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Geospatial Analysis of Landslide Susceptibility and Its Impact on Community Livelihood in Rwanda, a Case of Nyabihu District

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ABSTRACT
Nyabihu District, located in Rwanda's Western Province, is highly vulnerable to landslides, with many areas susceptible to this hazard. This research aimed to assess the landslide susceptibility in Nyabihu district using geospatial analysis, particularly Geographic Information Systems (GIS). The study focused on the spatial distribution of landslides, their contributing factors, and their impact on the livelihoods of local communities. Landslide susceptibilitymapping was carried out using the Analytic Hierarchy Process (AHP), considering nine critical factors: elevation, slope, aspect, curvature, land use/land cover, rainfall, soil texture, proximity to roads, and proximity to rivers. The data used in the analysis was derived from remote sensing imagery, digital elevation models, climate data, and field surveys, offering a comprehensive assessment of landslide-prone zones. The results revealed that Nyabihu is largely dominated by high landslide hazard areas, particularly in the central and southwestern zones, due to steep slopes, loose soil, and high rainfall. Very high hazard zones are concentrated in the west and southeast, likely driven by unstable geology or intensive land use. In contrast, low and very low hazard areas, mainly in the north and some eastern parts, feature flatter, more stable terrain and are safer for development. The study also highlighted that public awareness about landslide risks is limited, with 37.5% of residents lacking knowledge of landslide causes. Furthermore, 35.5% of those surveyed had been displaced due to landslides, and 24% reported damage to infrastructure, including roads, homes, schools, and hospitals, which affect community livelihood.

Keywords: Landslide, Susceptibility, GIS, Community livelihood, GIS, Nyabihu district

I. INTRODUCTION

Landslides are among the most devastating natural hazards, posing significant threats to human lives, property, and environmental resources worldwide (Dibanga B. Placide & Gatera Frederic, 2017). Defined as the downward movement of soil, rock, and debris under the influence of gravity, landslides are triggered by a combination of natural and anthropogenic factors, including heavy rainfall, steep slopes, deforestation, and unregulated construction (Cruden, 1991; Yalcin, 2007). Globally, landslides account for approximately 5% of all disaster-related deaths, with annual economic losses surpassing $20 billion (World Bank, 2021).

Africa, particularly the eastern region, is notably vulnerable to landslides due to its complex topography and seasonal rainfall. Rwanda, known as the “Land of a Thousand Hills,” is particularly affected. Its mountainous terrain and intense rainfall events make it highly susceptible to recurrent landslide incidents, especially in the Western and Northern Provinces. Between 2018 and 2023 alone, landslides in Rwanda caused over 250 fatalities, destroyed thousands of homes, and severely disrupted agricultural activities (MIDIMAR, 2015). Nyabihu District, located in Rwanda’s Western Province, stands out as a hotspot for landslide hazards due to its steep topography and high rainfall levels.

Geographically, the relief of Nyabihu is 90% rugged mountains with more than 55% of the total area characterized by steep slopes, making it highly prone to landslides (Republic of Rwanda, 2018). The district receives an average annual rainfall of approximately 1,400 mm, which, combined with these steep slopes, further exacerbates landslide susceptibility. Climate change is expected to intensify this issue by increasing rainfall intensity, leading to more frequent and severe rainfall-induced landslides (Muhire, Ahmed, & Abutaleb, 2015).

In addition to topographical and climatic factors, Nyabihu District's soil composition plays a graet role in landslide exposure. The district's soils comprising sandy, clay, lateritic, and volcanic materials are particularly unstable in sectors such as Bigogwe, Jenda, and Rambura, where sandy, highly permeable soils dominate. This weak soil structure contributes to ground instability, further increasing landslide risk (Dibanga, Frederic, & Dominique, 2016).

Beyond the natural factors, human activities, including unsustainable agriculturalpractices, deforestation, mining, and construction on steep slopes, have further aggravated the risk of landslides in Nyabihu. Population growth which grown from 268,367 in 2002 to 295,580 in 2012, and reaching 319,047 in 2022 (NISR, 2005, 2014, 2023) has intensified land pressure, leading to increased land degradation. The removal of protective vegetation due to these activities accelerates soil erosion and weakens land stability, amplifying the impact of heavy rainfall and landslides.

The consequences of these combined factors are severe. Notably, Nyabihu District frequently experiences landslides that result in loss of life, displacement, destruction of homes, and disruptions to agriculture (Menk et al., 2022). Vulnerable communities face disproportionate challenges due to limited access to emergency services, shelter, and livelihood support following landslides (Nema et al, 2023). Along these, disaster risk reduction policies in the district often follow a top-down approach, limiting community involvement and weakening local adaptive capacity (Anderson & Holcombe, 2013).

While existing studies have examined landslides in Nyabihu District, there remains a gap in the integration of geospatial analysis for systematically assessing landslide susceptibility and its socio-economic impact. That's why existing disaster management strategies often lack the spatially detailed insights required for effective risk assessment, mitigation, and response. Without accurate geospatial data, policymakers and local authorities are unable to implement proactive measures to reduce landslide risks and protect vulnerable populations.

This study seeks to bridge this gap by leveraging geospatial techniques, particularly Geographic Information Systems (GIS), to analyze landslide susceptibility and its effects on community livelihoods.

II. METHODOLOGY

2.1 Study area description

This research was carried out in Nyabihu, a district located in the Western Province of Rwanda. The study focused on Nyabihu District because of its unique combination of environmental and geographical factors that make it particularly susceptible to landslides. This region is characterized by steep mountainous terrain, high levels of rainfall, and a history of frequent landslide occurrences, which have resulted insignificant damage to property, infrastructure, and human life.

The geographical location of Nyabihu is depicted in the figure below:

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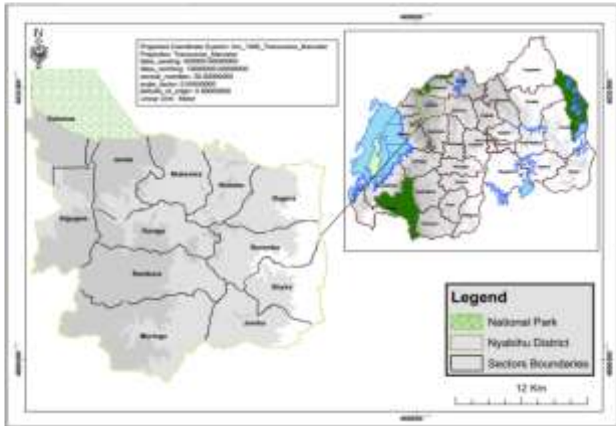

Figure 1: Study area description

2.2. Methods and Materials

The study used both primary and secondary data. Secondary data included satellite imagery and spatial datasets from different sources were used. Landsat 8 imagery from USGS was used for land cover classification, while Digital Elevation Model (DEM) from RCMRD helped derive topographic features like elevation, slope, aspect and curvature. Rainfall data were obtained from Meteo Rwanda and WorldClim, and soil data from the Rwanda Geoportal provided critical input into assessing slope stability. Additionally, literature from REMA, NISR, RFA, and academic journals supported the contextual and conceptual framing of the research.

