



Analysis of the impact of landslides on rural community livelihood in Rwanda: Case of Ngororero district

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ABSTRACT

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The study entitled “Analysis of the impact of landslides on rural community livelihood in Rwanda. Case of Ngororero District” was conducted to analyze the impact of landslides on rural community livelihood in Rwanda, a case of Ngororero District. The study objectives were to: Delineate landslides endangered areas and identify the causes, evaluate rural community livelihood status in Ngororero district throughout the study (2016-2020), and analyze the impact of landslides on rural community livelihood in Ngororero District. The study targeted 19,999 households as the study population; from the three sectors of the Ngororero district namely, Muhanda, Kavumu, and Sovu sectors. A sample of 392 members from that population was selected purposively. Data collection tools and techniques used to obtain primary and secondary data were interviews, questionnaires, observation, and documentation. The study was survey in nature and used qualitative, quantitative, and correlative research designs. Data analysis and map production were done using SPSS 16.0, and Geographic Information System (GIS) 10.8 software. The study findings confirm that the landslides occurrence had a significant impact on community members' livelihood in Ngororero District, such as deaths and injuries of community members, income reduction, food insecurity problems, displacements and houses destruction. It is recommended that the government manages the situation and keeps it in control so that both government and the citizens use appropriate and durable materials in the construction of houses and infrastructures like roads, classrooms, and health centers to avoid potential damage due to landslide occurrence.

Contribution/Originality: The research analyzed the impact of landslides on the livelihoods of a rural community in Ngororero District. The study revealed that landslides had a remarkable impact on community livelihoods.

1. INTRODUCTION

Landslides are one of natural hazards that cause serious problems in most parts of the planet and are caused by both natural phenomena and human activities (DN Petley, Mantovani, Bulmer, & Zannoni, 2005). They rank as the 7th most killing natural hazard (D Petley, 2012). Losses like fatalities, physical asset damage and economic cost occur when people are exposed to landslides. Landslide is influenced by factors like topography of a region and the lithology, as well as soil type and land cover slopes, the presence of water accumulation zones, as well as soils with an impermeable (Corominas et al., 2014). Landslides consequences become intense mostly in developing nations

such as sub-Saharan African countries, since they are unable to establish the measures to fight and mitigate against landslides disasters. They impoverish people in those areas and their livelihoods especially in rural areas (Anderson & Ostrom, 2015).

Landslides are one of the most deadly natural disasters in Rwanda, as they are throughout most of East Africa, killing people without warning while also transporting the fertile soil to water catchments, where Rwanda nation loses an average of 15,000,000 tons of extremely fertile soils annually (Bizimungu, 2017). The most landslide vulnerable part of Rwanda is North-Western part in the districts of Nyabihu, Rubavu, Musanze, Burera, Gakenke and Ngororero where resides the case of this study.

Statistics indicate that in 2019, 81 people died due to landslides occurrences, 21 injured, 113 houses damaged, 477 hectares of crops damaged and 19 roads and 12 bridges were damaged and destroyed. Ngororero district ranks first to have recorded deaths resulted to landslides with 48 people who died in that period. It is observed that the livelihoods of the majority of Rwandan households living especially in rural areas are based agricultural and livestock practices and are the main areas affected by landslides events.

Therefore, the motivation behind this research is to investigate the impact of landslides on rural community livelihood in Rwanda, especially in the areas mostly affected by these events taking the case study of Ngororero District.

2. MATERIAL AND METHODS

2.1. Profile of Ngororero District

Ngororero District is one of the 7 districts that make up the Western Province of Rwanda and shares borders with Gakenke and Nyabihu Districts in the northern part, Karongi in the southern part, Muhanga in the eastern part, and Rutsiro in the west. Ngororero District has an area of 679 km² and is divided into 13 administrative sectors, 73 administrative cells, and 419 villages.

Figure 1 illustrates Location of Ngororero district in Rwanda.

