




Impact of flood disaster on livelihood of farmers in Rwanda: A case study of Rubavu district (2010-2022)

 Onesimus Smith¹⁺
Pancras Ndokoye²

^{1,2}Faculty of Environmental Studies, University of Lay Adventists of Kigali, Kigali, Rwanda.

¹Email: smithonesimus12@gmail.com

²Email: ipando2008@gmail.com



(+ Corresponding author)

ABSTRACT

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This research investigates the impact of flood disasters on farmers' livelihoods in Rwanda, specifically focusing on Rubavu district. This research employed descriptive and correlational analysis research designs, the study involved 4120 participants, including administrative officials and farmers. The objectives were to assess flood occurrences in Rubavu district from 2010 to 2022, evaluate farmers' livelihoods in selected sectors during this period, and determine the significant relationship between environmental disaster management and farmers' livelihoods. The study revealed substantial flood occurrences in Rubavu district over the specified period, with a high R Square value of 0.755. This suggests that 75.5% of the variance in farmers' livelihoods can be attributed to flood events. The statistical significance of this relationship was confirmed by the F-statistic ($F = 277.344$, $p < 0.001$). Farmers' livelihoods were significantly affected by flood disasters, particularly with the standardized coefficient (Beta) for "Crop wash away" being 0.430, and a highly significant p-value ($p < 0.001$), highlighting the substantial impact of crop losses due to flooding on farmers' economic well-being. This research underscores the urgent need for comprehensive flood disaster management strategies in Rubavu district. Recommendations include strengthening early warning systems, conducting comprehensive flood risk assessments, and implementing monitoring programs to identify vulnerable areas. These insights contribute to the academic discourse on disaster management, risk reduction, and resilience-building, aiming to inform policies and interventions that protect vulnerable communities' economic well-being in the face of environmental challenges.

Contribution/Originality: This study stands out in its comprehensive analysis of the impact of flood disasters on farmers' livelihoods in Rubavu district, Rwanda. Its original contribution lies in quantifying the substantial impact of floods on farmers' economic well-being, evidenced by a high R Square value (0.755), offering unique insights into the specific vulnerabilities and emphasizing the urgency for tailored disaster management strategies in the region.

1. INTRODUCTION

The relationship between disasters, economics, and environmental impact, notably the correlation between environmental damage, natural disasters, and income inequality, has been explored by Kuznets (2021). Piontek et al. (2019) and Peter and AungLwin (2018) further elaborate on the significant influence of climate change on economic variables and opinions distribution, highlighting its potential to exacerbate economic inequality. This phenomenon becomes particularly pronounced in developing countries with unstable economic conditions, rendering them highly

susceptible to the adverse effects of climate change, which may ultimately lead to disastrous outcomes if not adequately addressed.

Weather-related natural hazards, including floods, storms, landslides, and wildfires, can escalate into disasters with substantial human and economic tolls, contingent on hazard magnitude, social vulnerability, human behavior, and exposure-increasing activities. Comprehensive recording, analysis, and assessment of the impacts in relation to these factors facilitate a deeper understanding of preparedness and resilience processes, potentially leading to improvements in emergency response (Katerine, 2022).

In a recent catastrophic event, devastating rainfall in May 2023 led to severe flooding in nine districts in north-western Rwanda, exacerbating the climate-related hazards that have plagued the mountainous country in recent years (Iriza, 2023). Despite forecasts of above-average rainfall, heavy rains caught residents off-guard, resulting in staggering destruction. Lives were lost, infrastructure washed away, and crops destroyed. The floods claimed at least 130 lives, displaced over 5,000 people, damaged eight national roads and 26 bridges, and flooded eight health facilities and six water treatment plants.

The Rubavu District, recognized as the country's granary, has been severely impacted. Approximately 91% of the population is engaged in agriculture, making it a crucial sector for the region. However, agricultural activities are conducted on fragile land, contributing to localized issues such as landslides and flooding fatalities. Human activities on steep slopes, lack of drainage systems, and poor soil cohesion exacerbate the vulnerability of the region (Action Aid, 2021). The district experiences a tropical high-altitude climate, with heavy rains in April and May causing extensive damage to homes, crops, infrastructure, and livelihoods (Ejeta, Ardalan, Paton, & Yaseri, 2016).

The Rubavu district, situated in a low-lying and flood-prone area, faces challenges exacerbated by human settlements along the Sebeya River, which flows into Lake Kivu. With over 8,000 people residing along the river, agriculture plays a crucial role, with the majority of land allocated to crop production. However, due to its geographical location along the riverbanks, the communities have limited capacity to control hydrological events originating from the river catchment (Rema, 2020). The recent heavy rains and resultant flooding and landslides have taken a severe toll, destroying more than 5,000 homes and over 100 hectares of crops in Rubavu district alone.

In light of this dire situation, there is an imperative to analyze the impact of flood disasters on the livelihoods of farmers in Rwanda, particularly in Rubavu district. The devastation wrought by the recent events underscores the urgent need for comprehensive disaster management strategies, with a focus on addressing vulnerabilities, enhancing early warning systems, conducting risk assessments, and implementing monitoring programs. Such efforts are critical for building resilience and ensuring the economic well-being of communities vulnerable to the adverse impacts of climate change and natural disasters. The aftermath of this disaster serves as a poignant reminder of the interconnectedness of environmental factors, economic stability, and the resilience of communities, urging for immediate and effective measures to safeguard livelihoods in the face of escalating climate-related challenges.