Primary data were collected through interviews and field surveys. A total of 17 historical landslide sites were identified via field measurements and GPS mapping, with support from community members for inventory mapping. Interviews were conducted to assess public awareness and the impacts of landslide on their livelihoods. A sample of 379 households was selected from a population of 28,461 households in four high-risk sectors—Bigogwe, Jenda, Jomba, and Kabatwa—using proportionate stratified sampling based on Krishnaswamy's formula as follow:

$$n = \frac{z2 * p(1-p)/e2}{1 + (z2 * p(1-p))/ z2 * N}$$

- Z = 1.96 (Z-score corresponding to a 95% confidence level)
- p = 0.5 (assumed proportion for maximum variability)
- e = 0.05 (margin of error)
- N = 28,461 (total household population in Nyabihu)

The researcher then calculated the sample for each sector based on the proportionate sampling method, which was used to determine the number of respondents from each sector.

$$ni = \frac{Ni * n}{N}$$

In this formula, ni represents the sample size to be determined for each sector, Ni is the population of each sector, n is the total sample size of 379 households, and N is the overall population of 28,461 households considered in the study. The households'distribution for each sector is provided in Table below:

Table 1: Sample size employed in each among selected sector

Sectors	Households (Ni)	Sample size (ni)
Bigogwe	7,797	104
Jenda	10,352	138
Jomba	5,266	67
Kabatwa	5,046	68
Total	**28,461**	**379**

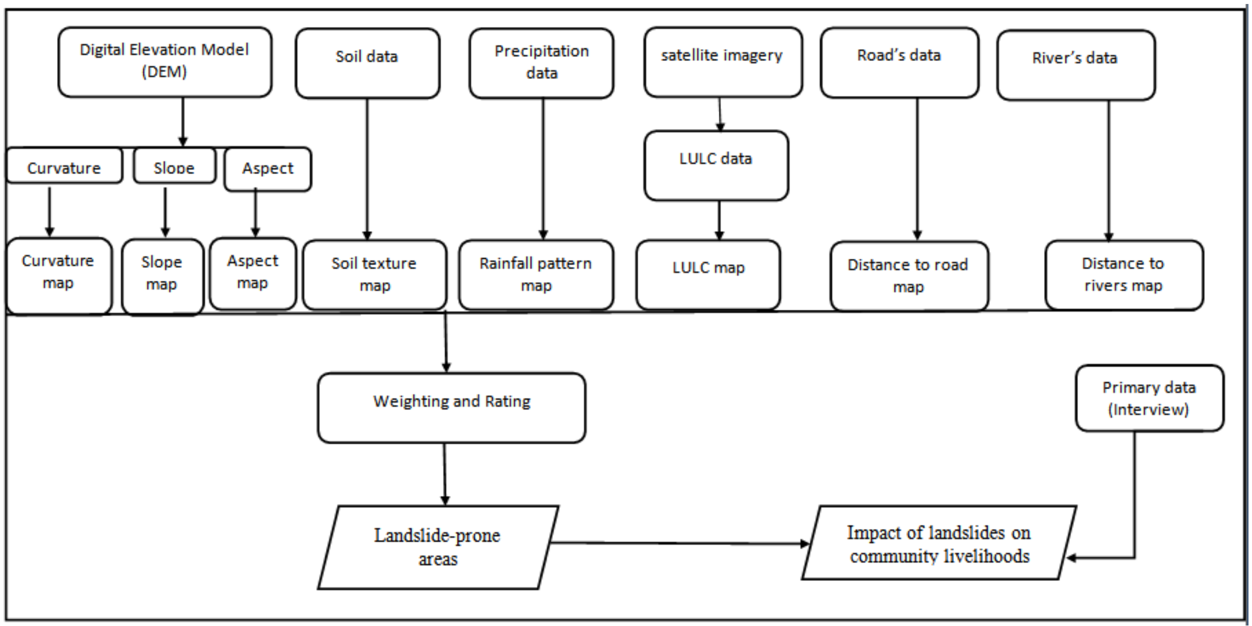

Figure 2: Methodological framework

Data analysis involved spatial analysis and community-level analysis. GIS tools, specifically ArcGIS 10.8.1 with Spatial Analyst, were used to develop the landslide susceptibility map by overlaying weighted raster layers derived from the Analytic Hierarchy Process (AHP). During data analysis, various factors contributing to landslides were categorized based on assigned ratings for each factor. A scale ranging from 1 to 9 was used to assign weights to each key factor. These weight values were derived from relevant literature, field data, and analytical reasoning (MIDIMAR, 2015). Interview responses were transcribed and analyzed descriptively using Microsoft Excel to generate tables and graphs summarizing the qualitative data.

III. RESULTS

3.0. Landslide Inventory

This study assumes that future landslides are likely to happen under environmental and geological conditions like those that triggered past landslides. Landslide susceptibility mapping typically begins with the creation of a landslide inventory, a fundamental step that has gained widespread recognition (Ayalew and Yamagishi, 2004). A landslide inventory map represents the most basic form of landslide distribution mapping (Hansen, 1984). The methods used to develop these maps vary based on the study's objectives, the geographical extent, the scale of base maps and aerial imagery, as well as the available resources (Guzzetti, 2000). These maps provide insights into past landslide occurrences, helping to analyze their spatial distribution and temporal patterns. Conducting field surveys alone to identify landslides is both costly and time-intensive. In this study, the landslide inventory map was generated using Google Earth imagery interpretation along with field assessments. Multiple field surveys were carried out to examine the type, activity, and extent of landslides. The fallowing map shows the past landslide occurrence (Inventory map).

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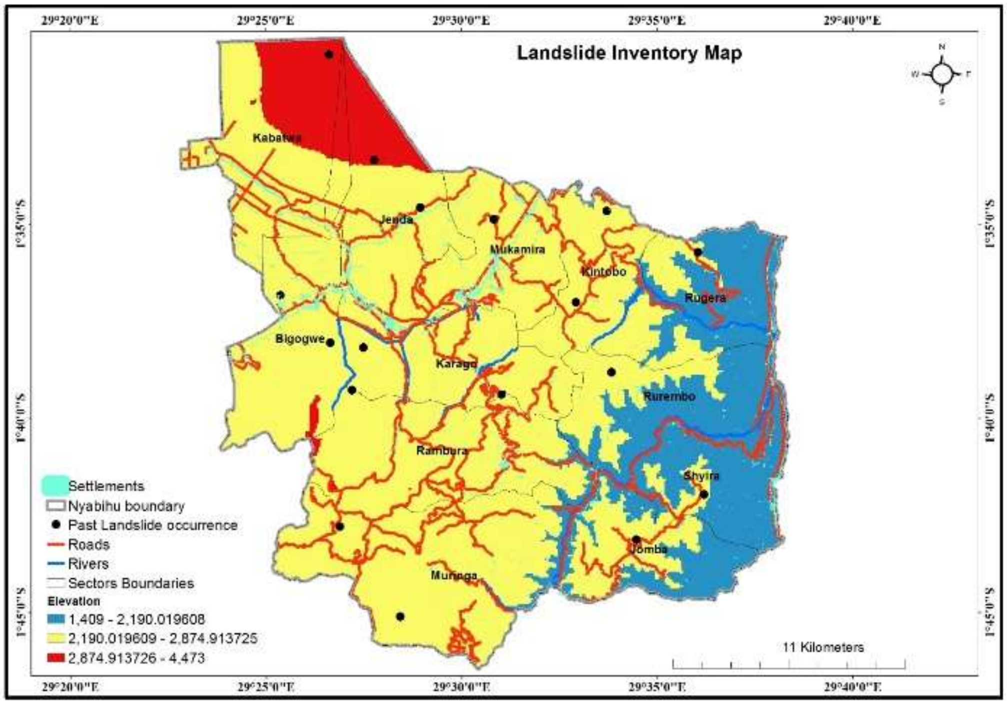

Figure 3: Nyabihu district Landslide inventory

3.1. Landslide Causative Factors

Landslides are triggered by a combination of natural and/or human-made factors (Ayalew, 1999). There is no universally established standard for selecting specific factorsin landslide susceptibility mapping; the choice depends on the characteristics of the area and the availabledata (Ayalew& Yamagishi, 2005). For this research, nine key factors were selected: elevation, slope,aspect, curvature, soil type, rainfall, land use/land cover, distance to roads, and distance to rivers. Thesefactors have also been commonly used in other studies related to landslide susceptibility and hazardmapping (Raghuvanshi, Ibrahim, &Ayalew, 2014). The significance of each causative factor incontributing to landslide susceptibility is evaluated and discussed in detail below.

