Daily rainfall above 75mm is a major trigger to landslides in the Muhunguzi, western Burundi

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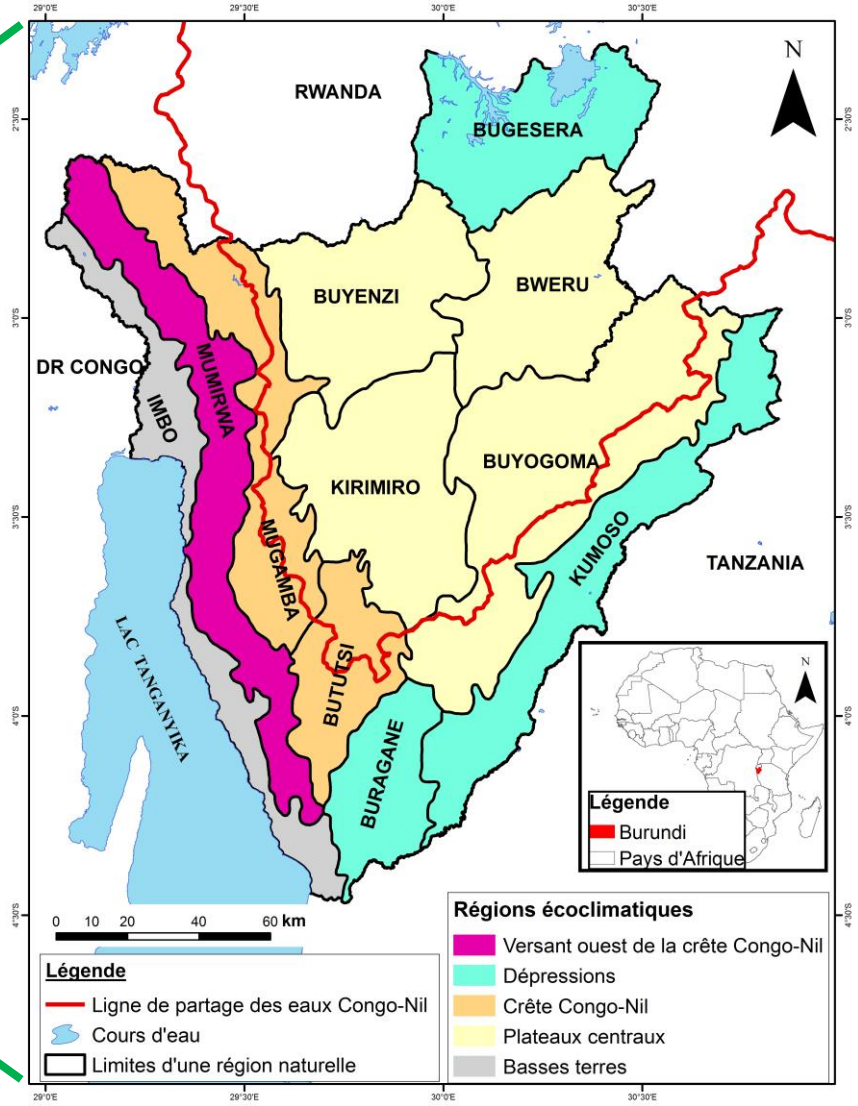
Muhunguzi watershed is located in the Mumirwa region

In the *Great African Lakes Region*, East Africa, Burundi (27800 km^2) is a high densely populated country. *Mumirwa* is one of Burundi's 11 natural regions, located in the western part of the country.