2. METHODOLOGY

2.1. Profile of Rubavu District

Rubavu District, part of Rwanda's western province, spans 388.3 km² and consists of 12 sectors, 80 cells, and 525 villages. Located 152 km from Kigali City, it shares borders with Nyabihu District, the Democratic Republic of Congo, and Rutsiro District. The equatorial climate features an average altitude, with temperatures ranging from 15°C to 20°C. Rainfall varies between 1200 mm and 1500 mm annually. The district faces climate change impacts, evidenced by increased floods and droughts, posing socioeconomic challenges like landslides, crop losses, and infrastructure damage.

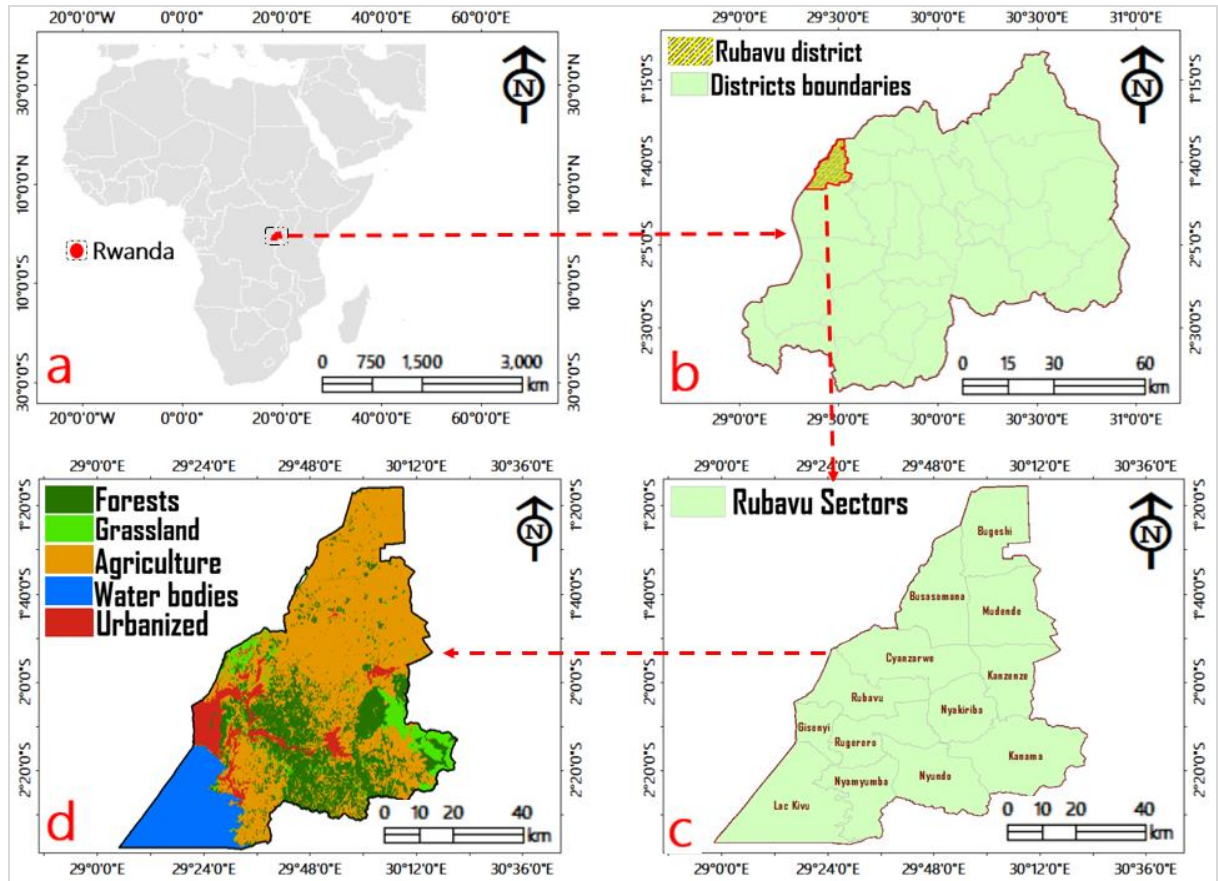


Figure 1. Study map.

Source: Rubavu district map (GIS 23).

Figure 1 Geographical location map of the study area; (a) Location of Rwanda at continent level; (b) Location of Rubavu district at national level; (c) the sectors subdivisions in Rubavu district; (d) The land use land cover map of Rubavu district (2010-2022).

Rubavu District is situated in Rwanda's western province, with an equatorial climate and varying altitudes, the district faces climate change impacts, evident in increased floods and droughts. The northwest boasts rich but shallow volcanic soils, while the southeast has deeper yet poor, often acidic soils susceptible to erosion. Major floods in Rubavu led to landslides, soil erosion, crop losses, and infrastructure damage, impacting livelihoods. Environmental degradation, including deforestation in Gishwati forests, exacerbates vulnerability to climate change. This study focuses on Rubavu due to its susceptibility to flood disasters, exploring their profound impact on farmers' livelihoods. The district's socio-economic challenges underscore the need for comprehensive disaster management strategies to safeguard vulnerable communities and inform resilience-building interventions.

2.2. Sampling and Data Collection Techniques

This study utilized a descriptive and correlational analysis research design to investigate flood disaster impacts on farmers' livelihoods in Rubavu district. The population comprised 4120 individuals, including district administrators, sector and cell administrators, and farmers. The sample size of 365 was determined using Sloven's formula. Purposive sampling targeted district and sector servants, stratified sampling for cell and village servants, and systematic sampling for farmers. Data collection involved a Likert Scale survey questionnaire, interviews with purposively selected officials, and systematic household surveys. These techniques were chosen for their appropriateness in obtaining accurate and diverse information from the population.