3.1.1. Slope

Slope is an important determinant in GIS-based landslide susceptibility mapping (Dai & Lee, 2002; Guzzetti, Carrara, Cardinali, & Reichenbach, 1999) (Guzzetti et al., 1999; Dai & Lee, 2002). As one of the primary factors influencing landslide, it plays a great role in regulating moisture distribution and pore pressure at a local scale while also affecting water continuity across larger regions(Ayalew & Yamagishi, 2005)

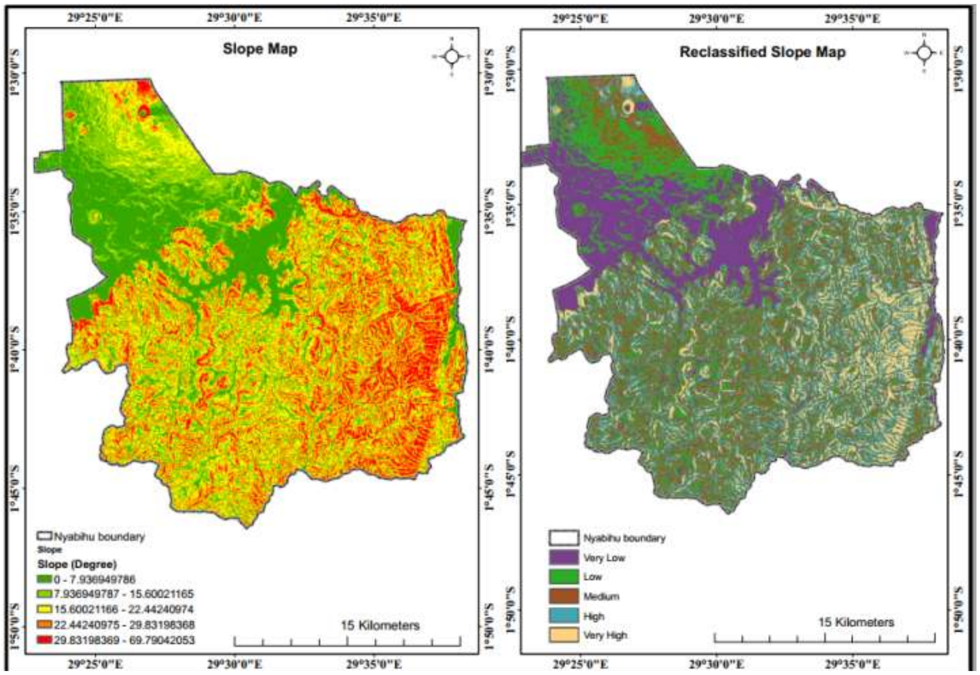

Figure 4: Nyabihu district slope map

According to above figure 4 and Table 2 below, show that approximately 44.3% of the total area, equivalent to 236.5 km², falls within the high and very high slope categories, highlighting a significant risk of landslides. The largest portion of the district, covering 118.1 km² (22.2%), consists of moderate slopes, where erosion may occur, but the likelihood of severe landslides is relatively lower. Meanwhile, flat or gently sloping land, classified under very low and low slope categories, accounts for about 33.5% of the area. These regions provide more stable terrain, making them suitable for agriculture and settlement development.

Table 2: Slope classification and reclassification area in sq. Km

Slope classification	Slope reclassificatiozn	Area (in sq. Km)	Percentage
0 - 7.936	Very low	94.6	17.7983481
7.936- 15.600	Low	83.31	15.67421121
15.600- 22.442	Moderate	118.1	22.21971365
22.442- 29.831	High	139.99	26.33816861
29.831- 69.790	Very high	95.51	17.96955843
Total		**531.51**	**100**

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3.1.2. Elevation

The elevation data reveal that Nyabihu district's terrain varies significantly, influencing land use, accessibility, and susceptibility to landslide.

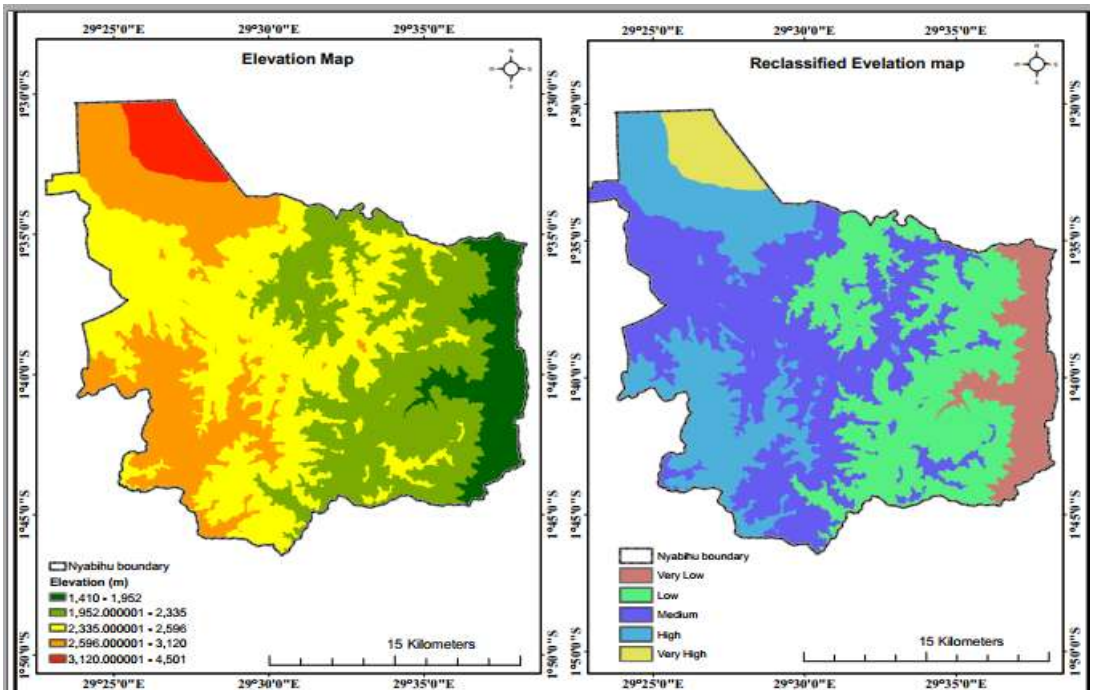

Figure 5: Nyabihu district slope map

The map above shows that the large area, approximately 198.8 km² (37.4%), falls within the moderate elevation range (2,334–2,598 meters), which represents a transitional zone between lowland and highland areas.Low-elevation areas (1,938–2,334 meters) cover 152.6 km² (28.7%), providing relatively stable land that is suitable for agriculture and settlements. Meanwhile, high-elevation zones (2,599–3,103 meters) occupy 114.2 km² (21.5%), which pose challenges for development due to steeper slopes and a higher landslide. Very low elevations occupy 45.9 km² (8.6%) of the Nyabihu district, are typically associated with valley, which may be more prone to flooding. In contrast, very high elevations (above 3,103 meters) make up only 19.98 km² (3.8%), likely consisting of rugged surface and forested or protected areas.

