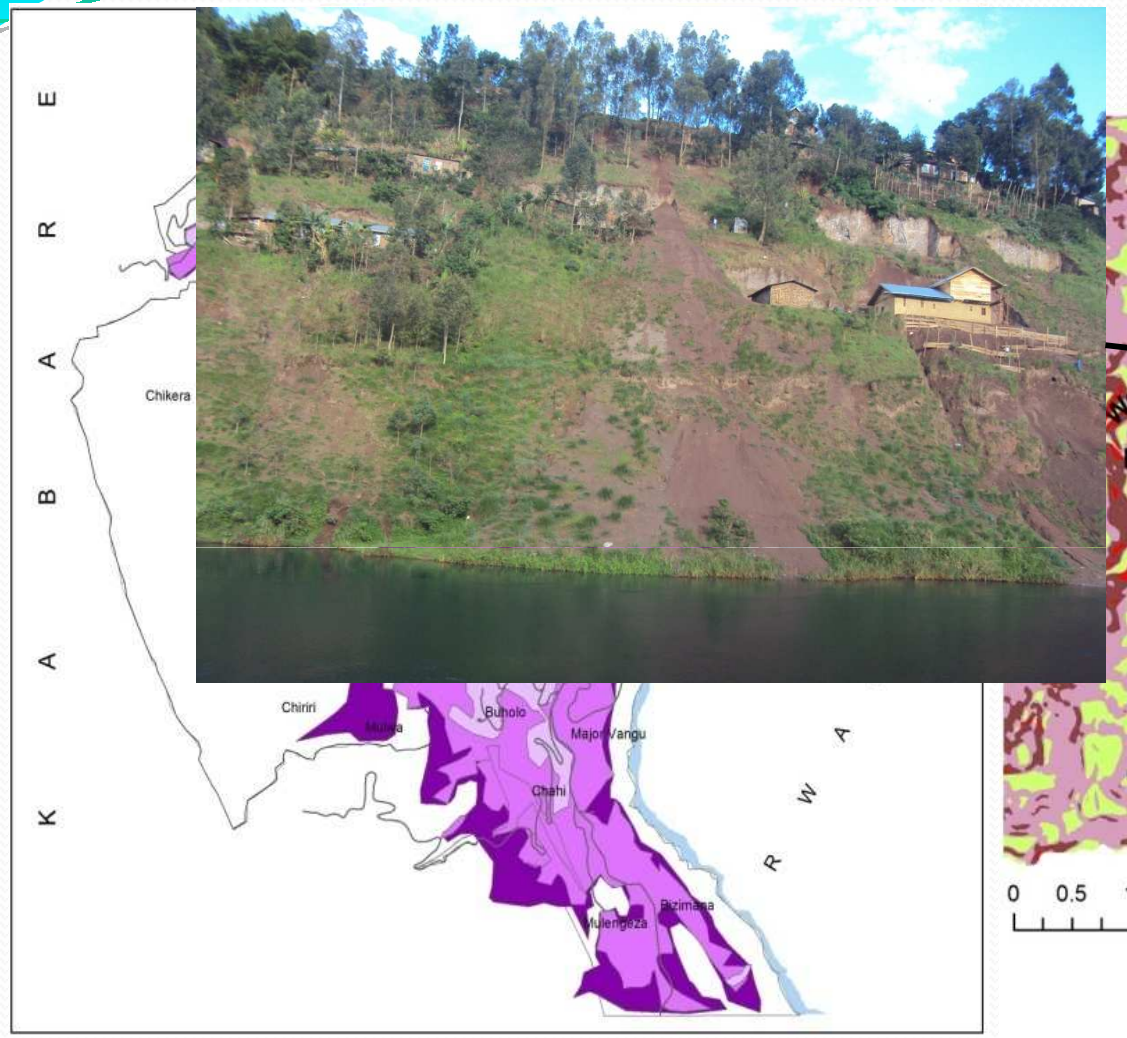


Figure 17: Bukavu between 1959 et 2009

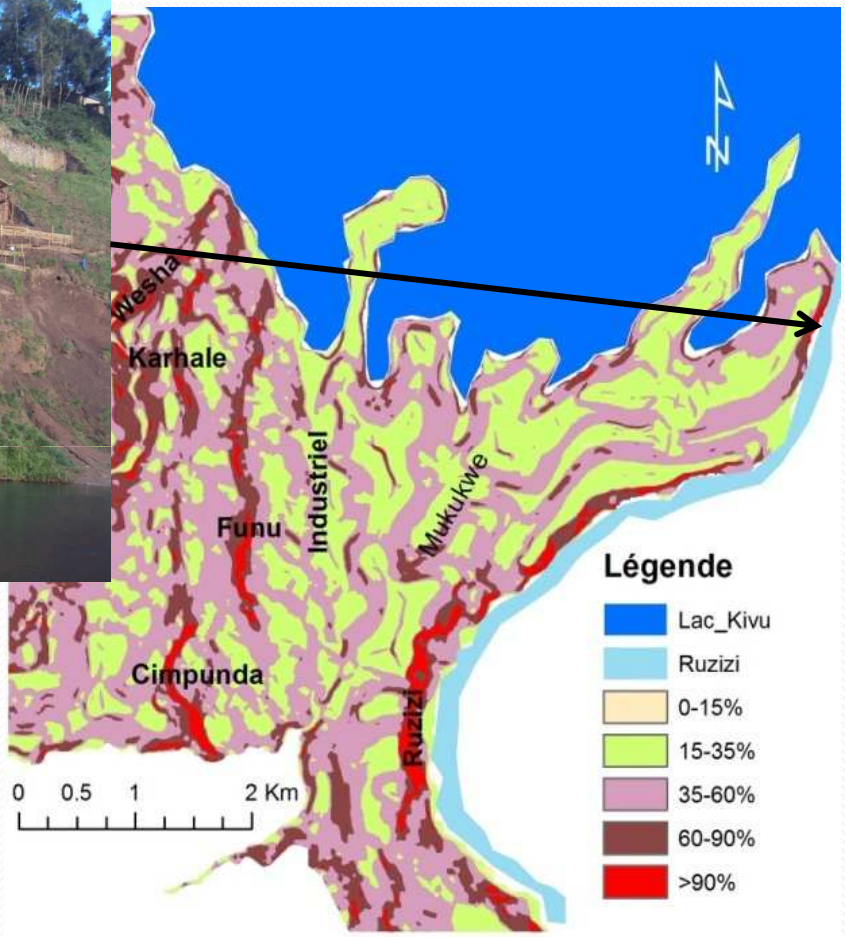


Figure 18: Slope map of Bukavu

Images Comparaison: High Risk Areas Identification

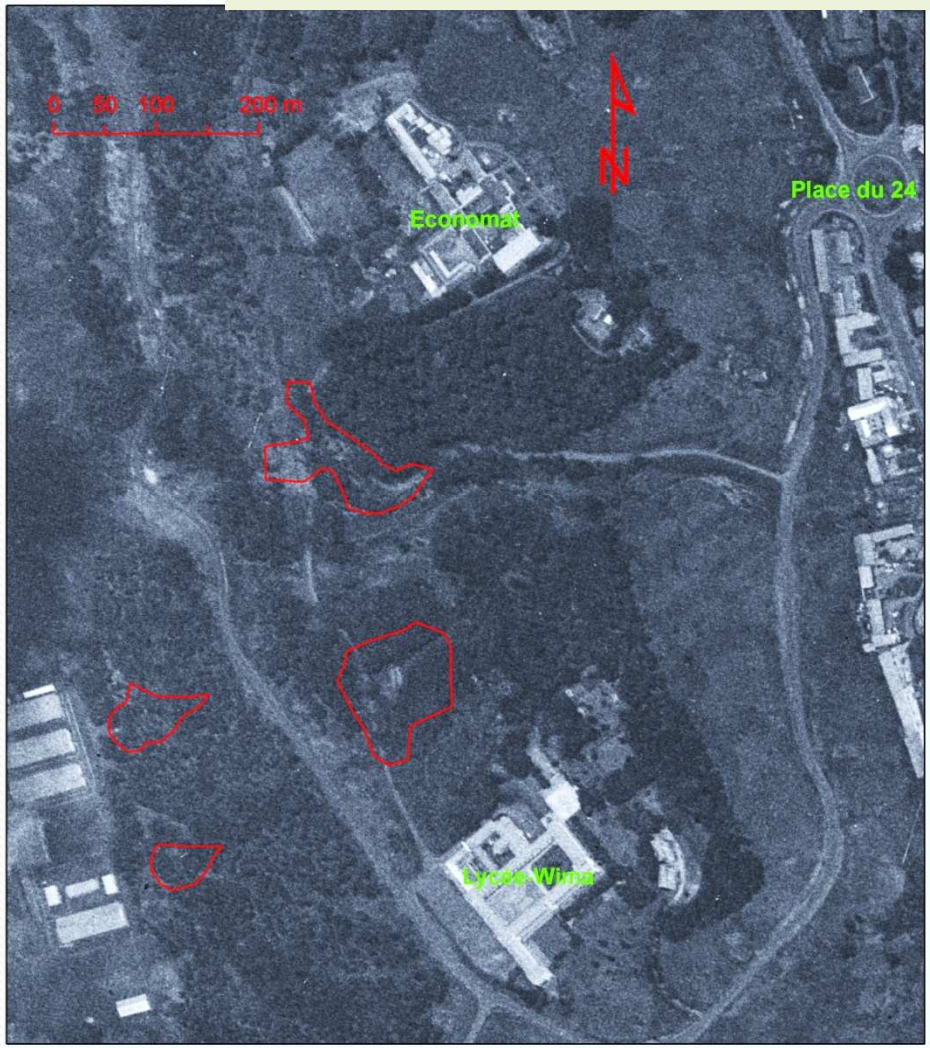


Figure 22: ITFM-Lycee Wima site on Corona image 1967

Figure 23: ITFM –Lycee Wima site on Google Earth image 2009

Figure 22: ITFM-Lycee Wima site on Corona image 1967

Figure 23: ITFM –Lycee Wima site on Google Earth image 2009

Images Comparaison: High Risk Areas Identification

Figure 21: SNCC site on aerial photography 1974 1974

Figure 22: SNCC site on Google Earth image 2009

Images Comparaison: High Risk Areas Identification

Figure 24: SNCC site on aerial photography 1974 1974

Figure 25: SNCC site on Google Earth image 2009

Images Comparaison: High Risk Areas Identification

Subsidence at Bushushu after the earth quake of 23rd Oct. 2002

Subsidence at Birava after the earth quake of 8th Feb. 2008

Figure 24:SNCC site on aerial photography 1974 1974

Figure 25: SNCC site on Google Earth image 2009

Interweaving of different factors: Water collector broken, earthquake, ground conditions