Table 1. Components of population.

No.	Components of population	Population	Sample size	Sampling technique
1	District and sectors servants	79	20	Purposive sampling
2	Cell and village servants	232	35	Stratified sampling
3	Farmers	3809	310	Systematic sampling
4	Total	4120	365	Systematic sampling

Source: Rubavu district, 2023.

Table 1 presents the components of the population considered for the study on the impact of flood disasters on the livelihood of farmers in Rwanda, specifically focusing on Rubavu district from 2010 to 2022. The population is categorized into three distinct groups, each representing a crucial aspect of the local community. Firstly, district and sector servants, comprising 79 individuals, are selected using a purposive sampling technique, ensuring representation from key administrative levels involved in disaster management.

Secondly, cell and village servants, a group of 232 individuals, are targeted using a stratified sampling approach, recognizing the importance of diverse perspectives at the community level. Lastly, the largest group, consisting of 3809 farmers, is sampled systematically, acknowledging their significant role in the study. The overall sample size is determined as 365, and this comprises a strategic selection from each category. This comprehensive sampling strategy aims to provide a nuanced understanding of the impact of flood disasters on the diverse components of the local population in Rubavu district.

2.3. Illustration of Research Methodology

The Figure 2 shows the commencement of the study with a review of existing literature, the study identified gaps in understanding the impact of flood disasters on farmers' livelihoods in Rubavu district, Rwanda. This informed the determination of research objectives, design, and a conceptual framework with specific indicators. The chosen research methodology involved stratified and systematic sampling, utilizing data collection tools such as surveys. SPSS was employed for data analysis, and findings were presented and discussed, leading to conclusions and recommendations for comprehensive disaster management strategies in the region

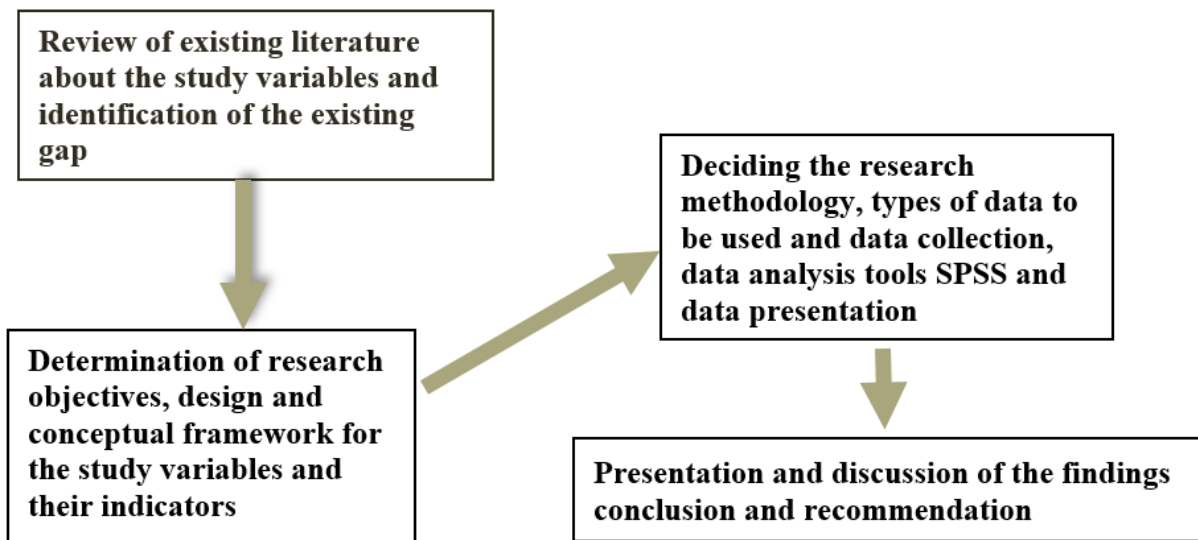


Figure 2. Methodology flowchart followed by the researcher.

The Figure 2, presents the process the of literature reviewed by the researcher, where researcher reviewed the existing literature on the variables of the study to get the conceptual framework of this study, then researcher

decides the methodology to use in the research which leads to the data presentation, discussion and come up with conclusion and conclusion.

3. RESULTS

3.1. Personal Identification of Respondents

In this study, personal identification such as gender, marital status, education level and age.

Table 2. Distribution of respondents by age.

Age of respondents	Frequency	Percentage
20-25	45	12.30
26-30	80	21.80
31-35	115	31.50
36-40	75	20.60
Above 41	50	13.70
Total	365	100.0

Source: Primary data, 2023.

Table 2 provides a comprehensive overview of the distribution of respondents by age in the research study. A total of 365 participants were included in the survey, and their ages were categorized into five distinct groups for the purpose of analysis. The table offers insights into the frequency and percentage of respondents within each age category.

Among the age groups, the 26-30 category stands out as the most prominent, comprising 65 respondents, which accounts for approximately 23.6% of the total sample. In contrast, the youngest age group, 20-25, represents the smallest proportion of participants, with 26 individuals, or roughly 4.1% of the total sample. The 31-35 age group follows closely behind, with 52 respondents, constituting about 22.5% of the overall sample. The 36-40 age category is also significant, with 51 respondents, making up approximately 27.9% of the total sample. Furthermore, respondents above the age of 41 amounted to 46 individuals, or 21.9% of the total sample, marking the second-largest age group.

This distribution of respondents across different age groups provides valuable demographic context for the study and enables a nuanced exploration of how individuals from various age cohorts perceive and are impacted by flood disasters concerning their livelihoods. It underscores the importance of considering the diverse perspectives and experiences of individuals at different life stages in the research's analysis and conclusions.