Table 3: Elevation classification and reclassification area in sq. Km

	Elevation		
Classification	**Reclassification**	**Area (in sq. Km)**	**Percentage**
1,409 - 1,937.690196	Very low	45.9	8.63593603
1,937.690197 - 2,334.207843	Low	152.6	28.71119473
2,334.207844 - 2,598.552941	Moderate	198.8	37.40357479
2,598.552942 - 3,103.211765	High	114.22	21.4901223
3,103.211766 - 4,501	Very high	19.98	3.759172154
Total		**531.5**	**100**

3.1.3. Slope Aspect

Slope aspect refers to the direction in which the terrain's steepest slope (Guzzetti, Carrara, Cardinali, & Reichenbach, 1999). It influences various environmental factors, including exposure to sunlight, wind, and rainfall, which in turn affect soil moisture levels, weathering intensity, and the impact of rainfall (Huang et al., 2015).

The aspect map of Nyabihu district categorizes slope orientations into various directional ranges, which play a significant role in assessing landslide susceptibility. Slopes facing northeast (22.5°-67.5°) and east (67.5°-112.5°) are particularly vulnerable due to higher exposure to prevailing winds and rainfall, leading to increased soil moisture and potential slope failures. Similarly, southeast (112.5°-157.5°) and south (157.5°-202.5°) facing slopes may experience moderate landslide risks due to prolonged sun exposure, which can dry out surface soils and cause instability during heavy rainfall events. The southwest (202.5°-247.5°) and west (247.5°-292.5°) orientations are prone to erosion, particularly in steep areas, while northwest (292.5°-337.5°) and north (337.5°-360° and 0°-22.5°) facing slopes may retain more moisture, increasing susceptibility to landslides, especially in clay-rich soils. The flat areas (-1 value) pose minimal landslide risks but may still experience localized instability due to human activities and drainage issues.

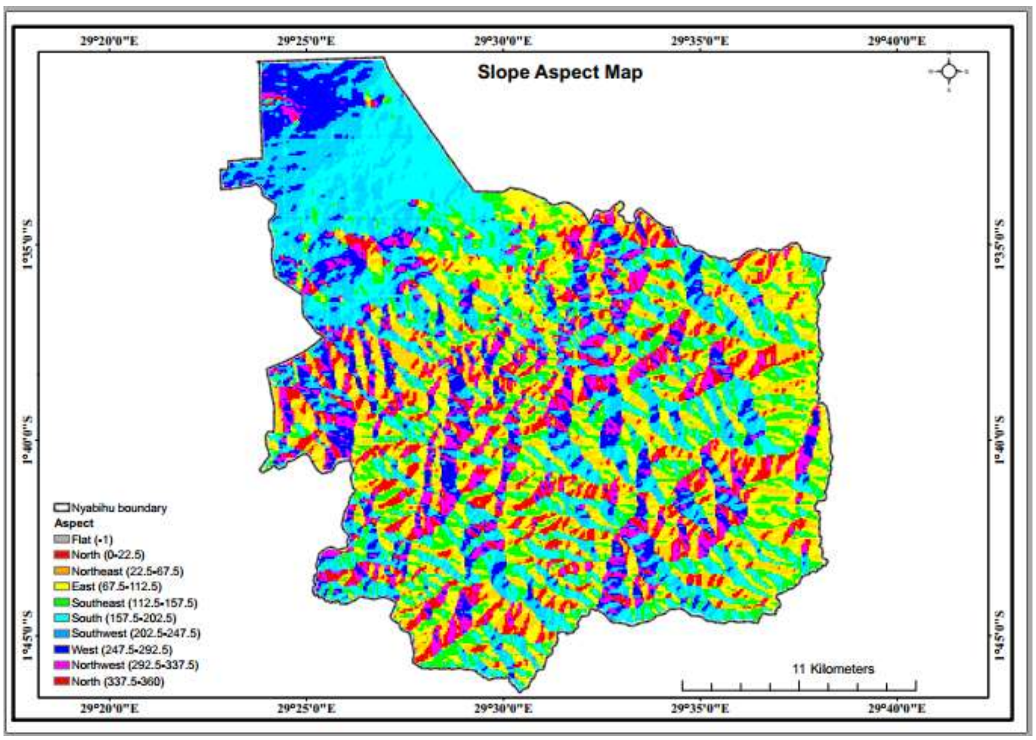

Figure 6:Nyabihu district slope aspect map

3.1.4. Curvature

Curvature is an important tool for identifying areas susceptible to landslides by assessing variations in terrain shape. The shape of a slope plays a crucial role in triggering landslides, as it significantly influences slope instability (Gadtaula and Dhakal, 2019). In the study area, concave and convex curvatures cover large part of the total land, directly affecting slope stability.

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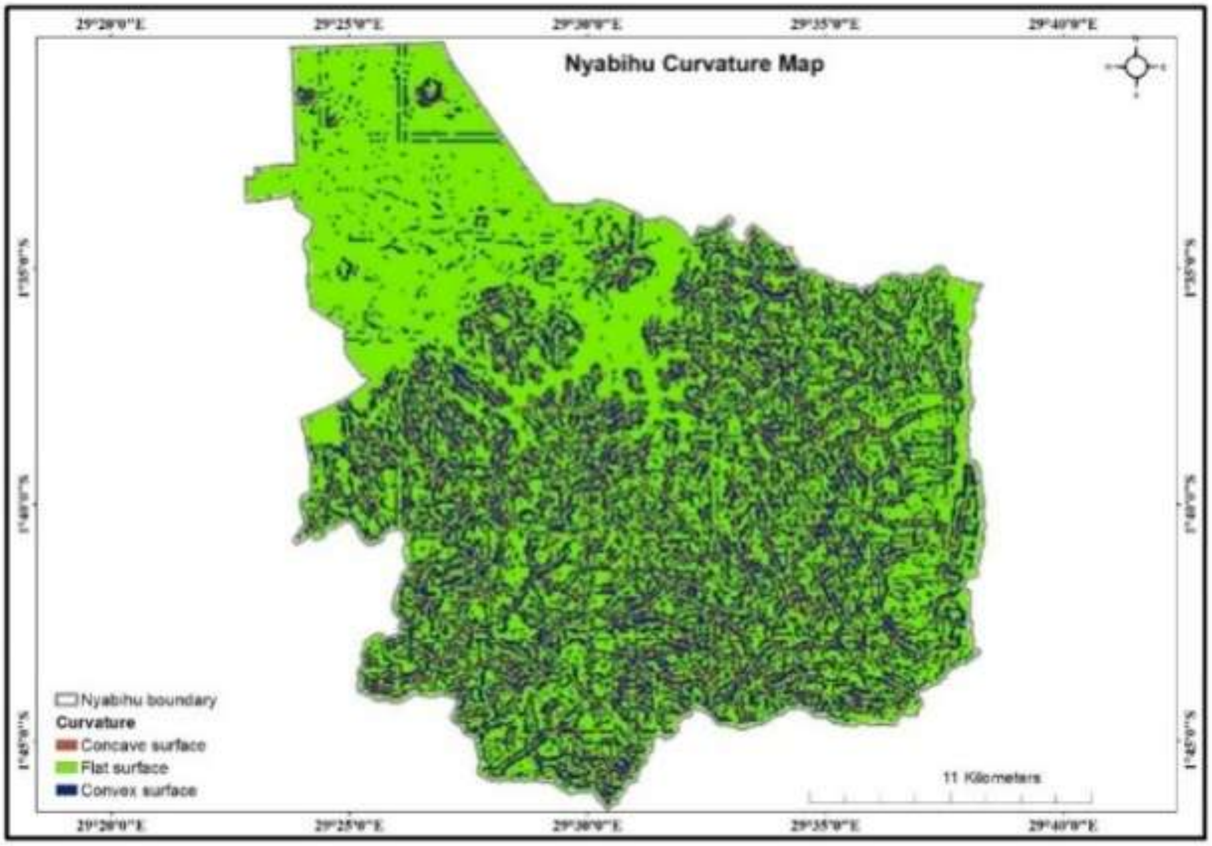

Figure 7:Curvature of Nyabihu district

According to the map above the concave surfaces represent valleys, depressions where water accumulation and soil deposition occur. These areas might be more prone to landslides due to water retention. The flat surface shows relatively stable terrain with minimal curvature. While the convex surfaces which represent ridges, peaks and steep slope where water runs off quickly. These areas are less prone to water accumulation but are more susceptible slope failures and landslides.