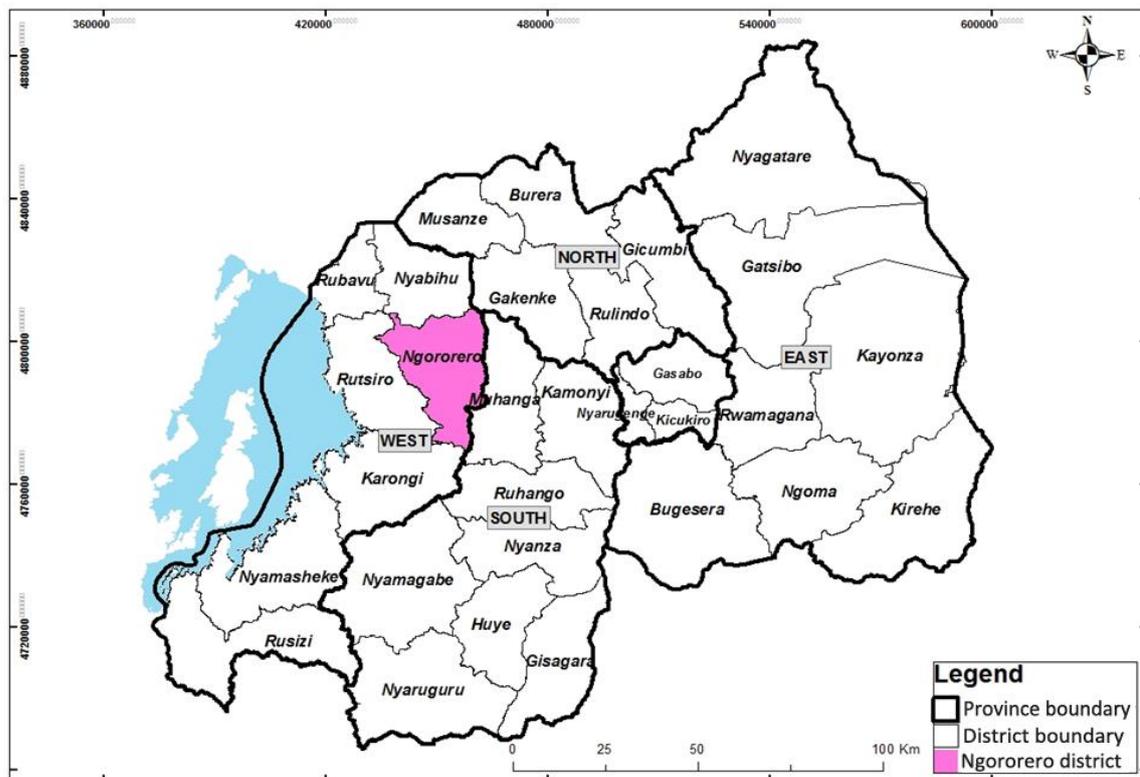


Figure 1. Location of Ngororero district in Rwanda.

The poverty rate reported by Integrated Household Living Conditions Survey IHLCS4 in Ngororero District is 49.6% compared to 39.1% nationally and extreme poverty is 23.5% compared to 16.3% nationally. Since this strategy is for transformation, this situation requires a deep understanding of the current situation, existing problems, available resources, and how they can be used to reverse this poverty trend (Ngororero District Development Strategy Plan (DDSP), 2015-2021).

The Ngororero district was selected due to high mountain elevation and steep slopes found in the regions, as well as heavy rainfall found in the region especially in rainy season of March to May. The sectors having high level of landslide are mainly, Muhanda, Kavumu, Sovu, and some parts of Kabaya, Bwira, and Ndaro. The remaining parts have medium and low level of landslide occurrences. As mentioned above, the study focused only on three sectors namely Muhanda, Kavumu and Sovu, due to their high level of vulnerability to landslides in terms of high elevation, heavy rainfall and land cover type where forestland is has been reduced and replaced by cropland.

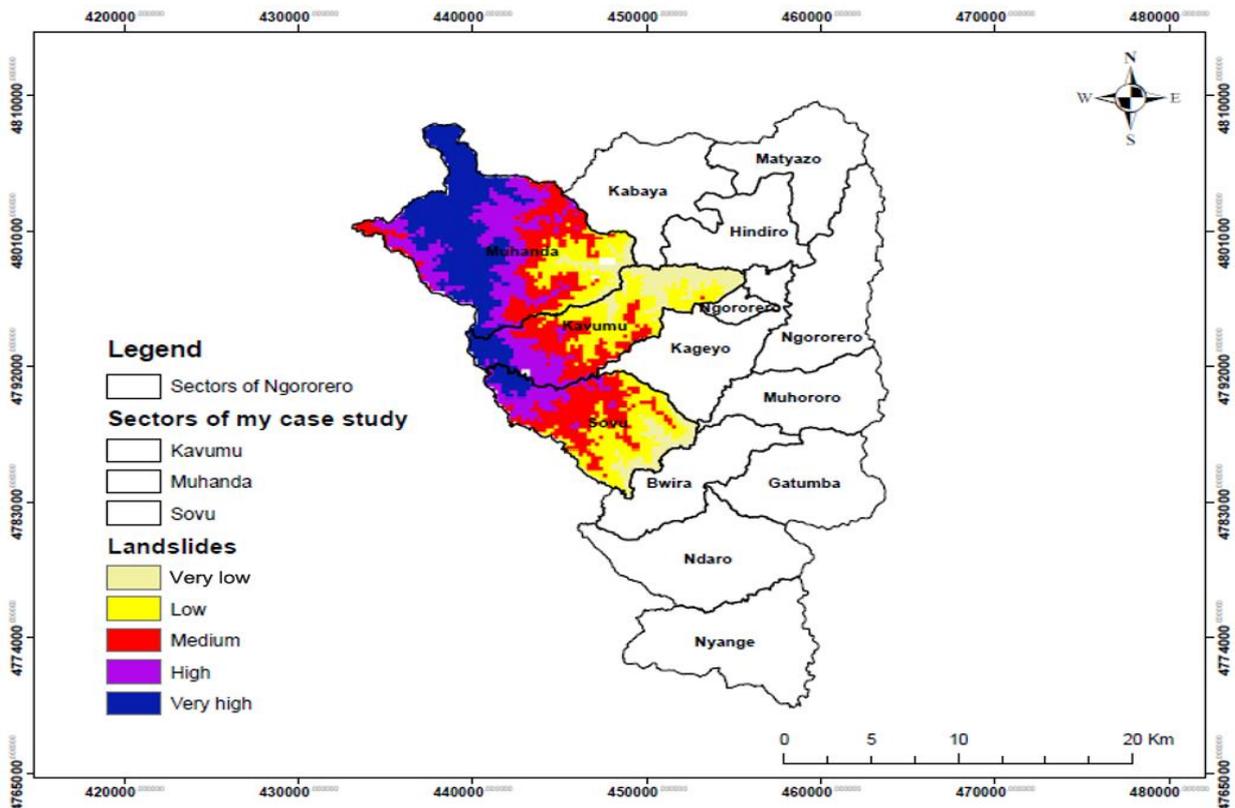


Figure 2. Landslides in the selected sectors of Ngororero district.