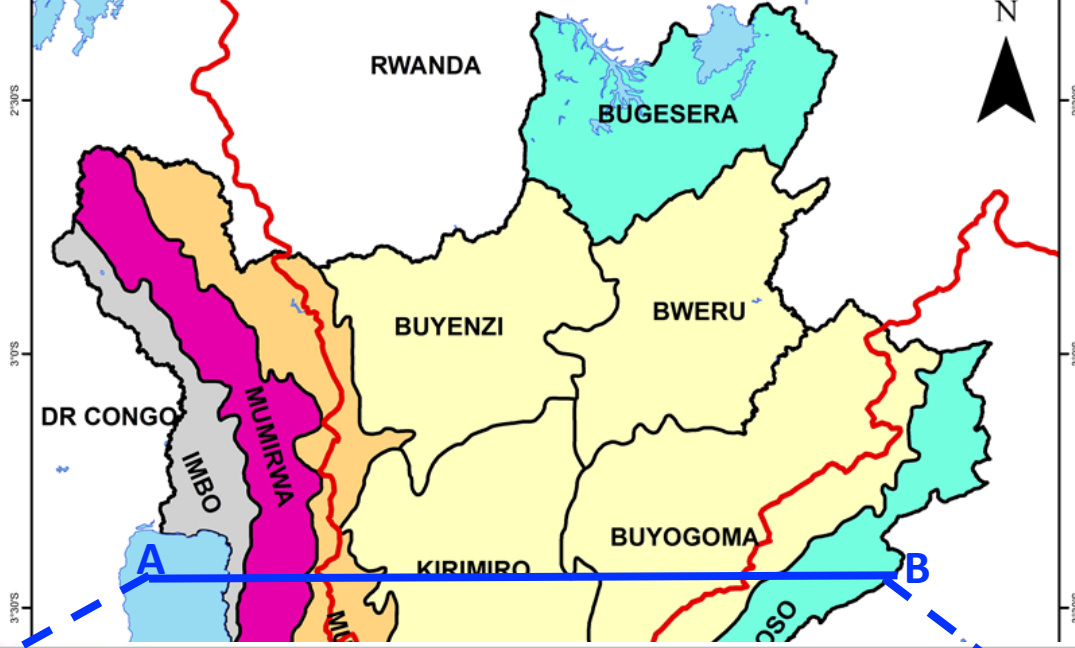


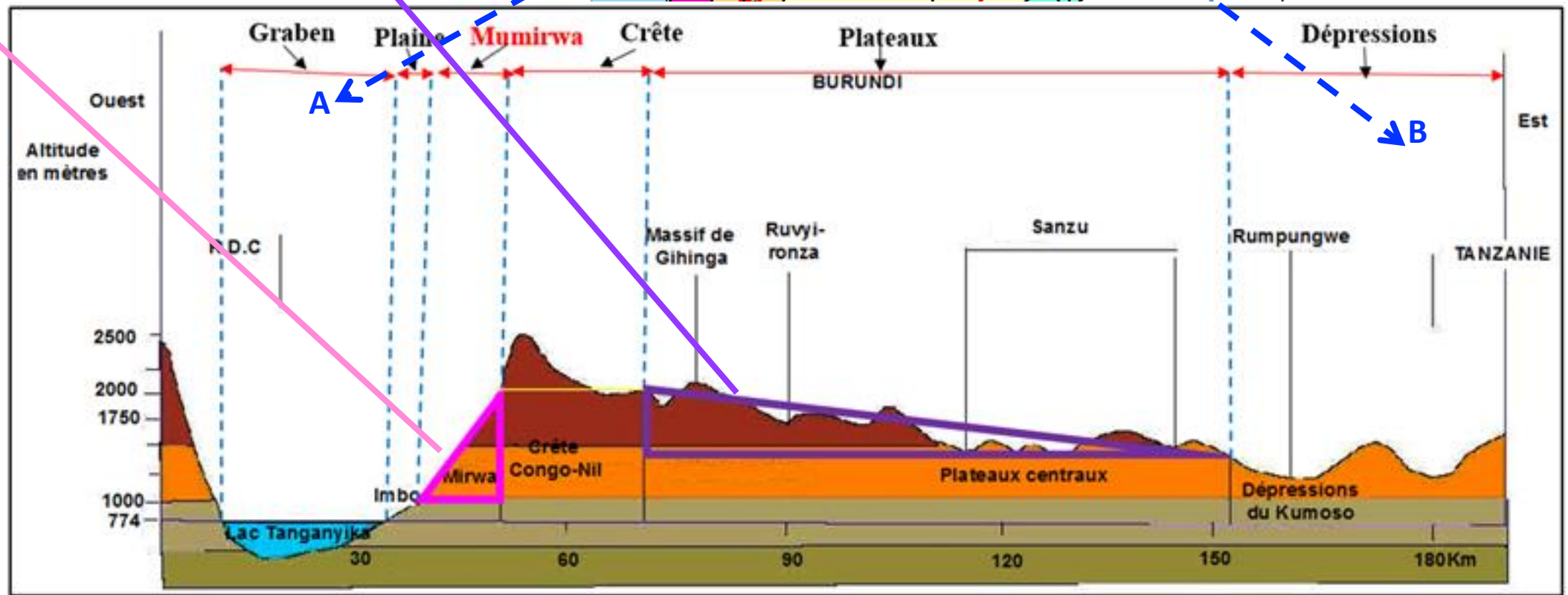
Mumirwa region

Burundi is a mountainous country in which the Congo-Nile ridge separates contrasting eastern and western slopes.

The eastern slope gradually decreases from the crest to the peneplanate relief.

The western slope(Mumirwa) is very steep from the ridge into Lake Tanganyika.