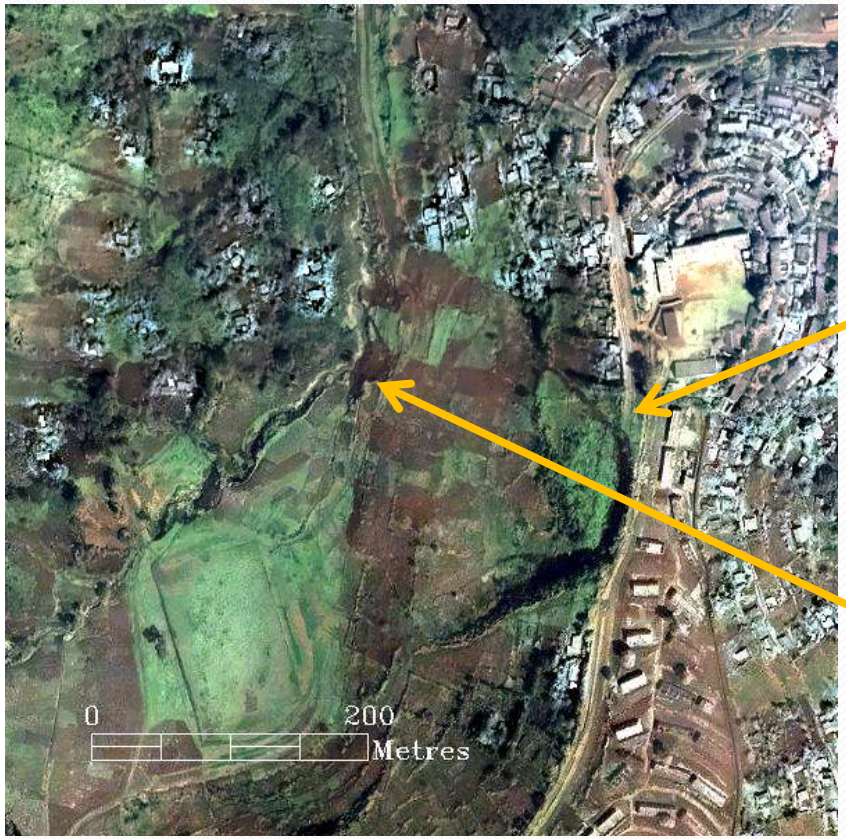


Figure 26: Landslide on Ikonos 2001

Figure 27: Landslide 1 day after event (12/8/1997)

Figure 28: Landslide 1 week after event (18/8/1997)

Interweaving of different factors: Water collector broken, earthquake, ground conditions