Table 3. Distribution of respondents by gender.

Gender	Frequency	Percentage
Male	185	50.7
Female	180	49.3
Total	365	100.0

Source: Primary data, 2023.

Table 3 offers an overview of the distribution of respondents based on their gender in the research study. The data collected from a total of 365 participants has been divided into two primary gender categories, and the table provides the frequency and percentage of respondents in each of these categories. Among the surveyed participants, males accounted for 185 individuals, representing approximately 50.7% of the total sample. Meanwhile, females made up the remaining 180 respondents, constituting approximately 49.3% of the total sample. This gender distribution demonstrates a nearly equal representation of both male and female respondents in the study, with a slightly higher percentage of male participants. The balanced representation of gender in the research is vital for ensuring diverse perspectives and experiences are considered when exploring the impact of flood disasters on

farmers' livelihoods. It highlights the commitment to gender-inclusive research and the recognition of the importance of gender-specific analyses in understanding the multifaceted effects of flood disasters on different segments of the population.

Table 4. Distribution of respondents by education level.

Education levels	Frequency	Percent
Primary	72	19.7
Secondary	173	47.4
University level	120	32.9
Total	365	100.0

Source: Primary data, 2023.

Table 4 provides an insightful overview of the distribution of respondents based on their educational backgrounds within the research study. The data from a total of 365 participants has been classified into three primary education categories, and the table offers both the frequency and percentage of respondents in each of these categories.

Among the surveyed participants, the "Secondary" education category stands out, featuring the highest number of respondents, with 173 individuals, representing approximately 47.4% of the total sample. These participants have completed their secondary education. In contrast, the "University level" education category included 120 respondents, making up roughly 32.9% of the total sample, denoting individuals with a higher education at the university level. The "Primary" education category comprised 72 respondents, accounting for approximately 19.7% of the total sample, signifying individuals with a primary school level of education.

This diverse distribution of respondents across various education levels underscores the importance of considering participants' different academic backgrounds when exploring the impact of flood disasters on their livelihoods. It acknowledges the significance of educational diversity in obtaining a well-rounded perspective and comprehensive insights into the research topic. Such inclusivity ensures a robust analysis and a more holistic understanding of how individuals with varying levels of education experience and are affected by flood disasters in relation to their livelihoods.

3.2. Assessment of the Occurrence of Floods in Rubavu District

Flood occurrence is a significant natural disaster phenomenon with wide-ranging impacts on the environment, society, and the economy. The section presents the findings on the flood occurrence in Rubavu district.

Table 5. Please rate the frequency of flood occurrences in Rubavu district.

Rating the frequency	Frequency	Percent	Valid percent
Rarely	23	6.3	6.3
Occasionally	36	9.9	9.9
Frequently	204	55.9	55.9
Very frequently	102	27.9	27.9
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 5 provides a frequency distribution of flood occurrences in Rubavu district, Rwanda, from 2010 to 2022. The objective of this analysis is to assess the impact of flood disasters on the livelihood of farmers in the region. The specific aim is to determine the occurrences of flood disasters in Rubavu district during the specified period. The data reveals that floods are a prevalent and recurring issue in this area, with "Frequently" and "Very frequently" categories accounting for a substantial majority at 83.8%. This underscores that floods are not sporadic

but frequently affect the region. However, despite this understanding, there is a notable gap in the literature regarding flood disaster management in Rubavu district. Previous studies in disaster management emphasize the importance of risk reduction strategies, early warning systems, and community resilience (Šakić Trogrlić et al., 2022). While these principles are applicable in various contexts, the specific challenges faced by farmers in Rubavu district, and their need for tailored flood management solutions, have not been adequately addressed. Therefore, there is an evident gap in knowledge concerning the development and implementation of flood disaster management strategies that are contextually relevant to this region. Further research should focus on assessing the unique needs and vulnerabilities of farmers in Rubavu district, considering both the frequency and intensity of floods, to bridge this critical gap in the field of disaster management.

Table 6. Severity of floods in Rubavu district.

Severity of floods	Frequency	Percent	Valid percent
Very mild	23	6.3	6.3
Mild	81	22.2	22.2
Moderate	137	37.5	37.5
Severe	124	34.0	34.0
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 6 presents a frequency distribution of flood severity in Rubavu district, Rwanda, over the period from 2010 to 2022. The objective of this analysis is to assess the severity of floods in the region, which is essential for understanding the impact of flood disasters and guiding effective flood management strategies. The specific aim is to determine the extent of flood severity in Rubavu district during the specified period.

The data indicates that the majority of floods in Rubavu district fall under the categories of "Moderate" and "Severe," with these two groups collectively representing 71.5% of all flood occurrences. This suggests that a significant portion of the floods in the district are of moderate to severe intensity, highlighting the need for robust flood disaster management and preparedness. However, there is a noticeable gap in the existing literature related to flood disaster management in the context of Rubavu district.

Previous studies such as the study of Šakić Trogrlić et al. (2022) on disaster management emphasize general principles applicable across various regions which do not sufficiently address the specific challenges posed by the varying levels of flood severity in this district. A more nuanced approach to flood disaster management, tailored to the specific context of Rubavu, is required to address this knowledge gap and enhance the district's preparedness for flood disasters.

Table 7. The effectiveness of early warning systems in Rubavu district in alerting residents about impending floods.