3.1.5. Rainfall

Heavy rainfall is the primary factor responsible for slope failures. To account for the varying distribution of rainfall data across the study area, a rainfall map was created using kriging interpolation in GIS, as the rainfall stations are spaced apart. The continuous rainfall data was then categorized into five distinct classes, ranging from 1,110 mm to 1,378 mm of rainfall annually. The reclassified rainfall map was divided into zones representing very low, low, medium, high, and very high rainfall levels.

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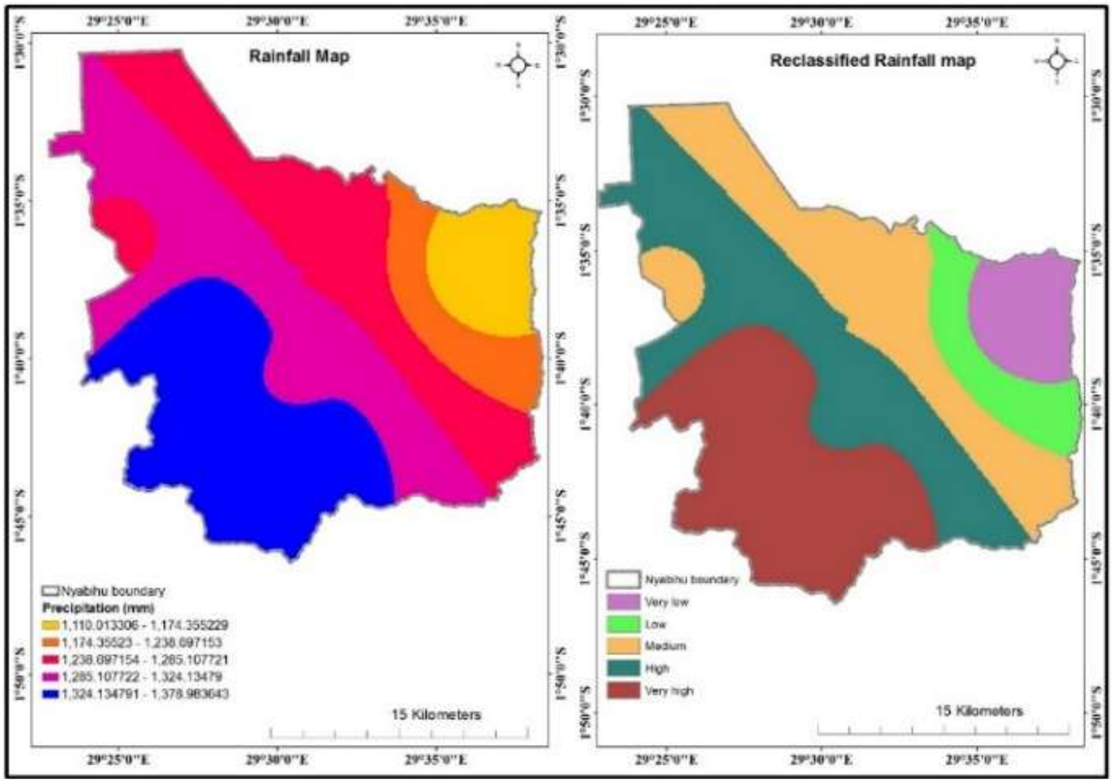

Figure 8: Nyabihu district rainfall distribution

Over 58.6% of Nyabihu district (311.44 km²) experiences high to very high rainfall levels, exceeding 1,285 mm per year. These regions are particularly vulnerable to landslides due to prolonged soil saturation and increased surface runoff, which weaken slope stability. Moderate rainfall areas, covering 135.39 km² (25.47%), act as transitional zones where erosion can still contribute to slope instability, especially in areas with steep gradients or poor vegetation cover. In contrast, low and very low rainfall zones make up only 15.93% of the total area (84.69 km²), representing relatively stable regions with minimal landslide risk.

Table 4: Rainfall classification and reclassification area in sq. Km

	Rainfall		
Classification (in mm)	**Reclassification**	**Area (in sq. Km)**	**Percentage**
1,110.013306 - 1,174.355229	Very low	41.56	7.819084889
1,174.35523 - 1,238.697153	Low	43.13	8.114464178
1,238.697154 - 1,285.107721	Moderate	135.39	25.47223058
1,285.107722 - 1,324.13479	High	157.37	29.60754064
1,324.134791 - 1,378.983643	Very high	154.07	28.98667971
Total		**531.52**	**100**

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The impact of rainfall on landslide susceptibility is evident across different precipitation zones. High and very high rainfall regions are the most prone to landslides, as intense precipitation reduces soil cohesion, increases groundwater pressure, and triggers slope failures. Moderate rainfall areas may still face erosion-related instability, particularly in deforested or steep terrains. Conversely, low rainfall regions are generally more stable, making them suitable for infrastructure development and agricultural activities with lower risks of landslide occurrences

3.1.6. Soil

Landslide susceptibility is closely related to soil texture, as different soils have varying capacities to retain water and resist landslide.

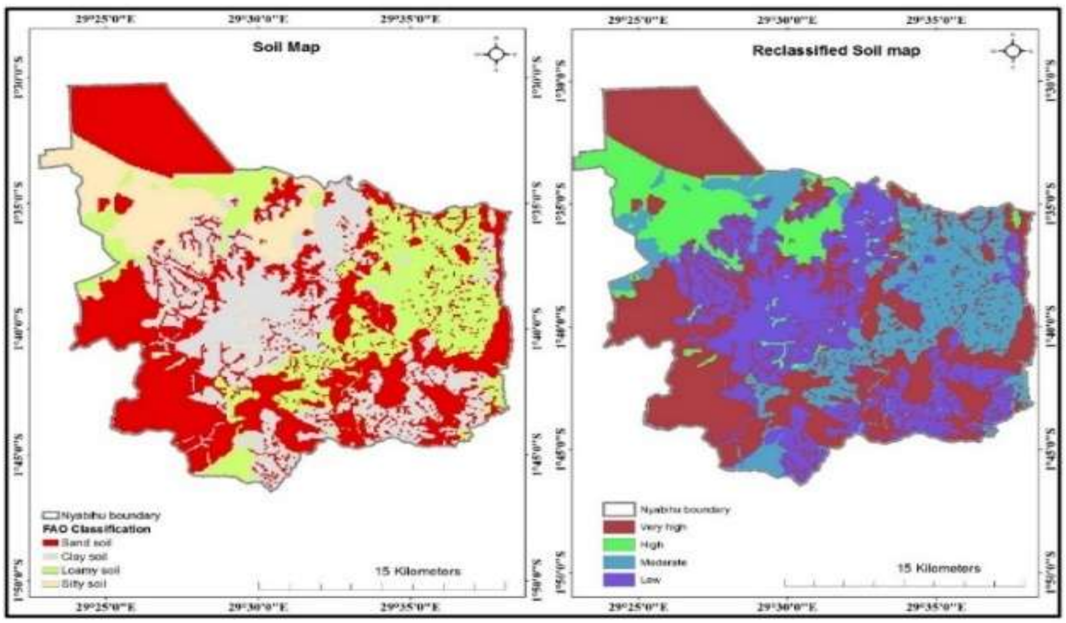

Figure 9:Soil texture distribution in Nyabihu district

Based on the map above and the table below, sandy soil, which covers the largest area (217.9 sq. km, 40.99%), is highly susceptible to landslides due to its loose texture and poor cohesion. Silty soil, classified as highly susceptible, covers 61.7 sq. km (11.6%) and is prone to erosion when saturated. Loamy soil, with moderate susceptibility, spans 113.6 sq. km (21.37%), balancing water retention and drainage. The least susceptible category, labeled as low, covers 138.31 sq. km (26.02%) and likely consists of compact and well-structured soils that offer higher stability.