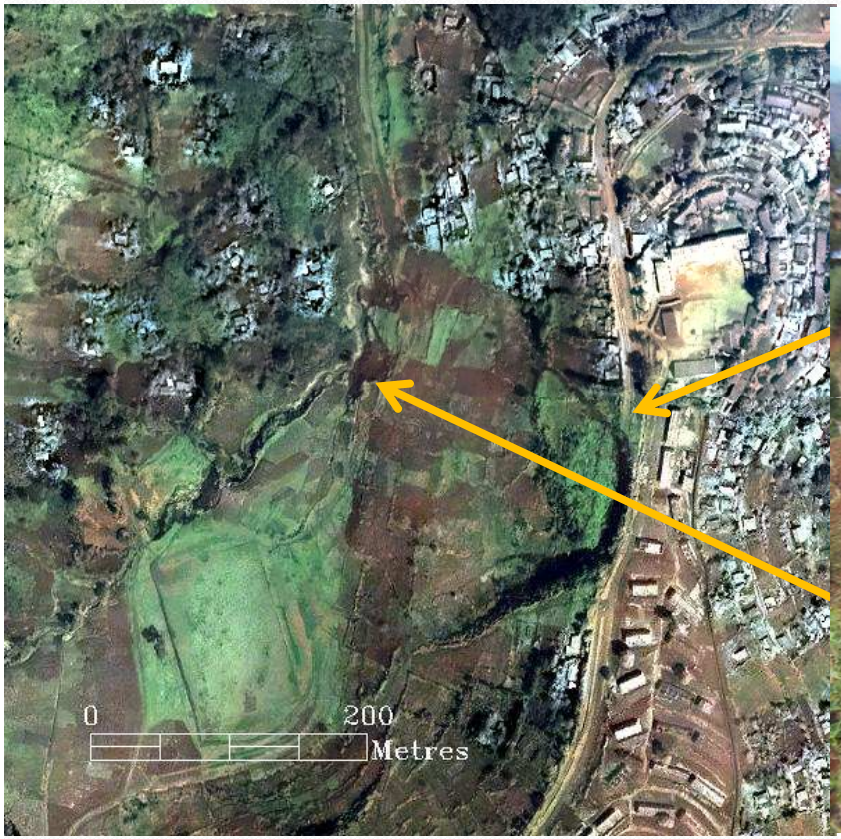
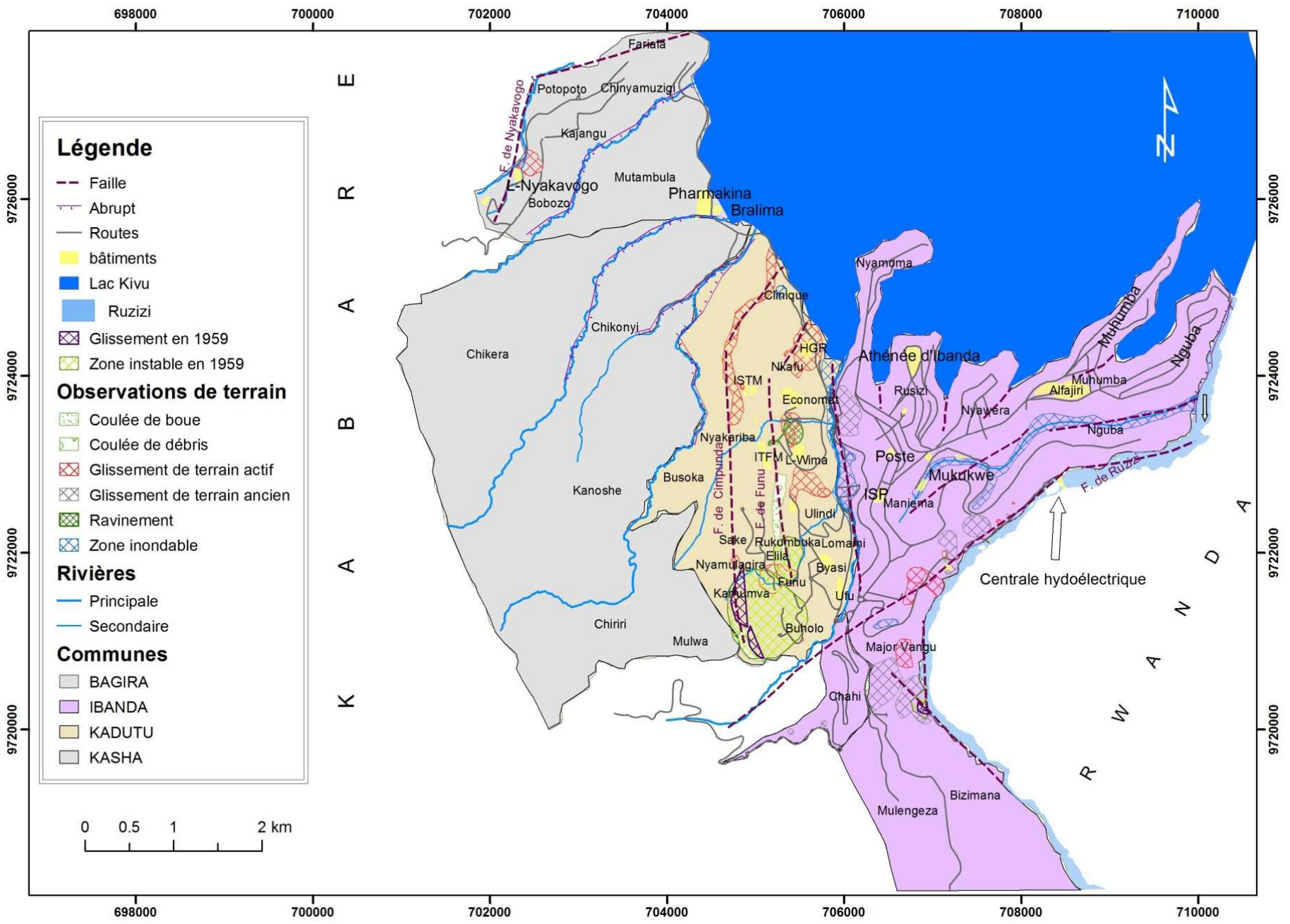


Figure 26: Landslide on Ikonos 2001

Figure 28: Landslide 1 week after event (18/8/1997)

Result: Map of vulnerability of the Bukavu city



Stages of Natural Hazards Management in Bukavu

Risk = Hazard x Vulnerability

Short Term (Remedial measures): Response after an event

- Evacuation
- Soil stabilization: bag of sand, gabion walls
- Surface water drains

Medium Term: preparation and prevention

- Evacuation plans
- Systematic drainage
- Soil stabilization with erosion control plants
- Gaps ventilated houses in flooding zones (suggestion)
- Vulnerability mapping
- Sensitization

Drainage and slope stabilization in Bukavu

Long Term: Prevention and Management

- Extend the City according to the demographic growth
- Encouraging Research in Natural Hazard Management

Gaps ventilated house in Belgium (Sadiki, 2009)