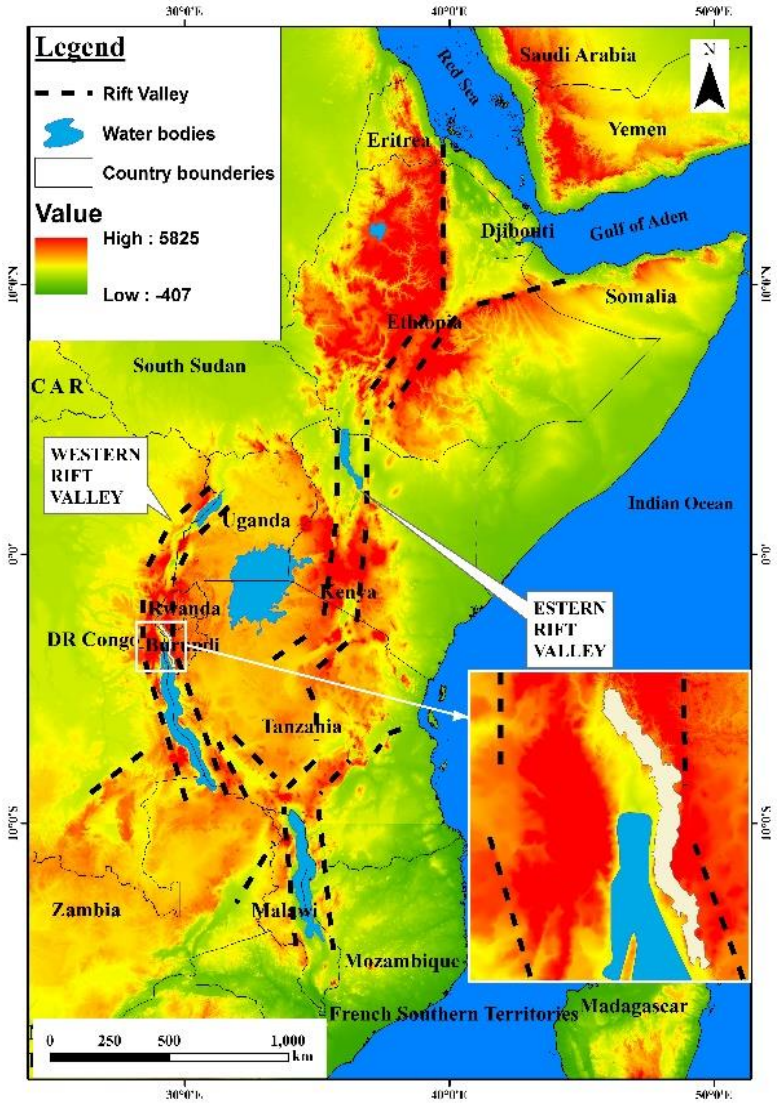




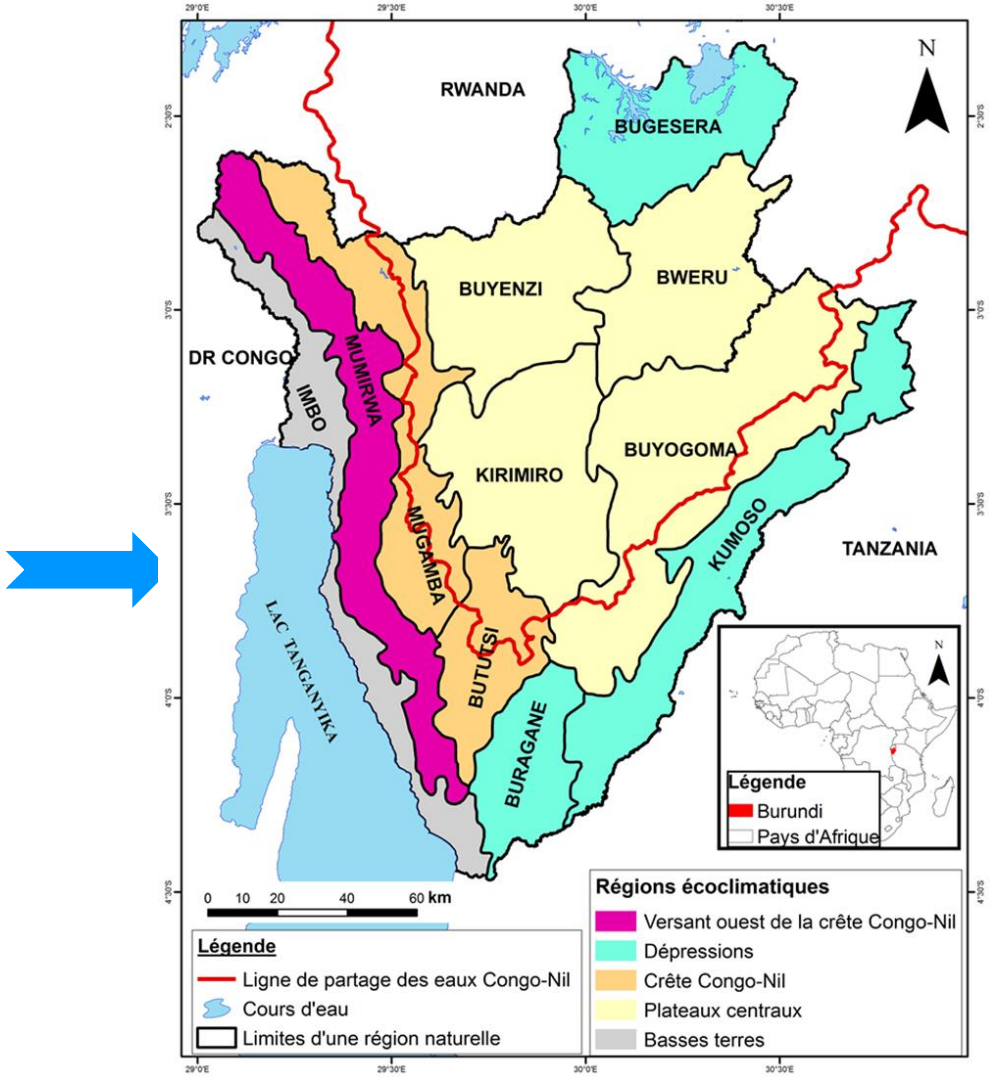

Mumirwa landscape
Steepy lands are intensively used for agriculture.
Landslides occur in rainy seasons. They have dramatic consequences on human communities

Geomorphology in Mumirwa

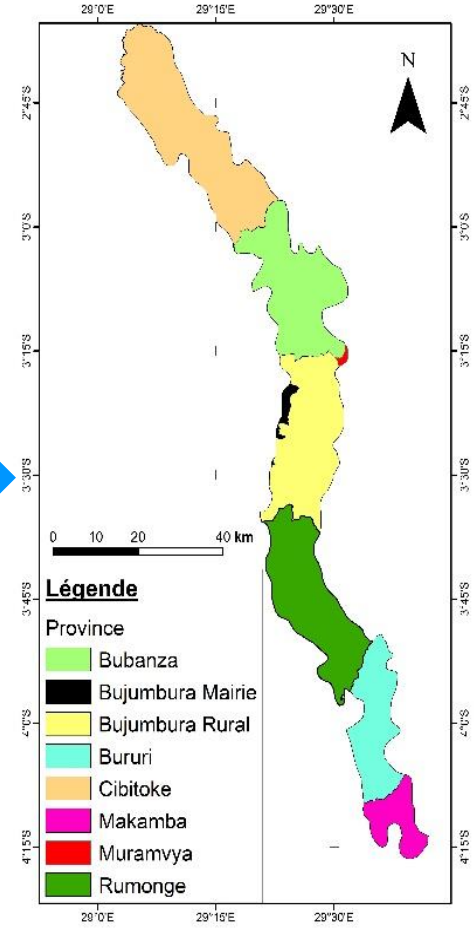
The regional geomorphology is closely related to the formation of the Great African Rift (*Rift Valley*) where several lakes and volcanoes are located.



Rift Valley



Ecoclimatic and natural regions- Burundi



Mumirwa

Mumirwa landslides

- ✓ environmental degradation
- ✓ loss of cultivated land
- ✓ loss of life
- ✓ destruction of infrastructures …

Consequences of the Mumirwa landslides

uplands

- ✓ loss of croplands
- ✓ destruction of houses
- ✓ loss of life….

lowlands

- ✓ deaths
- ✓ mudslides
- ✓ floods….

Bujumbura city is regularly threatened by floods from muddy rivers heavily loaded with stones of varying sizes torn off during landslides.