As presented in Figure 2, Landslides are very high and high in Western part of Muhanda Sector and Kavumu sector, and the same in north-west of Sovu sector. The remaining parts of the sectors, especially in their central and eastern parts, have relatively moderate, low and very low landslides intensity. This implies that the effects of landslide are likely to be more disastrous in western and central parts than in northern parts of the selected sectors.

2.2. Sampling and Data Collection Techniques

The useful data in the study were obtained by selecting a sample of 392 respondents, from a total population of 19,909 population including 18,999 households, 9 staff from the selected sectors and one (1) from district staff making a total of 18,909 study population. Data were collected using questionnaire, documentation and observation. Purposive sampling technique was used to select three sectors, and random sampling was used to select individual households to be surveyed. Both quantitative and qualitative research methods were used in the study.

Table 1 presents Sample size and sampling techniques used.

Table 1. Sample size and sampling techniques used.

Category of respondents	Population	Sample size	Sampling techniques
Sectors	13 sectors	3 sectors	Stratified sampling
Staff of district	1	1	Purposive sampling
Staff of sector	9	9	Purposive sampling
Heads of households	19899	382	Random sampling
Total	19,909	392	

Figure 3 illustrates methodology flowchart followed by the researcher.

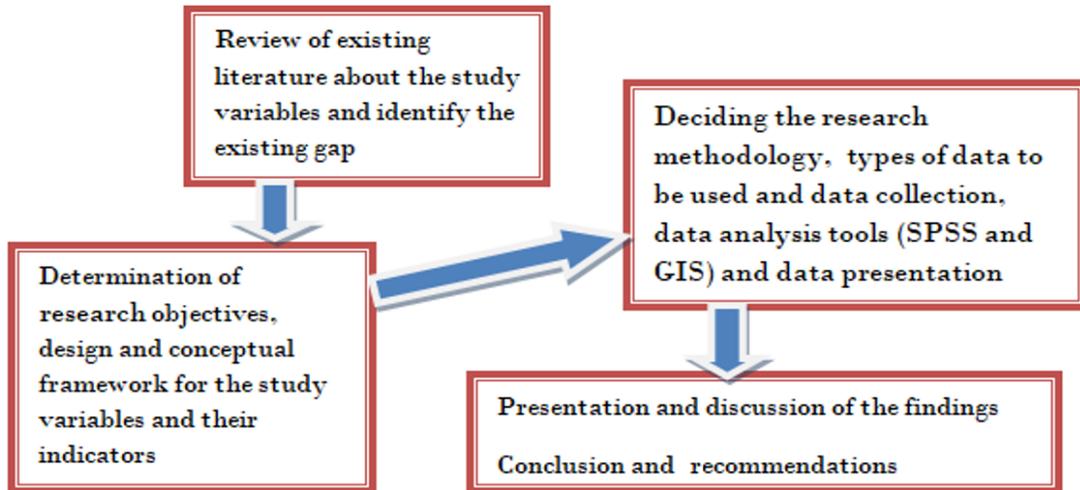


Figure 3. Methodology flowchart followed by the researcher.

3. RESULTS

3.1. Background of Respondents

Basing on the information presented in the Table 2, three (sectors) were selected from thirteen(13) using stratified sampling, one district staff in charge of environment was purposively selected, and 9 sector agents(three for each sector) were purposively selected. The heads of households were selected randomly; it means all of them had equal probability of being selected.

Table 2. Sample size subdivision per sector and category.

Sector/Category	Heads of households	Sector staff	Staff of district	Total
Kavumu	127	3		130
Muhanda	127	3		130
Sovu	128	3		131
Staff of district			1	1
Total	382	9	1	392

3.2. Delineation of Landslides Gravity in the Study Area

To analyze the impact of landslides on the livelihoods of rural communities in the Ngororero District, the study first began by delineating the gravity of landslides in the study area. The figure below shows the level of susceptibility to landslides in the Muhanda, Kavumu, and Sovu sectors.

As presented in the Figure 4, very high and high landslide susceptibility is found in all of the three selected sectors, with Muhanda sector most dominated by very high and high susceptibility compared to others. The remaining landslides levels of susceptibility are found scattered and dispatched in every corners of the selected sectors.

The map (Figure 5) shows that, in Muhanda Sector, the larger part of Bugarura, Mashya and a small part of Rutagara cell have elevation which is very high, while others have relatively high, moderate low and very low

elevation. In Kavumu Sector, a very high and high elevation is in Tetero, Rugeshi, Nyamugeyo, Birembo and small part of Gitwa, and the remaining part are with a low and very low elevation.