Table 5:Soil texture and classification area in sq. Km

Soil texture	Soil Reclassification	Area (in sq. Km)	Percentage
Sandy soil	Very high	217.9	40.99640646
Silty soil	High	61.7	11.60843634
Loamy soil	Moderate	113.6	21.37306918
Clay	Low	138.31	26.02208801
Total		**531.51**	**100**

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3.1.7. Land use land cover

Land use is also one of the key factors that initiate landslides.

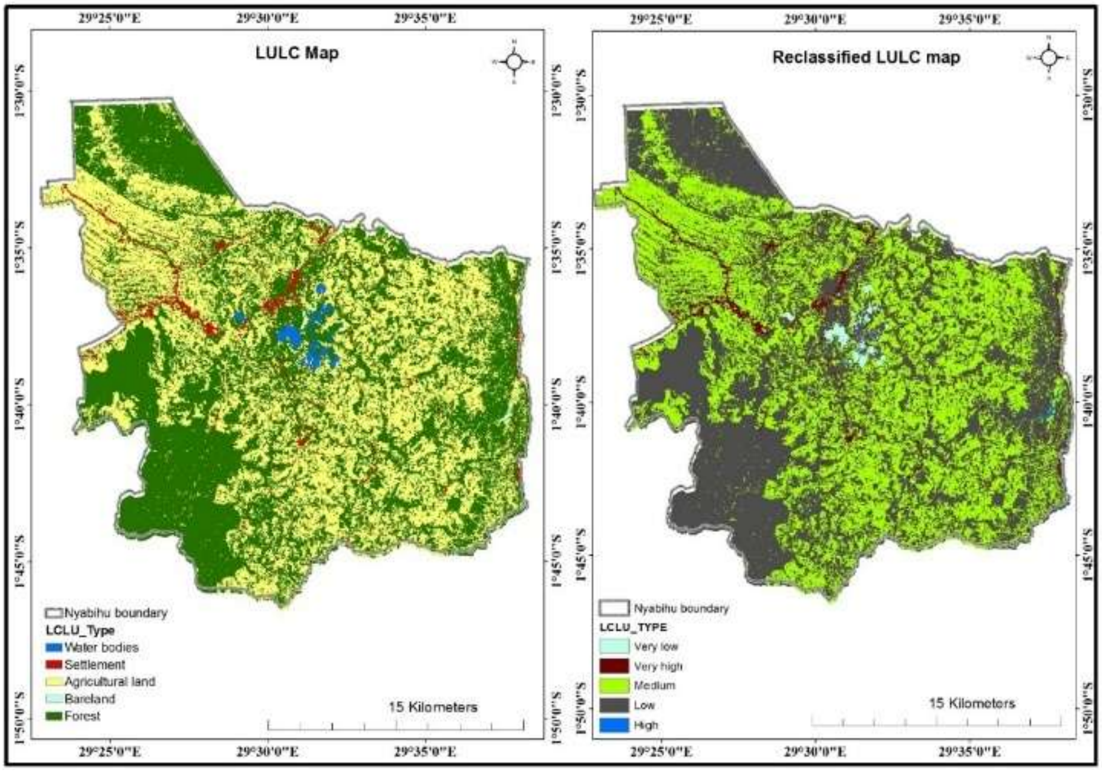

Figure 10:Nyabihu District LUL distribution

Map above and table below, settlement areas, which are classified as having very high landslide susceptibility, cover 75.2 sq. km (14.14%). These areas are significantly impacted by human activities, including construction, deforestation, and road building, which disturb the natural slope and heighten the risk of landslides. In addition, poor land management practices like overgrazing and extensive tree clearing exacerbate this risk by removing protective vegetation. Without roots to stabilize the soil, these regions are particularly vulnerable to heavy rainfall and surface runoff, leading to landslides.

Similarly, bare land, covering 7.4 sq. km (1.39%), is highly susceptible to landslides due to the lack of vegetation. The absence of plant cover weakens the soil, particularly in areas with steep slopes, where the absence of root systems makes the soil more prone to erosion and collapse.

Agricultural land, spanning 189.24 sq. km (35.6%), shows moderate susceptibility to landslides. Although farming practices provide some soil cover, activities like plowing, deforestation, and irrigation can degrade the soil structure, making it more prone to erosion and instability.

In contrast, forested areas, covering 229.62 sq. km (43.2%), exhibit low susceptibility to landslides due to the dense vegetation. The deep roots of trees help stabilize the soil, reduce erosion, and improve slope stability. For example, the extensive forest cover in Nyabihu's southern and northern regions acts as a natural barrier, stabilizing the terrain and preventing landslides.

Lastly, water bodies, covering 30.04 sq. km (5.65%), show very low direct susceptibility to landslides. However, they can contribute indirectly by saturating the surrounding soil, weakening its structure and increasing the likelihood of slope failure.

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Table 6:Nyabihu LULC classification area in sq. Km

	Classification	**Area (in sq. Km)**	**Percentage**
Water bodies	Very low	30.04	5.651928504
Forest	Low	229.62	43.20225776
Agricultural land	Moderate	189.24	35.60489182
Bare land	High	7.4	1.392285983
Settlement	Very high	75.2	14.14863594
	Total	531.5	100

3.1.8. Distance to Roads

The Distance to Roads Map and the Reclassified Distance to Roads Map provide a detailed spatial analysis of road networks in Nyabihu.