Materials and methods

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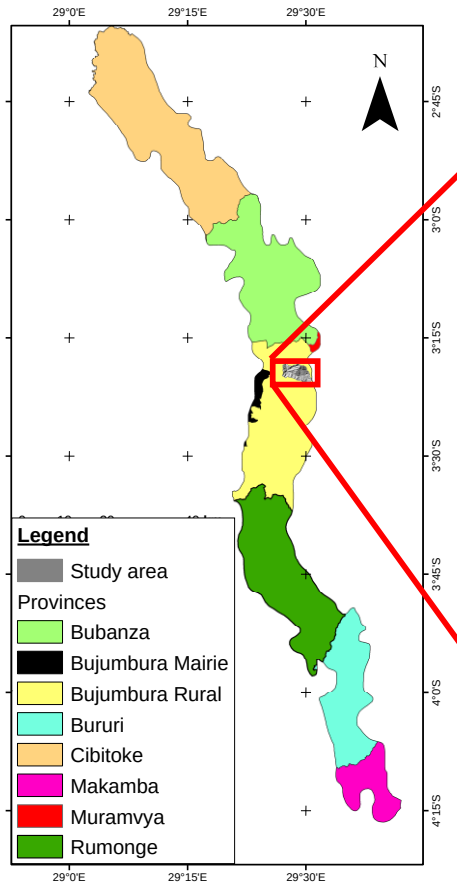
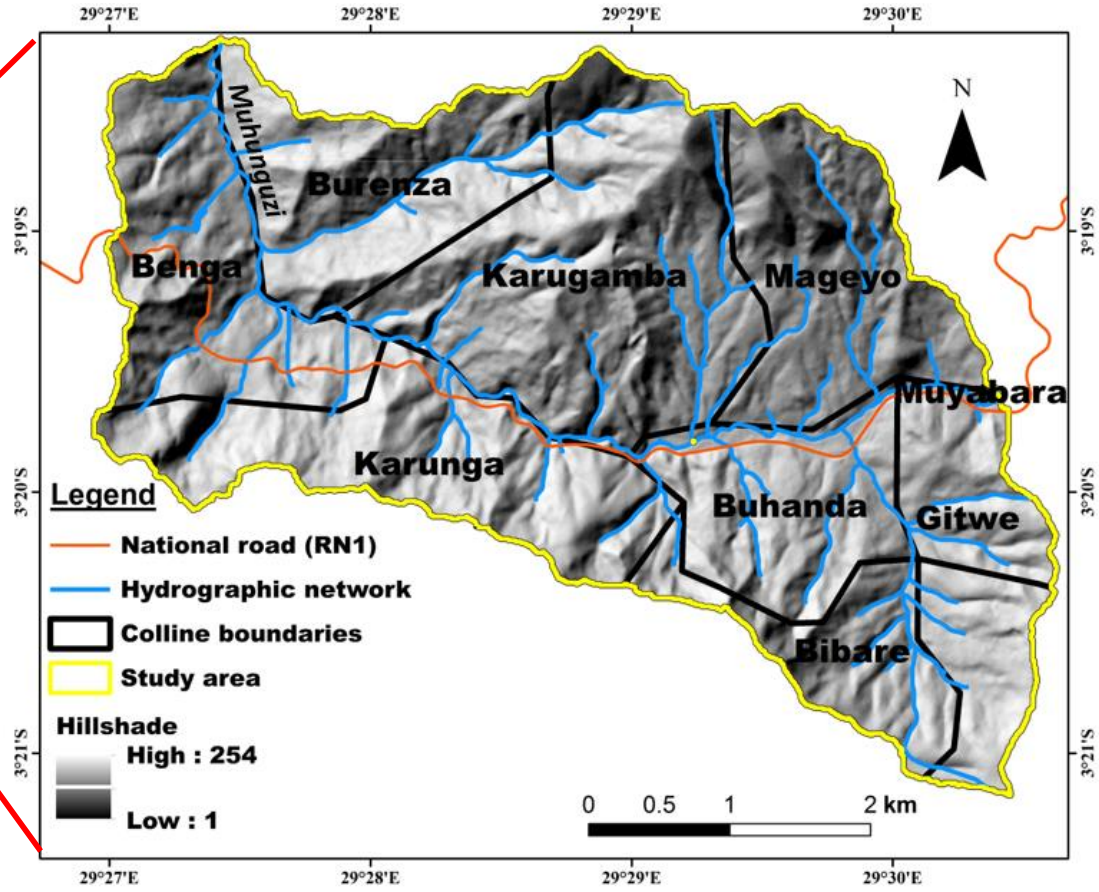
- **Study of the Muhunguzi watershed, Mumirwa region**

  - ✓ Spatial repartition
  - ✓ Slope
  - ✓ Lithologie
  - ✓ Soil
  - ✓ Hydrographic network
  - ✓ Antropogenic influence