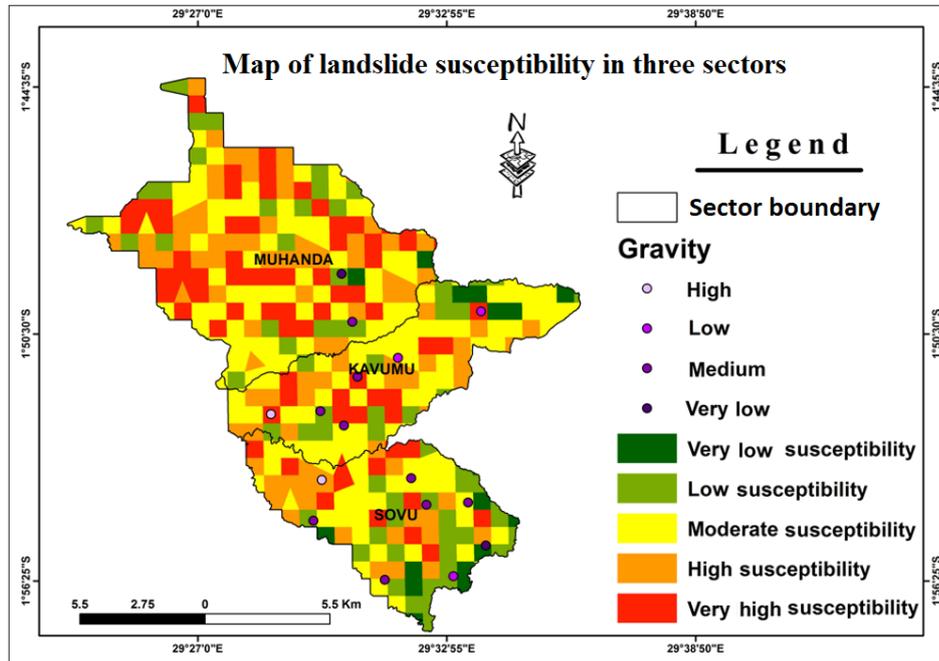


Figure 4. Landslide susceptibility in the study area.

In Sovu Sector, a very high and high elevation is in Nyabipfura Cell, Nyabipfura, Kagano and Birembo Cells, a moderate elevation is in a big part of Birembo and Kagano Cells, a small part of Kanyana, Rutovu and Musenyi Cells, and the remaining part is with a low and very low elevation.

This implies that the larger part of the study area is made of high elevation which may induce the higher vulnerability to landslides events and triggering factors like steep slopes and heavy rainfall.

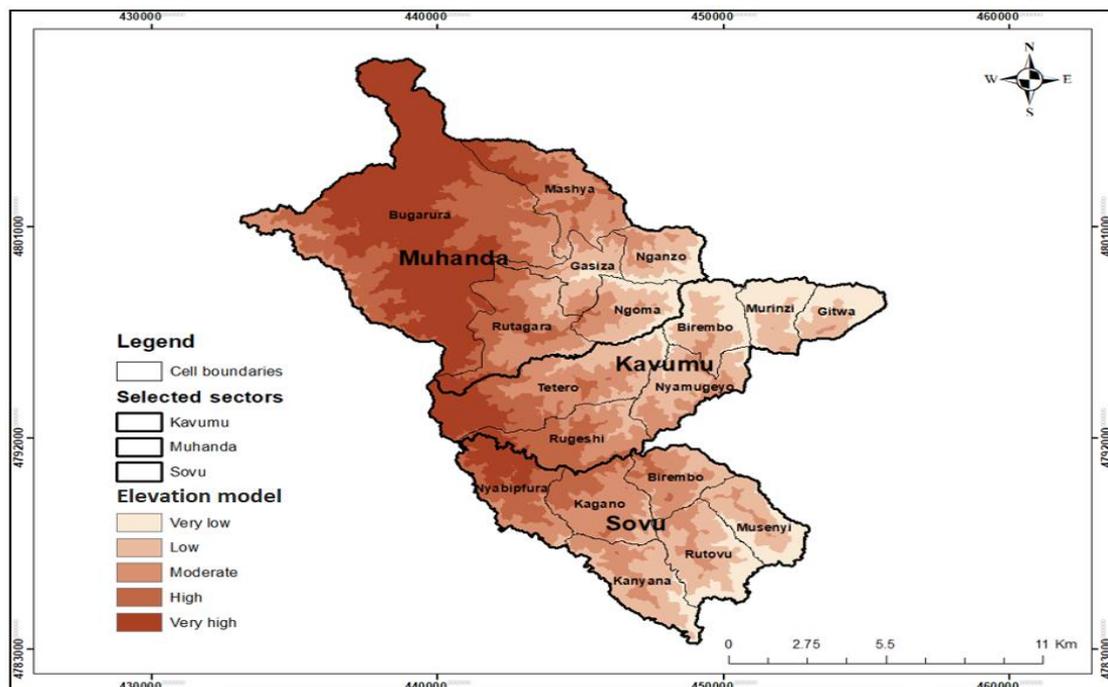


Figure 5. Elevation model for the three sampled sectors.

The annual precipitation for the baseline period of 2016 to 2020 in Muhanda, Kavumu and Sovu sectors are shown in the Figure 6. Most of the minimum rainfall of 1295 mm has been recorded in 2019 while the maximum 2018 of 1707 mm.

3.3. Analysis of Variance (ANOVA)

From ANOVA Table 3, the F-statistic, 4.544 is higher than the critical value, 3.936. The F value is 4.544, which reaches significance with a p-value of 0.044 (which is less than the 0.05 alpha level). This means that there is a statistically significant difference between the means of the different income ranges of the monthly income variables. There was a statistically significant difference between the groups as demonstrated by one-way ANOVA $F(3.936) = 4.544, p = 0.044$. Therefore, from these results it is confirmed that landslides have affected respondents' monthly income hence affecting the community livelihood in terms of their health in general.