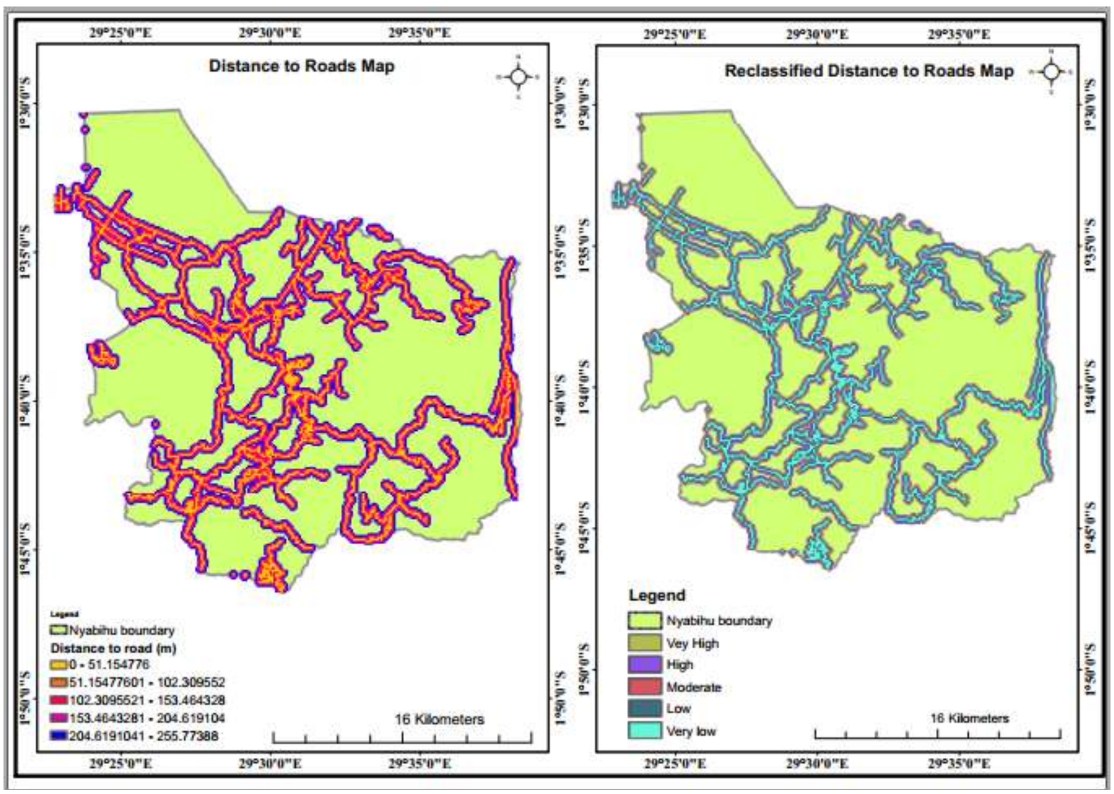

Figure 11:The distance to roads

The distance to roads is divided into five categories: 0–51.15 m, 51.15–102.31 m, 102.31–153.46 m, 153.46–204.62 m, and 204.62–255.77 m. Areas closest to roads, specifically within the 0–51.15 m range, are more prone to landslides due to the disturbance of natural slope stability caused by road construction. The reclassified map categorizes these areas into susceptibility levels: very low, low, moderate, high, and very high.

Regions with very high susceptibility, marked in blue on the map, are areas where landslides are more likely to occur, posing a risk to transportation networks. These areas require immediate attention for mitigation strategies, such as slope stabilization, effective drainage systems, and road reinforcement. On the other hand, areas classified as very low susceptibility, mostly located further from the roads, face a reduced risk of landslides and are less likely to impact transportation infrastructure.

3.1.9. Distance to the rivers

Landslide occurrences can also be influenced by their proximity to drainage systems (Kumar &Anbalagan, 2019). River incision plays a significant role in slope instability by causing erosion at the base of slopes and saturating the soil, which can increase the steepness and destabilize the terrain (Mathew et al., 2007; Abebe et al., 2010). To assess this factor, a map showing the proximity of rivers was created, and a distance-to-river map was generated using Euclidean distance buffering with intervals of 50 meters. This resulted in a classification that divided the area into five distance categories: 0–50 m, 50–100 m, 100–150 m, 150–200 m, and 200–250 m.

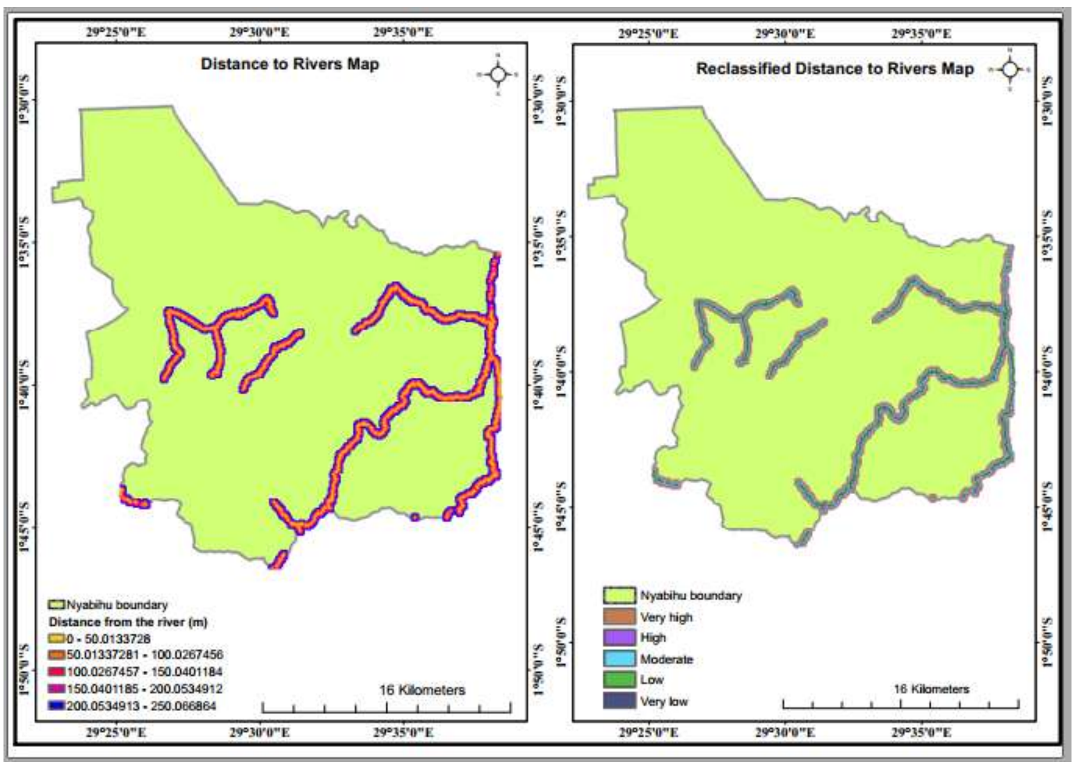

Figure 12:Distance-to-river map

3.2. Landslide susceptibility map

3.2.1. Analytic Hierarchy Process (AHP)

The pair-wise comparison matrix for these criteria was constructed by assigning relative importance values to each pair of factors based on their influence on landslide susceptibility. These values were determined using the Saaty scale, which ranges from 1 (equal importance) to 9 (extreme importance of one factor over another). Each element in the matrix represents the comparative significance of one factor relative to another. For instance, rainfall, identified as the most influential factor, was given higher comparative values when paired with other factors like soil type or land use/cover. Similarly, slope and elevation, which share equal weights, were considered to have moderate to strong importance over land use and soil type. The diagonal values in the matrix are set to 1, indicating that each factor is equally important when compared to itself. This pair-wise comparison matrix forms the basis for calculating the normalized weights of each factor, ensuring a consistent and rational assessment of their relative contributions to landslide susceptibility in Nyabihu District.