- **Rainfall analysis**

  - ✓ Standardized Precipitation Index (SPI);
  - ✓ intense rain events





Results

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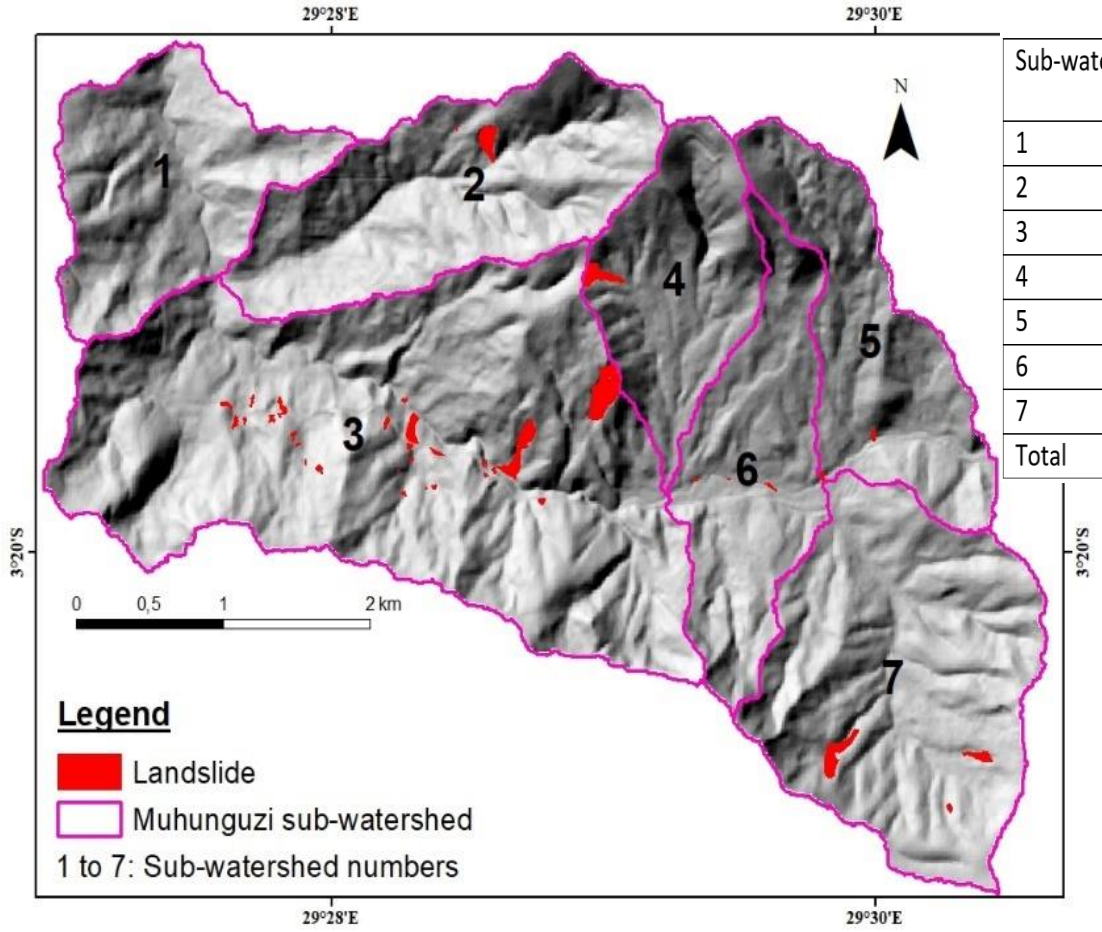
• Spatial distribution of landslides and landslide typology



Sub-watershed	Area (km^2)	Landslides number	Density
1	2,1	1	0,5
2	2,7	2	0,7
3	7,3	29	4,0
4	1,6	1	0,6
5	1,9	2	1,1
6	2,0	5	2,5
7	3,6	3	0,8
Total	21,2	43	2,0

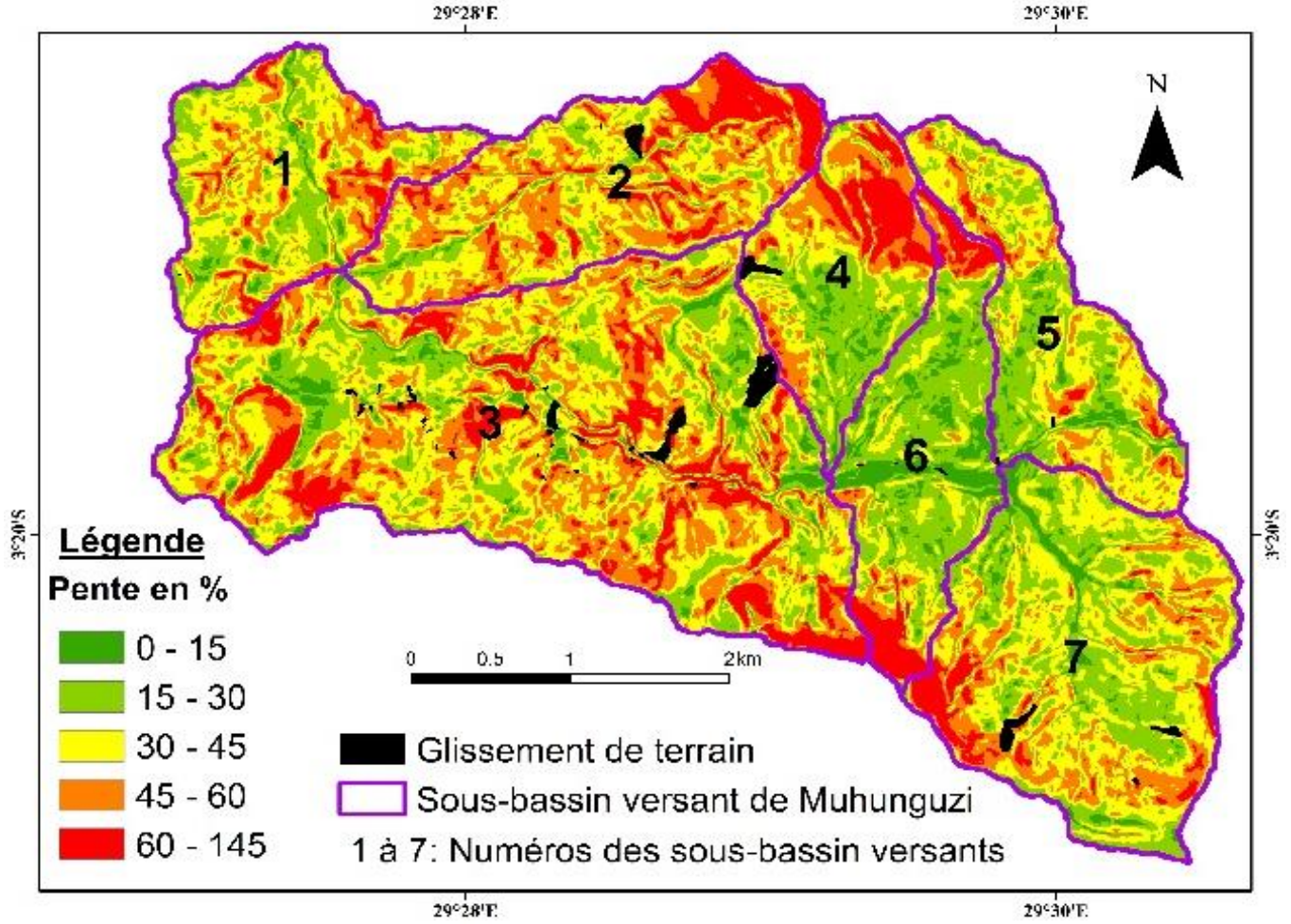
- ✓ most are shallow landslides
- ✓ the majority are rotational landslides