Approach for a good management of natural hazards in Bukavu

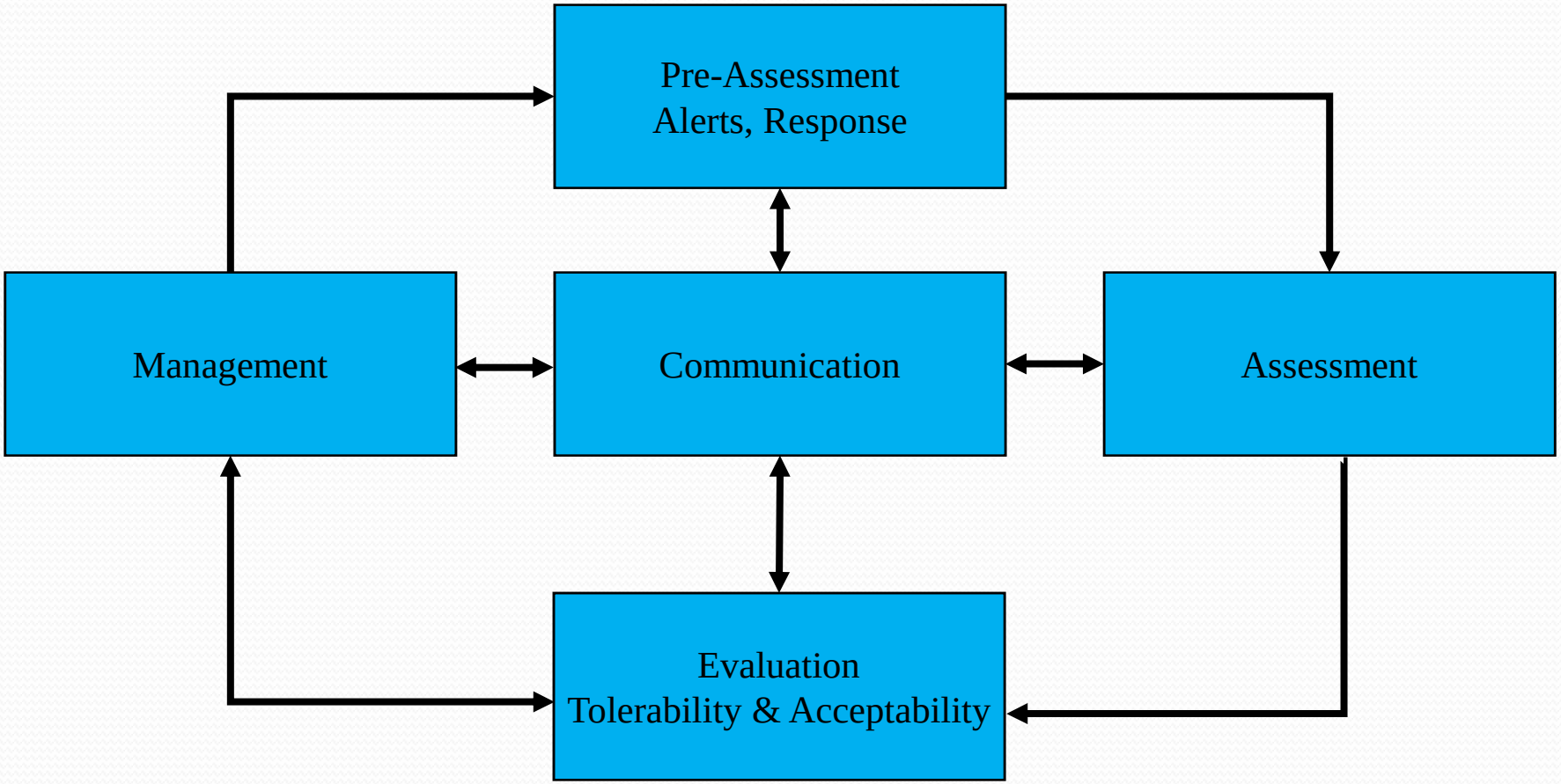


Figure 26: Risk Governance Framework (Sébatient Brunet, 2009)

IV. CONCLUSION & PERSPECTIVES

- Interweaving of different factors
- Urban plan
- GIS and remote sensing: an essential tool in urban planning and land use
- Detailed study for each type of geomorphologic hazard
- To extend the city of Bukavu

Thank you for your attention