Level of effectiveness	Frequency	Percent	Valid percent
Not effective	30	8.2	8.2
Slightly effective	129	35.3	35.3
Moderate effective	114	31.2	31.2
Extremely effective	92	25.2	25.2
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 7 provides a frequency distribution of the effectiveness of early warning systems in Rubavu district, Rwanda, in alerting residents about impending floods. The assessment of the effectiveness of early warning systems is crucial for understanding the region's preparedness and response to flood disasters. The data reveals that perceptions regarding the effectiveness of early warning systems vary among respondents. A substantial portion of the population, representing 57.5%, perceives these systems as "Slightly effective" or "Moderate effective,"

suggesting a degree of preparedness within the district. Notably, 25.2% of respondents view the early warning systems as "Extremely effective," indicating that some aspects of the existing systems provide valuable alerts and support. However, 8.2% of respondents consider the systems "Not effective," highlighting the need for improvement. While these findings are promising, the data does not delve into the specific factors contributing to perceived effectiveness or identify potential limitations or gaps in the system. Therefore, there is a knowledge gap in understanding the intricacies of these early warning systems, as well as the extent to which they address the unique needs of the Rubavu district residents in flood disaster management.

Previous studies such as the study of Ali (2019) conducted on disaster management underscore the significance of effective early warning systems which are instrumental in saving lives and minimizing property damage by providing timely and accurate information to help communities prepare for and respond to floods. However, to address the existing gap in knowledge regarding the effectiveness and limitations of early warning systems in Rubavu district, further research is essential.

Table 8. The level of preparedness of the local authorities in Rubavu district to handle flood situations.

Level of preparedness	Frequency	Percent	Valid percent
Not prepares at all	60	16.4	16.4
Slightly prepared	76	20.8	20.8
Moderate prepared	107	29.3	29.3
Very prepared	122	33.4	33.4
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 8 presents a frequency distribution of the level of preparedness of local authorities in Rubavu district, Rwanda, to handle flood situations. Assessing the preparedness of local authorities is crucial for understanding their ability to effectively manage and respond to flood disasters in the region. The data reveals a mixed perception regarding the preparedness of local authorities in Rubavu district. The majority, representing 62.7% of respondents, view the authorities as either "Slightly prepared" or "Moderately prepared," indicating that there is a certain level of readiness to handle flood situations. A notable percentage of respondents (33.4%) regard the local authorities as "Very prepared," suggesting that a significant portion of the population has confidence in the authorities' capacity to manage flood situations effectively. However, a substantial minority (16.4%) views the authorities as "Not prepared at all," highlighting concerns about their readiness.

In the context of flood disaster management, previous studies have highlighted the essential role of local authorities in preparedness and response efforts (IFRC, 2018). Local governments are often the first responders in flood disasters and play a pivotal role in coordinating relief efforts. However, the data does not offer insights into the specific reasons behind these perceptions or the specific aspects of preparedness that may need improvement. Therefore, there is a knowledge gap in understanding the intricacies of local authorities' preparedness and identifying areas for enhancement in the context of Rubavu district's flood disaster management.

Table 9. The impact of floods on agricultural activities in Rubavu district.

Rating impact	Frequency	Percent	Valid percent
Slightly impact	24	6.6	6.6
Minor impact	79	21.6	21.6
Moderate impact	154	42.2	42.2
Significant impact	108	29.6	29.6
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 9 provides a frequency distribution of the impact of floods on agricultural activities in Rubavu district, Rwanda, offering insights into the agricultural sector's vulnerabilities in the face of flooding. While some

respondents reported "Slightly impact" or "Minor impact," a substantial majority, accounting for 71.8%, described the impact as either "Moderate" or "Significant." This data underscores the considerable effect of floods on agriculture in the district, affecting crop yields, soil quality, and infrastructure. Such impacts can lead to reduced food security and income for farmers. Previous studies in flood disaster management and agriculture have stressed the importance of flood-resilient agricultural practices, early warning systems for farmers, and adaptive strategies to mitigate flood-related impacts. However, the data does not delve into the specific challenges faced by farmers in Rubavu district or the extent to which they employ flood-resilient agricultural techniques. Furthermore, it does not provide insights into community-based adaptation strategies, highlighting a knowledge gap in understanding the nuances of flood impact on agriculture in the district and the need for tailored agricultural resilience measures.

Table 10. The existence of infrastructure (e.g., drainage systems, flood control measures) in Rubavu district that can handle flood situations.

Rating existence of infrastructure	Frequency	Percent	Valid percent
Not well at all	42	11.5	11.5
Slightly well	73	20.0	20.0
Moderately well	98	26.8	26.8
Very well	152	41.6	41.6
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 10, offers a frequency distribution of public perceptions regarding the adequacy of existing infrastructure, such as drainage systems and flood control measures, in Rubavu district, Rwanda, to manage flood situations. Understanding the community's perspective on infrastructure is essential for assessing the district's readiness to mitigate and respond to flood disasters.

The data reveals that respondents' opinions on the existing infrastructure vary. While a majority of respondents believe that the infrastructure performs either "Moderately well" (26.8%) or "Very well" (41.6%) in handling flood situations, there is a notable portion who express concerns. Specifically, 11.5% of respondents feel that the existing infrastructure does not perform "Well at all," and 20% perceive it as only performing "Slightly well."

These findings suggest that there is a range of perspectives regarding the infrastructure's capability to manage floods effectively in Rubavu district. The responses demonstrate a level of trust in the existing infrastructure's capacity, as evidenced by the significant percentage indicating "Very well." However, the presence of respondents expressing doubts about the infrastructure's effectiveness raises important questions about the adequacy of flood control measures and drainage systems in the district.