- ✓ only 19 landslides cover more than 1000 m^2 each, of which 5 cover more than 10000 m^2.
- ✓ moved material consists mainly of soil with the addition of rock debris of different sizes.

Results

- **Position of landslides on the slope**

The majority of landslides are located on steep slopes (30% to 60%).

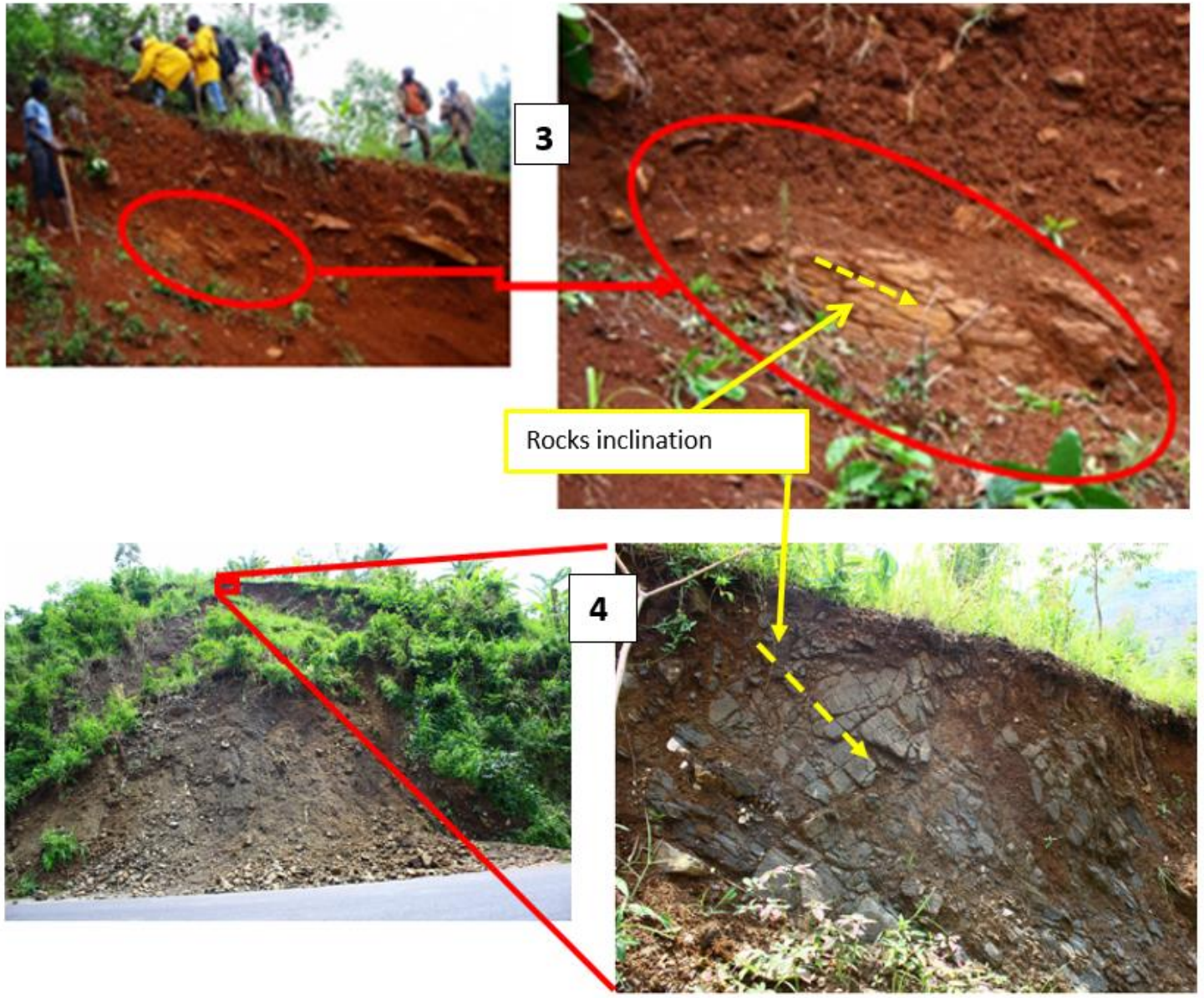


Results

- **Geology**

Schists occupy a large proportion of the lithology of the study area.

These formations, fractured and visible on the fracture surface or at the foot of the slide fracture surface, are inclined parallel to the inclination of the slopes.



Results

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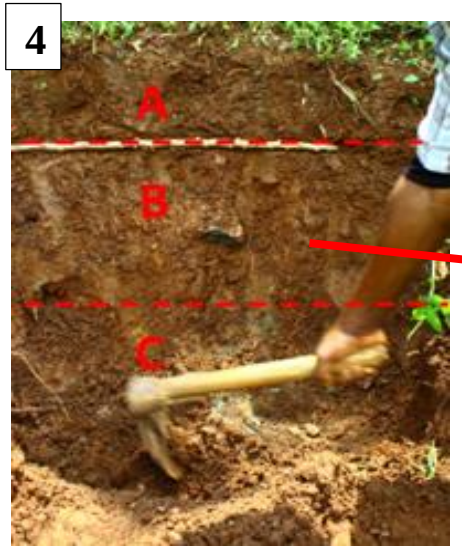
- **Soils (red and black)**

✓ Nitisols cover the entire Muhunguzi watershed.
✓ Nitisols generally derived from basic rocks, but they also develop on schists and micaschists.
✓ Nitisols are characterized by a relatively high clay content and nitic properties, characterized by a.o.well developed blocky structure.