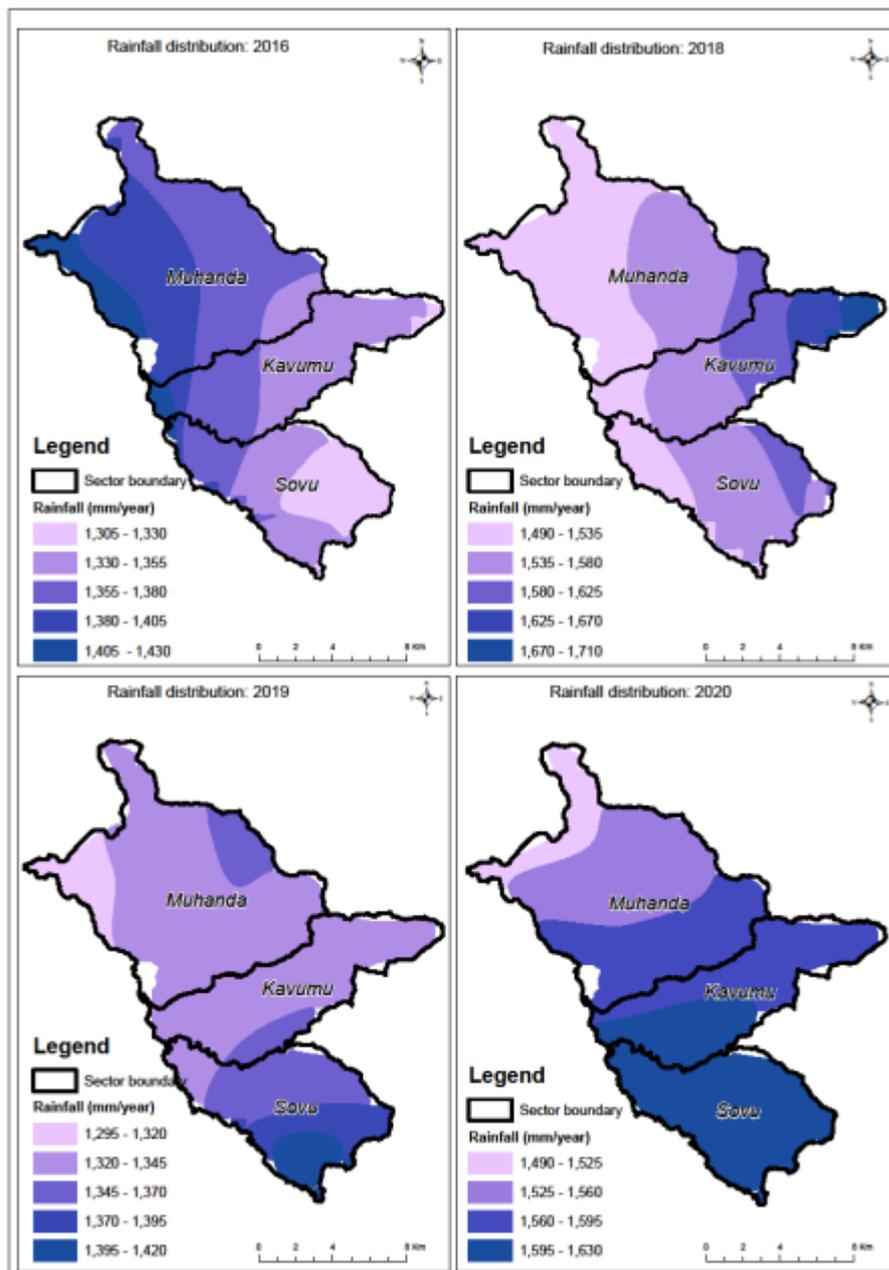


Figure 6. Rainfall distribution in Muhanda, Kavumu and Sovu Sectors from 2016 to 2020.

Table 3. Anova for monthly income received after landslides.

Model		Sum of squares	Df	Mean square	F	Sig.
1	Regression	0.033	1	0.033	4.544	0.044 ^a
	Residual	73.381	97	0.757	-	-
	Total	73.414	98			

Note: a. Predictors: (Constant), Most remarked Landslide indicator in the study area.

Table 4. Anova of number of meals taken per day after landslides events.

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	2.850	1	2.850	7.623	0.007 ^a
	Residual	36.262	97	0.374	-	-
	Total	39.111	98			

Note: a. Predictors: (Constant), Most remarked landslide indicator in the study area.

From Analysis of Variance (ANOVA) [Table 4](#), the F-statistic, 7.623 is greater than the critical value, 3.936 and P-value 0.007 less than 0.05 alpha levels (i.e. with 95% confidence interval). This leads to conclude that independent variable landslide indicators explain number of meals taken, hence affecting the rural community livelihood in terms of their health in general.

Table 5. Anova of respondents' agreement on landslides impact on rural community livelihoods.

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	0.256	1	0.256	5.612	0.043 ^a
	Residual	40.653	97	0.419	-	-
	Total	40.909	98			

Note: a. Predictors: (Constant), Most remarked Landslide indicator in the study area.

As presented in the ANOVA [Table 5](#), F-statistic value is, 5.612 is greater than the critical value, 3.936 and P-value 0.043 less than 0.05 alpha levels (i.e. with 95% confidence interval). These results show that there is statistical significance of the impact of landslides indicators on rural community livelihoods as dependent variable explained by the indicators such as income level, food security level, and homelessness, destruction of infrastructures and loss of human and livestock. This leads to conclude that independent variable landslide indicators explain number of meals taken, hence affecting the rural community livelihood in terms of their housing in general.

Table 6. Anova of number of family members killed by landslide disaster.