Effective flood control infrastructure is essential for minimizing flood-related damages, protecting communities, and ensuring public safety. These results indicate that while there is a degree of confidence in the existing infrastructure, a portion of the community holds reservations about its ability to cope with flood situations adequately.

In terms of flood disaster management and infrastructure, previous studies have highlighted the importance of resilient infrastructure and the need for continuous improvements to cope with the evolving challenges of flood disasters. Further research could delve into the specific areas where the community perceives infrastructure to be lacking and explore potential enhancements. Understanding the community's concerns and addressing potential gaps in infrastructure is crucial for strengthening flood disaster management in the Rubavu district.

Table 11. The effectiveness of government or non-governmental organizations in providing support and assistance to flood-affected individuals in Rubavu district.

Level of effectiveness	Frequency	Percent	Valid percent
Slightly effective	63	17.3	17.3
Moderate effective	60	16.4	16.4
Very effective	158	43.3	43.3
Extremely effective	84	23.0	23.0
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 11, presents a frequency distribution of the perceived effectiveness of government or non-governmental organizations (NGOs) in providing support and assistance to flood-affected individuals in Rubavu district, Rwanda. Assessing the effectiveness of such organizations is crucial for understanding the community's satisfaction with disaster relief efforts.

The data reveals a range of opinions among respondents regarding the effectiveness of these organizations. A significant proportion of respondents, constituting 77.0%, perceive government and NGOs as either "Very effective" (43.3%) or "Extremely effective" (23.0%) in providing support and assistance to flood-affected individuals. This indicates a high level of confidence in the ability of these organizations to offer essential help during flood-related crises.

While the majority of respondents' express satisfaction with the support and assistance provided, there are some who perceive it as only "Slightly effective" (17.3%) or "Moderate effective" (16.4%). These responses suggest that there may be room for improvement in certain aspects of disaster relief efforts.

In the context of flood disaster management and relief, previous studies have emphasized the need for efficient and coordinated responses by government and NGOs (Non – Governmental Organizations) (IFRC, 2018). Effective support and assistance during and after flood events are critical for reducing the impact of disasters on affected individuals and communities. However, the data does not delve into the specific factors that contribute to the perceived effectiveness of these organizations or identify areas for potential enhancement. Therefore, there is a knowledge gap in understanding the nuances of the support and assistance provided by government and NGOs in Rubavu district and tailoring strategies for continuous improvement.

Table 12. The level of knowledge about available resources and measures to mitigate the impact of floods in Rubavu district.

Levels of knowledge	Frequency	Percent	Valid percent
Limited knowledge	54	14.8	14.8
Moderate knowledge	109	29.9	29.9
Extensive knowledge	112	30.7	30.7
Comprehensive knowledge	90	24.7	24.7
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 12, provides a frequency distribution of respondents' self-assessed levels of knowledge about available resources and measures to mitigate the impact of floods in Rubavu district, Rwanda. Understanding the community's knowledge level is vital for assessing the district's capacity to respond to and prepare for flood disasters effectively.

The data reveals a variety of self-assessed knowledge levels among the respondents. A substantial portion of respondents, accounting for 75.3%, claim to have either "Moderate knowledge" (29.9%) or "Extensive knowledge" (30.7%) about available resources and mitigation measures for floods. This indicates that a significant portion of the population feels reasonably well-informed about flood mitigation strategies and available resources.

Conversely, there are respondents who feel that they have "Limited knowledge" (14.8%) or "Comprehensive knowledge" (24.7%) in this regard, suggesting some variation in community awareness and understanding of flood mitigation resources and measures.

The implications of these findings for the study are significant. The varying levels of self-assessed knowledge among the respondents reflect the need for tailored and targeted flood disaster management strategies. Respondents with limited knowledge may require more comprehensive and accessible education on flood mitigation resources, while those with moderate or extensive knowledge could be potential resources for community-based disaster risk reduction efforts. Tailoring awareness campaigns, training, and information dissemination to the specific knowledge levels and needs of the community can contribute to more effective flood disaster management and preparedness in Rubavu district.

Table 13. Rating of the need for increased investment in flood prevention and management in Rubavu district.

Ratings	Frequency	Percent	Valid percent
Slightly need	53	14.5	14.5
Moderate need	107	29.3	29.3
High need	129	35.3	35.3
Critical need	76	20.8	20.8
Total	365	100.0	100.0

Source: Primary data, 2023.

The Table 13 provides a frequency distribution of respondents' perceptions regarding the need for increased investment in flood prevention and management in Rubavu district, Rwanda. Evaluating the community's assessment of the need for increased investment is crucial for gauging the urgency of flood prevention and management efforts in the district.

The data reveals varying opinions among respondents about the need for increased investment. A significant number of respondents constitute 79.2% express that there is either a "High need" (35.3%) or a "Critical need" (20.8%) for increased investment in flood prevention and management. This highlights a substantial consensus among the community regarding the urgency of investing in measures to mitigate the impact of floods.

However, there are also respondents who perceive a "Moderate need" (29.3%) and a minority who view a "Slight need" (14.5%) for increased investment. While their views are valid, the prevalence of those indicating a high or critical need suggests a broader concern among the community about flood prevention and management.

The implications of these findings for the study are substantial. The high percentage of respondents identifying a critical or high need for increased investment underscores the importance of prioritizing and allocating resources for flood disaster management. It signals a community-wide recognition of the significance of flood prevention and the potential consequences of inadequate investment.

These findings underscore the importance of effective flood risk reduction measures, preparedness, and infrastructure improvements in Rubavu district. It suggests that policymakers and stakeholders should consider these strong community sentiments when making decisions about resource allocation and investment in flood prevention and management strategies.