- **Illustrations of Nitisols in the studied area)**

(1) illustrates a typical stony/rocky profile,
(2) and (3) are two typical deep soils,
(4) illustrates the A-B-C soil profile development suggesting limited to moderate weathering,
(5) shows subangular and angular blocky aggregates in the weathered B horizon of profile (3), a Nitisol.



Results

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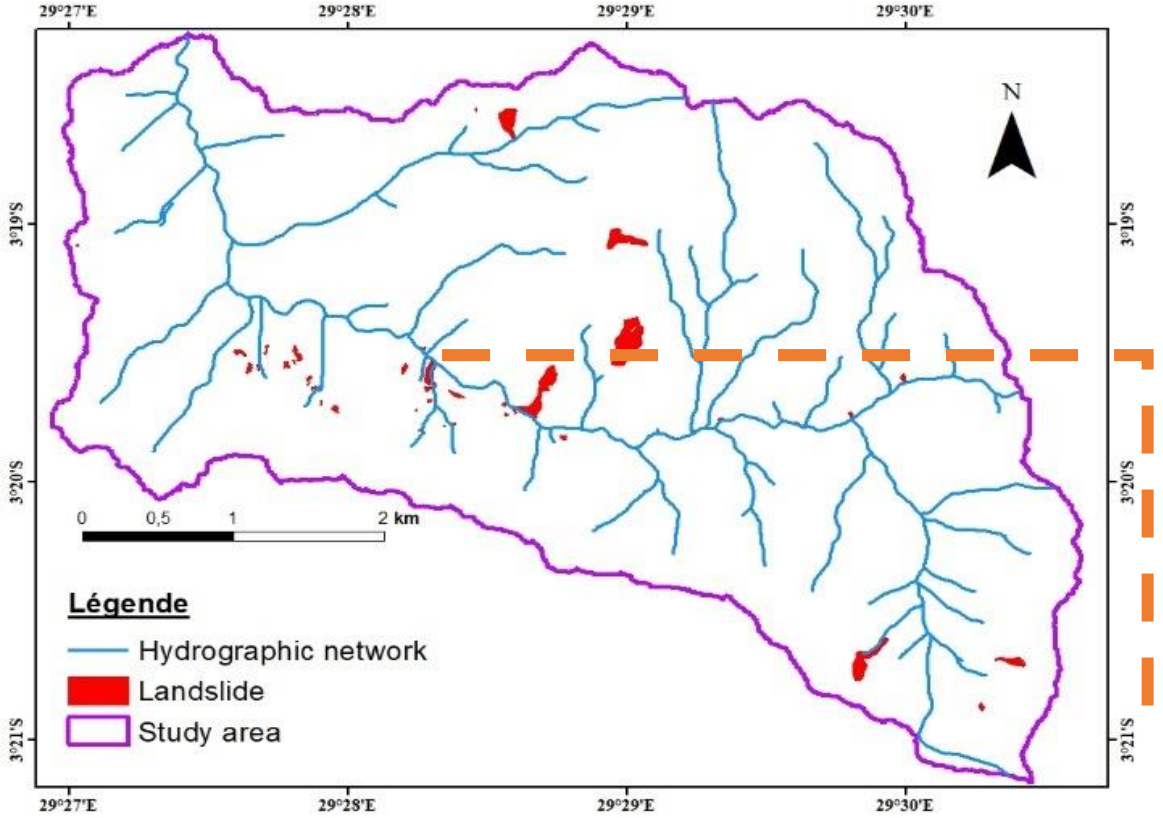
- **Location of landslides in relation to hydrography (river network)**
  - ✓ 44% of landslides affect rivers.
  - ✓ Bank undercutting is located locally on concave parts of the river.



Results

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• Anthropogenic influence

- ✓ All uplands are occupied by farms and houses, even on very steep slopes(**1**).
- ✓ Only the top parts of the Muhunguzi watershed are covered by state forest of eucalyptus trees.
- ✓ Landslides are absent on areas permanently covered with vegetation consisting mainly of oil palm or banana crops that are less dispersed as in figure (**2**).
- ✓ Of the 43 landslides, 11 have affected the national road RN1; two of them have damaged roads as illustrated in figure (**3**).
- ✓ At the head of most landslides, there is a path of about 30 cm wide as shown in figure (**4**).
- ✓ The majority of landslides occurred on farm fields under seasonal crops as in figures (**5**) and (**6**)