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	0.290	1	0.290	0.532	0.467 ^a
	Residual	52.821	97	0.545	-	-
	Total	53.111	98			

Note: a. Predictors: (Constant), Most remarked Landslide indicator in the study area.

Statistical information summarized in Analysis of Variance (ANOVA) [Table 6](#) shows that, the F-statistic, 0.532 is less than the critical value, 3.936. The P-value is 0.467 which is greater than 0.05 alpha levels. There was no statistically significant difference between groups as demonstrated by one-way ANOVA results, since as described in previous section, above 90% of the total respondents reported not having recorded any family member death due to landslides. Therefore, from these results it is confirmed that landslides have contributed a little on the death of rural community dwellers.

Table 7. Anova of number of domestic animals lost due to landslide occurrence.

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	9.540	1	9.540	10.784	0.001 ^a
	Residual	85.813	97	0.885	-	-
	Total	95.354	98			

Note: a. Predictors: (Constant), Most remarked Landslide indicator in the study area.

Basing on the information presented in Analysis of Variance (ANOVA) Table 7, the F-statistic, 10.784 is greater than the critical value, 3.936. Therefore, from these results it is confirmed that landslides have had impact on the number of domestic animals lost due to landslides occurrence.

Table 8. Anova of landslide impact on respondent's livelihoods.

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	1.311	1	1.311	4.12	0.022 ^a
	Residual	308.709	97	3.183	-	-
	Total	310.020	98			

Note: a. Predictors: (Constant), Most remarked Landslide indicator in the study area.

Basing on the information presented in ANOVA Table 8, the F-statistic, 4.12.784 is greater than the critical value, 3.936. And the P-value 0.022 is less than alpha level(0,05)Therefore, from these results it is confirmed that landslides have had impact community livelihood, considering the respondents views.

Table 9. Model summary for correlation between landslides indicators and their impact on community livelihoods.

Model	R	R square	Adjusted R square	Std. error of the estimate	Change statistics				
					R square change	F change	df1	df2	Sig. F change
1	0.713	0.509	0.501	1.78397	0.004	4.12	1	97	0.022

Note: Predictors: (Constant), Most remarked Landslide indicator in the study area.

From the above model summary, in this case, the value is 0.509, which confirms that the livelihood of the rural community is affected by the occurrence of landslides. The adjusted R-squared shows the generalizability of the results, i.e. the variation of the sample results from the population in the multiple regression. The difference between the minimum R-squared and the Adjusted R-squared is required. In this case, the value is 0.501, which is slightly different from 0.509, so it is statistically good and significant.

Therefore, the model summary Table 9 is satisfactory and we can conclude that landslides occurrences in Ngororero district have impact on rural community livelihoods.

3.4. Discussion

The study's main objective was to analyze the impact of landslides on the livelihood of a rural community in Rwanda concerning three sectors of Ngororero District (Muhanda, Sovu, and Kavumu) as a case study.

According to Figure 7, human activities such as road construction, engineering structures, mines and quarries, dams and reservoirs, canals, groundwater rise, changes in vegetation cover, tunnels, and communication systems have a great influence on the stability of the earth and are considered as major factors causing slope failures in the twentieth century. These human modifications fundamentally change the stability of the hillside. The undercutting of slopes for the construction of houses and footpaths causes concentrated flow that triggers landslides, especially in the western part of Rwanda.

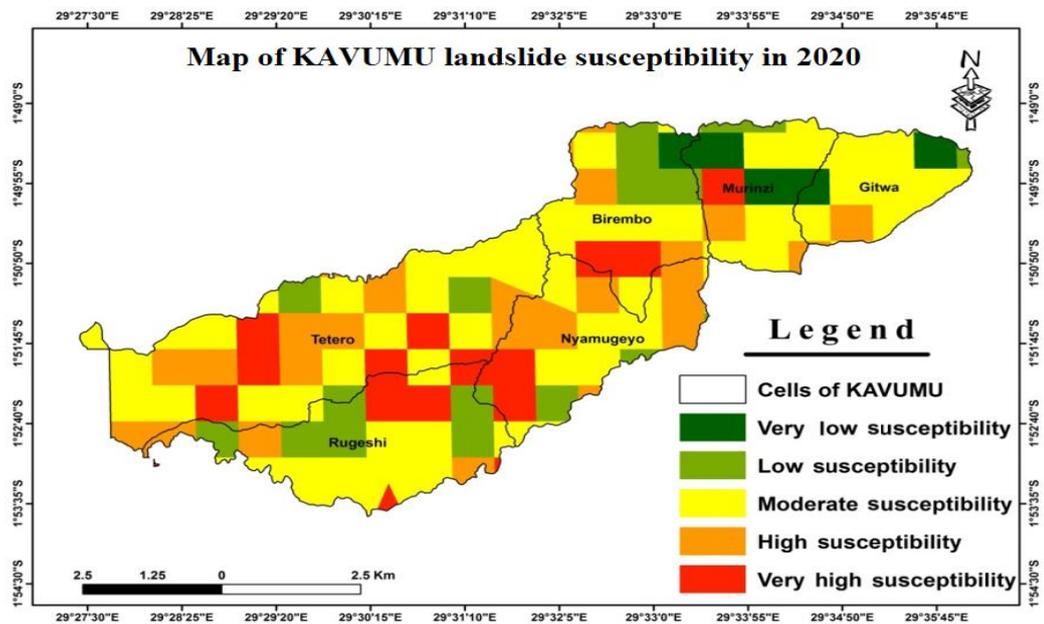


Figure 7. Landslides caused by manmade works (Roads), Ngororero and Rubavu.