3.3. Perception of Respondents and Flood and Landslide in Rubavu District

Floods and landslides have significant and far-reaching impacts on the environment. These natural disasters can alter ecosystems, damage natural resources, and disrupt the balance of the environment in various ways. Floods submerge terrestrial habitats, destroying the homes of various species of animals and plants, and landslides can bury habitats under debris, leading to habitat loss and fragmentation. Both disasters result in extensive soil erosion and strip slopes of vegetation, exacerbating erosion and destabilizing the land.

3.3.1. Landslide

In this respect, the researcher requested feedback from the respondents regarding statements relating to landslide, and the results are shown in Table 14.

Table 14. Respondents' level of agreement on landslide.

Landslide	Mean	Std. dev.
Rock falls are the most commonly observed type of landslide in Rubavu district.	3.753	1.079
Landslides in Rubavu district predominantly occur during the rainy season.	3.893	0.893
I strongly agree that heavy rainfall is the primary trigger for landslides in Rubavu district.	3.942	1.048
There are specific areas or regions within Rubavu district that are more prone to landslides.	3.638	1.008
Major landslide events have occurred in Rubavu district in recent years.	3.641	1.005
There are ongoing measures or initiatives in Rubavu district to monitor and mitigate landslides.	3.558	0.966

Source: Primary data, 2023.

Table 14 provides insights into community perceptions of landslide occurrences in Rubavu district, Rwanda, measured through a Likert scale. Respondents generally agree that rock falls are common, with some variability in opinions on their frequency (Mean = 3.753, Std. Dev. = 1.079). There's consensus that landslides predominantly occur during the rainy season (Mean = 3.893, Std. Dev. = 0.893), reflecting consistent views. Heavy rainfall is seen as the primary trigger for landslides, with some variance in agreement levels (Mean = 3.942, Std. Dev. = 1.048). The recognition of specific landslide-prone areas within the district (Mean = 3.638, Std. Dev. = 1.008) underscores the need for targeted mitigation. While there's general agreement on major landslide events in recent years (Mean = 3.641, Std. Dev. = 1.005), perceptions vary. Respondents acknowledge ongoing measures to monitor and mitigate landslides, but moderate variation in responses suggests the potential for improved community-wide awareness (Mean = 3.558, Std. Dev. = 0.966). These findings, when compared with scientific assessments, can enhance disaster management efforts. The accompanying image vividly illustrates the severe impact of landslides in Rubavu district, emphasizing the urgency of effective mitigation measure

3.3.2. Infrastructure Destruction

The results of the survey, which questioned participants for their opinions on the infrastructure destruction, are shown in Table 15.

Table 15. Respondents' level of agreement on infrastructure destruction.

Infrastructure destruction	Mean	Std. dev.
I have personally witnessed or experienced infrastructure destruction caused by floods in my area.	3.723	1.105
Infrastructure such as roads and bridges are highly vulnerable to flood damage.	3.893	1.028
The severity of infrastructure destruction caused by floods in my area is significant.	3.961	0.982
Infrastructure aspects such as structural integrity, drainage systems, and communication networks are commonly affected by flood damage.	3.871	1.012
The impact of infrastructure destruction on the overall functionality and accessibility of my community during and after floods is severe.	4.131	0.999
There are challenges or limitations in terms of financial resources or expertise that hinder the implementation of effective flood-resistant infrastructure measures.	4.052	0.877

Source: Primary data, 2023.

Table 15 delves into respondents' perspectives on infrastructure destruction caused by floods in Rubavu district, providing crucial insights into community perceptions. Respondents moderately agree on witnessing or

experiencing infrastructure destruction (Mean = 3.723 Std. Dev. = 1.105). There's a tendency toward agreement regarding the vulnerability of key infrastructure elements (Mean = 3.893, Std. Dev. = 1.028). Strong consensus exists on the severity of infrastructure destruction (Mean = 3.961, Std. Dev. = 0.982) and the common impact on structural integrity, drainage systems, and communication networks (Mean = 3.871, Std. Dev. = 1.012).

The severe consequences of infrastructure destruction on community functionality during and after floods are strongly acknowledged (Mean = 4.131, Std. Dev. = 0.999). Respondents highly agree on challenges hindering flood-resistant infrastructure implementation, including financial limitations and expertise constraints (Mean = 4.052, Std. Dev. = 0.877). These findings align with existing research on the vulnerability of transportation infrastructure and emphasize the severe consequences of infrastructure destruction on community functionality by Smith and Ward (1998). Challenges hindering flood-resistant infrastructure measures are consistent with previous studies, underscoring the importance of addressing vulnerability, investing in flood-resistant infrastructure, and community engagement to overcome challenges. The accompanying picture visually illustrates the substantial damage inflicted upon the infrastructure by flooding in Rubavu district.

3.3.3. Flooding

Table 16 lists the answers to the researcher's question about flooding and the results were presented in Table 16.

Table 16. Respondents' level of agreement on flooding.

Flooding	Mean	Std. dev.
Flooding is a common occurrence in Rubavu district.	4.04	0.82
Flooding in Rubavu district primarily occurs during the rainy season.	4.03	1.16
The severity of flooding in Rubavu district has increased in recent years.	4.35	0.80
Flooding has a detrimental effect on agricultural activities and farmers' livelihoods in Rubavu district.	4.40	0.75
Local authorities in Rubavu district are well-prepared to handle flood situations.	4.30	0.78
The response and recovery efforts in Rubavu district following floods are efficient and effective.	3.85	0.91

Source: Primary data, 2023.