1

2

3

4

5

6

Results

- **Extreme rainfall events : annual rainfall**

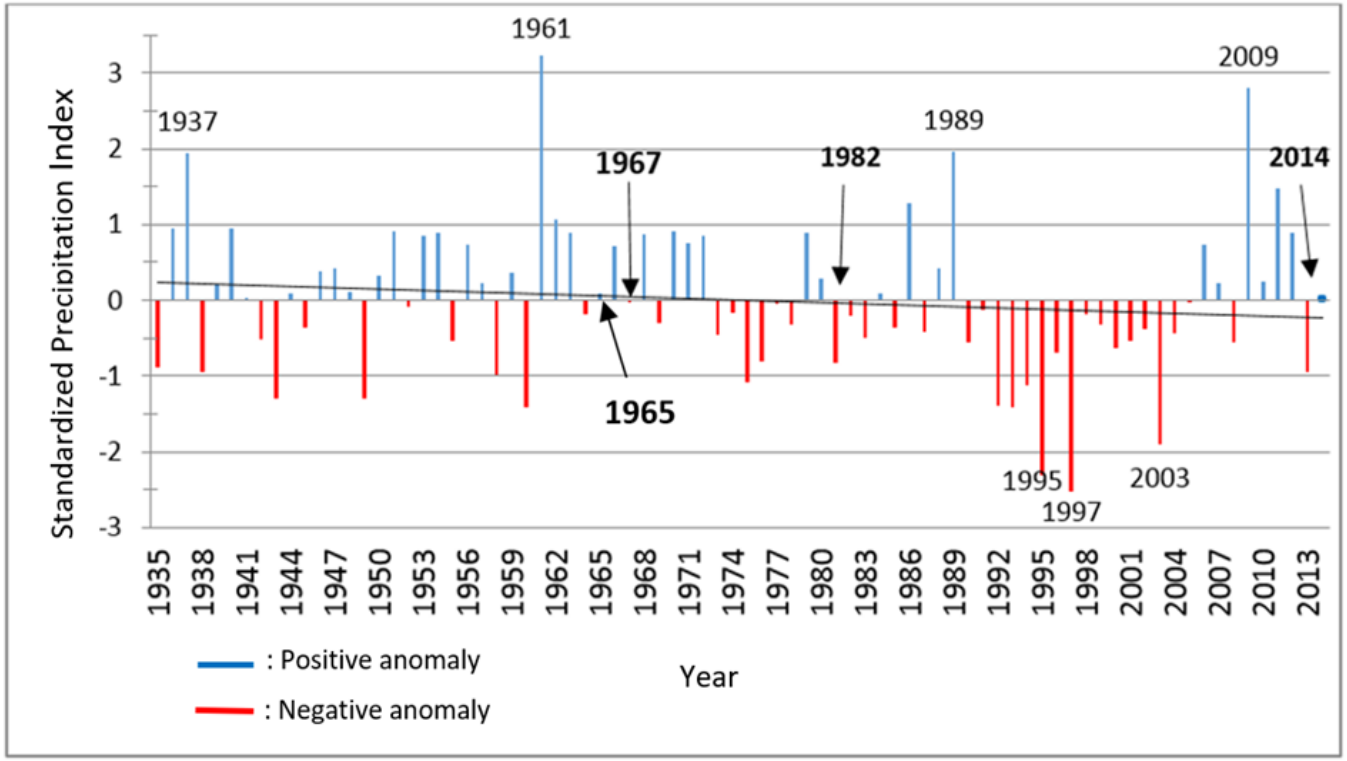
The evolution of the standardized rainfall index for the period from 1935 to 2014 highlights positive (blue) and negative (red) anomalies, corresponding to excess and deficit rainfall respectively.

7 years have been in surplus (SPI > 1σ), of which 1961 and 2009 were very much in surplus (SPI > 2σ). 10 years were in deficit (SPI < -1σ), of which 1995 and 1997 were much more in deficit (SPI < -2σ).

The years 1965, 1967, 1982 and 2014 are characterized by a normal annual precipitation.

Annual rainfall has no influence on landslides in our study area.

Landslides number	Occurrence date	Rain duration
3	November7, 1965	3h
1	May 18, 1967	Few hours
1	December 1,-1982	Few hours
38	February 9, 2014	3h30



Results

Extreme rainfall events : daily rainfall

The daily rainfall totals show that the years 1965, 1967, 1982 and 2014 each had a single day of intense rainfall (75mm ≤ Rainfall < 100mm) corresponding for each of these years to the day of the landslides.

→ The amount of daily rainfall had an instantaneous influence on the initiation of the landslide in this zone

17 days of intense rainfall have been identified in our series of 80 years.

→ **The return period of this intense rain is 80/17 years, i.e. 5 years**

The region has had the same or even higher daily rainfall levels over time than those observed in the four years without landslides.

→ This observation highlights the influence of rainfall intensity and duration factors in triggering landslides in our study area.

There is a relationship between daily rainfall and landslide type

→ Intense rainfall for a few hours triggers superficial and rapid landslides.
Moderate rainfall spread over several days causes deep and slow landslides.

Very heavy rainfall (>100mm/day)		Heavy rainfall (75 < Rainfall ≤100mm/day)			
Jour	Rainfall (mm)	Jour	Rainfall (mm)	Jour	Rainfall (mm)
Feb 1, 1957	128	Feb 12, 1936	82	Apr 29, 1977	93
Feb 12, 1970	116	Jun 3, 1936	83	**Dec 1, 1982**	**95**
Nov 11, 2009	142	Dec 9, 1961	84	Apr 8, 1986	88
Dec 22, 2009	122	dec 27, 1961	92	Feb 16, 1990	78
		Nov 7, 1965	**78**	Nov 16, 2000	77
		Mar 23, 1966	96	Feb 5, 2008	75
		May 18, 1967	**82**	Jun 4, 2008	80
		Jan 29, 1969	76	**Feb 9, 2014**	**80**
		Jan 31, 1971	96		

Landslides number	Occurrence date	Rain duration
3	Nov 7, 1965	3h
1	May 18, 1967	Few hours
1	Dec 1,-1982	Few hours
38	Feb 9, 2014	3h30

The abundance of shallow landslides in our study area is due to rainfall > 75 mm/day for short duration.

Conclusions

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This study shows that the vulnerability of the Muhunguzi watershed is the result of a combination of geological, geomorphological, climatic, soil and anthropogenic factors.

On the one hand, the *Great African Rif Valle*y tectonics had formed a montainous landscape with steep slopes where climatic conditions promoted rock weathering and clayey soil formation, hence affecting the mechanical performance of uplands and weathered soils.

On the other hand, weathering has led to the formation of clayey and fertile soils, which are intensively used for agriculture. Consequently, uplands are densely populated, farmers have cleared the natural forest lands and converted them into croplands, even on very steep slopes. Farming, demographic increase, house and road constructions are all human activities that that destabilize sloped terrains and increase soil instability and susceptibility to landslide.

In the Muhunguzi catchment area, shallow landslides are likely to recur every five years, especially if intense rains are concentrated over a short period of time.