Figure 8. Some Landslides in Ngororero District.

Due to the high amount of rainfall and the topographical structure, which is characterized by a steep slope, the district is often affected by landslides (Figure 8) and floods almost every year during periods of heavy rainfall. In the past, some victims drowned in water, others died after houses collapsed under heavy rains or landslides.



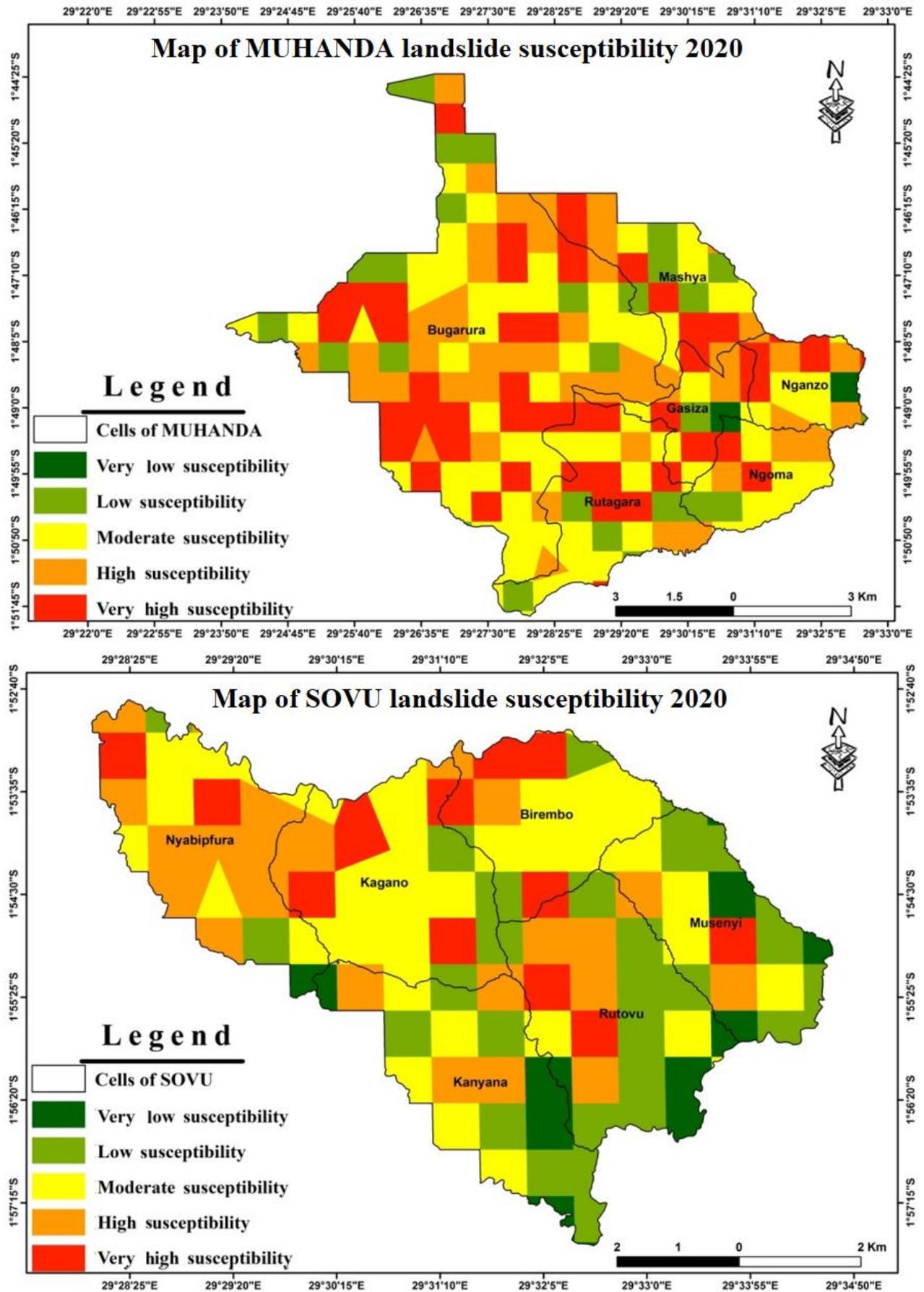


Figure 9. Landslide susceptibility in Kavumu, Muhanda and Sovu sectors 2020.

Figure 9 illustrates landslide susceptibility in Kavumu, Muhanda and Sovu sectors of Ngororero District.

Situation of Kavumu Sector in 2020: It was noted that 13.6% of the area's susceptible to landslides was very high, 20.0% of the area was high, 48.2% of the area was moderately susceptible to landslides, 18.2% of area was low and very low susceptible to landslide.

Situation of Muhanda Sector in 2020: It was noted that 26.1% of the area's susceptible to landslides was very high, 25.9% of the area was high, 33.7% of the area was moderately susceptible to landslides, and 14.3% of Muhanda Sector was low and very low susceptible to landslide.

Situation of Sovu Sector: It is remarkable that in Sovu Sector 2020, 13.1% of the area's susceptible landslide was very high, 22.8% of the area was high, 32.5% of the area's susceptibility to landslides was moderate, and 31.6% was low and very low susceptible to landslides.