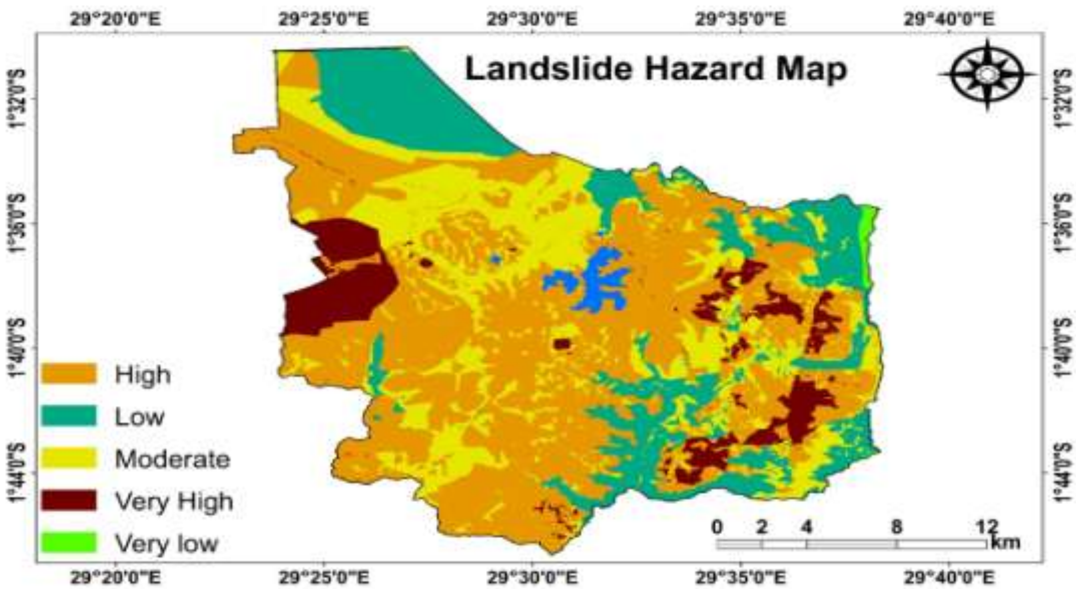

Figure 13: Landslide hazard Map

The generated map was classified into five hazard levels: very low, low, moderate, high, and very high, as illustrated in Figure 13. The High hazard areas dominate the region, especially in the central and southwestern zones, indicating extensive terrain that is vulnerable to landslides. These zones likely have steep slopes, loose soil, and possibly high rainfall all key factors in landslide occurrences. The Very High hazard areas are more concentrated in the west and southeastern sections of the map, showing regions where the risk is most severe, possibly due to unstable geology or intensive land use such as deforestation or farming on steep slopes. Low and Very Low hazard zones are mostly located along the northern and some eastern parts, where the terrain appears flatter or more geologically stable. These regions are safer for development and human settlement. The Moderate hazardzones, which form transition areas, arewidespread andindicate locations wherepreventive measures such as proper drainage,vegetation cover, and controlleddevelopment are necessary to minimize risk.Overall, this map is a crucial decision-making tool for planners,engineers, andenvironmental managers in identifyingpriority areas for landslide mitigation, zoningregulations,and community safety planning.

3.3. Impacts of Landslide to local community

Landslides are one of the major geological hazards affecting community livelihoods. However, studies (Bhatta, Aggarwal, Poudel, & Belgrave, 2015; Shaw, 2012; Wagesho & Claire, 2016) suggest that actively involving local communities in understanding the causal factors and their level of exposure can help them in landslide effects mitigation. This is largely because indigenous knowledge equips local people with a deeper understanding of their environment, providing a valuable foundation for developing effective risk reduction strategies. To assess the impact of landslide on local community, the interview was conducted and the results are detailed in the following sections

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3.3.1. Community Awareness of Landslide Susceptibility

The findings show that community awareness of landslide susceptibility in Nyabihu District remains low. The primary channels for disseminating information about landslides and their causes include local meetings (Intekoz'abaturage), radio, and television. According to Table below, the percentage of 43.75% of respondents received information through local meetings, followed by 29.1% via radio/TV, 16.6% from schools, and only 10.5% through training.

Table 7: Community Awareness on landslide occurrence

Channels					
Information channel	School	Meeting/ Intekoz' abaturage	Radio/TV	Trainings	Total
Frequency	63	166	110	40	379
Percentage	16.6	43.75	29.1	10.5	100

Causal factors' awareness						
Awareness	Very high	High	Moderate	Low	None	Total
Frequency	20	28	98	98	141	379
Percentage	5.2	7.3	25	25	37.5	100

The delivery of formal training and school-based education on landslides remains limited, which may contribute to the community's insufficient understanding of landslide risks and their impacts. This limited awareness could explain the continued negative effects on community livelihoods, including loss of life, injuries, destruction of infrastructure, and damage to natural resources (Table 4.9). The data suggest that while efforts are being made to inform the community, they are not receiving comprehensive knowledge about the causes and consequences of landslides.

Table 8: Impact of landslide on community livelihoods

Livelihood types	**Frequency**	**Percentage**
Human death and injury	55	14.5
Displacement	135	35.5
Lost livestock	23	6.2
Damage of resources	75	19.8
Destruction of infrastructures	91	24
Total	**379**	**100**

The level of awareness about landslide risks in Nyabihu district is relatively low among the local community. The study found that the primary channels for raising awareness about landslides and their causes are local community meetings (Intekoz'abaturage), as well as radio and television broadcasts. However, educational efforts, such as training programs in schools about landslides, are still limited in the district (Table 4.9). This lack of awareness may contribute to the ongoing negative impacts on the community, including fatalities, injuries, infrastructure damage, and harm to natural resources (Table 4.9). These findings suggest that while the community is being reached, they are not receiving comprehensive information on the causes of landslides and their broader effects on lives and livelihoods.

3.4. Analyzing the relationship between landslides and community livelihoods

Studies by Nahayo et al. (2018) and Mamon et al. (2017) have highlighted that a lack of formal education and training increases disaster risk, as communities remain unaware of key factors driving disasters. A similar situation is observed in Nyabihu District (Table 4.9), where landslide-related information is primarily disseminated through local meetings (Intekoz'abaturage), as well as radio and television. However, these channels often lack structured educational content and formal training on disaster risk reduction.

Additionally, Nyabihu district residents face heightened landslide exposure due to the undervaluation of their indigenous knowledge in landslide risk. Since local communities have high understanding of their environment, failing to incorporate their knowledge into disaster management strategies may negatively impact their livelihoods. Therefore, engaging local populations in planning and decision-making processes is essential to ensuring more effective and sustainable risk reduction measures.Survey results presented in Table 4.9. reveal that 43.75% of respondents receive landslide-related information mainly through community meetings or the so called Inteko z' abaturage, while 29.1% rely on radio and television broadcasts. However, access to formal education on disaster risks remains limited, leading to a none awareness level of 37.5% among respondents in Nyabihu District. Furthermore, only 5.2% demonstrated knowledge of landslide causal factors, indicating a significant gap in understanding disaster risks and adaptation strategies. As a result, inadequate awareness contributes to increased vulnerability, as many residents remain unaware of both the primary causes of landslides and the necessary preventive measures.

IV. CONCLUSION

In this research, we employed nine landslide causative factors (elevation, slope, aspect, curvature, land use, rainfall, soil texture, distance to river and distance to rivers). With the help of ArcGIS, these causative factors have been analyzed and rating according to their level of influence to landslide susceptibility. The study found that different areas within the Nyabihu district fall into varying levels of landslide susceptibility, categorized as very high, high, moderate, low and very low hazard zones. The findings reveal that The region is largely dominated by high landslide hazard areas, particularly in the central and southwestern zones, due to factors like steep slopes, loose soil, and high rainfall. Very high hazard zones are concentrated in the west and southeast, likely driven by unstable geology or intensive land use. In contrast, low and very low hazard areas, mainly in the north and some eastern parts, feature flatter, more stable terrain and are safer for development. The findings, based on questionnaire responses from selected participants, revealed that local communities have limited awareness of their vulnerability to landslides. This low level of awareness is largely influenced by the communication channels used to disseminate disaster-related information, which may not effectively reach or engage residents. Additionally, formal education and training on landslide risks remain undervalued, further contributing to the knowledge gap.

According to local community, landslides in Nyabihu District have severely impacted local communities, primarily through the destruction of infrastructure, including hospitals, schools, bridges, and homes.

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