3.4.1. Respondents' Perception of the Effect of the Landslide that Most Affected their Territory

Landslide has several catastrophic effects in geographical, ecological, economic, and social fields. The researcher suggested some effects and asked the respondents which most affects their area and the answers they gave are summarized: The majority of respondents confirmed that damage to infrastructure is the most common effect in the study area 43.4% of the total number of respondents, followed by the destruction of houses with 41.4% of respondents. 11.1% of the total respondents confirmed that crop damage is the most common landslide effect in the study area, while only 4.0% said that landslides cause business closures.



Figure 10. Destruction of crops due to landslide.

3.4.2. Impact Of Landslide on Food Security

According to Figure 10, Landslides affect the level of food security of people living in the affected areas. This is due to the reduction in crop harvest and people's income, which reduces their purchasing power. The change in food security of the respondents before and after the landslide has been indisputable. Respondents' opinions show that previously only 12.1% ate once a day, but after the landslides, the number of those who ate once a day increased to 33.3%. The percentage of people who ate twice a day moved from 58.6% to 54.6% and members who ate three times a day decreased from 29.3% to 12.1%, reflecting the strong impact of landslides on food security in rural communities in Ngororero District. Everyone is affected by landslides including farmers, monthly salary workers, and businessmen as the cost of food after the destruction of food crops by landslides affects each of them.

3.4.3. Impact of Landslides on Respondents' Income

Income is paramount in determining community livelihoods. Any improvement or decrease in people's livelihood is closely linked to an increase or decrease in their income. The answers generated by the respondents, when asked to compare their income before and after the occurrence of landslides in their areas, the majority of respondents (50.5%) reported that their monthly income was between 100,001 and 200,000 Rwandan Francs (RWF) before the landslides occurred in their locality. This was followed by those whose monthly income was between 50,001 and 100,000 RWF and between 200,001 and 500,000 Rwandan Francs (RWF) with 29.3% and

12.1% of respondents. Only one respondent confirmed receiving a monthly income estimated at over 500,000 RWF before the landslides. On the other hand, after the landslides in the region, the number of respondents receiving a monthly income between 200,001 and 500,000 RWF decreased from 12.1% to only 5.1% of the total number of respondents surveyed, while those whose monthly income ranged from 100,001 to 200,000 RWF fell from 50.5% to 15.2% (down 30.3%). After the landslides in the study areas, no respondent whose monthly income was higher than 500,000 RWF was found. More importantly, respondents whose income ranged from 50,001 and 100,000 RWF and 50,000 RWF (considered lower income ranges in the study) rose from 29.3% to 38.4% and 7.1% to 41.4%. Landslides have caused a decline in the rural population in Ngororero District, affecting their livelihoods in general.



Figure 11. Landslides and loss of human and animal life.

3.4.4. Loss of Human and Animal Life

With the Figure 11, it is clearly evidenced that Landslide cause loss of Human and animal life. During the study, respondents corresponding to 5.1%, lost one family member due to the landslide, others corresponding to 3.1% of the total number of respondents, lost two or three members households, while only one respondent reported losing more than three members to a landslide. 90.8% of the surveyed respondents confirmed that they did not lose any family members as a result of the landslide. On the animal loss side, the majority of respondents (46.4%) reported losing one pet in a landslide, followed by those who lost more than three pets (26.3%) as a result of a landslide and those, who lost two to three pets with 21.2% of the total number of respondents. The above results show that the landslides had a noticeable impact on the death of some community members and domestic animals due to the occurrence of landslides.

Respondents' overall views on the impact of landslides on the livelihood of the rural community, the majority of respondents selected from the study area (Muhanda, Sovu, and Kavumu sectors in Ngororero District) agreed that landslides had an impact on the livelihood of the rural community, with 76.8% strongly agreed, while 18.2% agreed. Only 16 respondents, corresponding to 4.0%, disagreed with the impact of landslides on the livelihoods of rural communities. These results are significant based on other information obtained and presented in the previous paragraphs of this paper that show the impact of landslides on the livelihoods of rural communities.

4. CONCLUSION AND RECOMMENDATIONS

This study analyzed the impact of landslides on the livelihoods of a rural community in Rwanda, referring to Ngororero District in Western Province as a case study.

The research accurately mapped landslides in vulnerable areas in Ngororero District and identified their causes. The results objectively showed that the main factors of landslides in Ngororero District include heavy rainfall, steep slopes, land cover changes and soil types. The researcher used various maps to delineate the location and severity of the landslide in the study area. In the three sampled sectors, a high severity of landslides was found in the Muhanda sector, especially in its northwestern part, in the western part of the Kavumu sector and in the

northwestern part of the Sovu sector, the remaining parts of the three sectors have relatively high, medium and low landslide severity.

The study also assessed the livelihood status of the rural community in Ngororero District during the study period (2016-2020). This was done by comparing the livelihoods of community members before and after being affected by the landslide. Livelihood indicators considered were earned income, level of food security, homelessness, and health problems. The results of the research findings showed that the monthly income earned by the community members in Ngororero District decreased after the landslides. Similarly, community members experienced disease and lack of food, so the researchers compared the number of people who could afford to eat two or three meals a day and found that their number decreased after the landslides in the region.

The research analyzed the impact of landslides on the livelihoods of a rural community in Ngororero District. The study also revealed that landslides had a remarkable impact on community livelihoods. It turned out that some of the households lost family members and others injured, lost pets due to landslides in their locality.

Based on the findings of the study, it is recommended that the government strengthen and help rural community members to protect their land from potential landslides. Suitable and durable materials should be used in the construction of houses and infrastructures such as roads, classrooms, and health centers.

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Competing Interests: The authors declare that they have no competing interests.

Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

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