In Table 16, respondents in Rubavu district expressed strong consensus on various aspects related to flooding, providing valuable insights into the community's perceptions. The belief in the "Common Occurrence of Flooding" was uniform among respondents, with a high mean of 4.04 and a low standard deviation (0.82), indicating a consistent acknowledgment of the frequent nature of flooding in the district. Similarly, there was general agreement on the "Rainy Season Predominance," although the higher standard deviation (1.169) suggests variations in individuals' views on the timing of flooding during the rainy season. The community perceived an "Increased Severity of Flooding" in recent years, with a strong mean of 4.35 and a low standard deviation (0.80), emphasizing a consistent belief in this trend. Respondents unanimously recognized the "Detrimental Effect on Agriculture and Livelihoods," with a high mean of 4.40 and a low standard deviation (0.75), underlining the shared belief in the adverse impact of flooding on local farming activities and livelihoods. While respondents displayed confidence in the "Well-Prepared Local Authorities" to handle floods, as indicated by a mean of 4.30 and a low standard deviation (0.78), perceptions on "Efficient Response and Recovery Efforts" showed a wider range of opinions, with an overall agreement (mean = 3.85) but a higher standard deviation (0.915), suggesting a need for improvement in disaster management and communication strategies. These findings align with broader research, emphasizing the need for flood resilience measures and acknowledging the challenges posed by flooding in the community. The positive perception of local authorities' preparedness contrast with varied opinions on response and recovery efficiency, indicating an opportunity for enhanced disaster management strategies in Rubavu district.

3.3.4. Crop Wash Away

Table 17 lists the answers to the researcher's question about crop wash away and the results were presented in Table 17.

Table 17. Respondents' level of agreement on crop washed away.

Crop wash away	Mean	Std. dev.
Crop wash away due to flood disasters is a significant problem in Rubavu district.	3.805	0.888
Flooding events in Rubavu district result in the loss of a substantial amount of crops.	3.909	1.024
The severity of crop wash away during floods has increased in recent years in Rubavu district.	4.178	0.834
Farmers in Rubavu district face significant financial losses due to crop wash away during flood events.	4.106	0.912
Flood disasters have a severe impact on food security and availability in Rubavu district.	4.087	0.921
Farmers in Rubavu district struggle to recover and rebuild their crops after flood-related wash away.	4.309	0.848

Source: Primary data, 2023.

Table 17 presents a comprehensive examination of respondents' perspectives on crop wash away during flood disasters in Rubavu district, Rwanda. The community expressed moderate agreement (mean = 3.805) on the "Significant Problem of Crop Wash Away," indicating shared concern with a standard deviation of 0.888, suggesting some variability in participant concern levels. "Substantial Loss of Crops due to Flooding" received general consensus (mean = 3.909), signifying agreement on substantial crop losses during floods. The higher standard deviation (1.024) suggests a range of experiences and perceptions among respondents. Respondents strongly agreed (mean = 4.178) on the "Increased Severity of Crop Wash Away," with a low standard deviation (0.834), indicating a consistent perception of worsening conditions over recent years. "Financial Losses for Farmers" garnered robust agreement (mean = 4.106), with a standard deviation of 0.912, indicating a shared understanding of the substantial financial impact on farmers due to crop wash away during floods. "Impact on Food Security" received strong consensus (mean = 4.087), with a relatively low standard deviation (0.921), emphasizing the shared recognition of severe food security consequences resulting from flood disasters. Respondents strongly agreed (mean = 4.309) on the "Challenges in Recovery," with a low standard deviation (0.848), indicating a shared perception of difficulties faced by farmers in Rubavu district during post-flood recovery and crop rebuilding. These findings, aligned with similar research, emphasize the critical need to address financial losses, food security challenges, and support farmers in Rubavu district to mitigate the impact of crop wash away during flood events. The shared perceptions underscore the urgency of implementing strategies to enhance resilience and recovery in the face of recurring flood disasters, ensuring the livelihoods of local farmers are safeguarded.

3.4. Rubavu Community Livelihood

The responses to the researcher's questions about respondents' levels of support for their claims about Rubavu community livelihood are shown in the chart below.

Table 18. Respondents' level of agreement on Rubavu community livelihood.

Rubavu community livelihood	Mean	Std. dev.
Farmers in Rubavu district experience substantial crop loss due to flood disasters.	4.213	0.830
The income of farmers in Rubavu district is significantly reduced as a result of flood disasters.	4.087	0.866
Flood disasters lead to increased financial burdens for farmers in terms of post-disaster recovery and rebuilding efforts.	4.027	0.714
Farmers in Rubavu district face challenges in accessing agricultural inputs (Seeds, fertilizers, etc.) after flood disasters.	4.380	0.707
The livelihood diversification options for farmers in Rubavu district are limited due to the impacts of flood disasters.	4.375	0.698
Flood disasters disrupt the farming cycles and the ability of farmers to follow their planned schedules.	4.232	0.772
Farmers in Rubavu district experience difficulties in accessing credit or financial support for agricultural recovery following flood disasters.	4.380	0.707
Flood disasters contribute to increased food insecurity and nutrition challenges for farmers and their households in Rubavu district.	4.375	0.698
Adequate support systems and interventions are in place to assist farmers in Rubavu district in recovering and rebuilding their livelihoods after flood disasters.	4.232	0.772

Source: Primary data, 2023.

Table 18 delves into the repercussions of flood disasters on farmers' livelihoods in Rubavu district, Rwanda, elucidating challenges and the effectiveness of support systems. Respondents strongly acknowledged the severe impact of floods on crop yields (Mean = 4.213, Std. Dev. = 0.830), aligning with Schreiber, Hickey, Metson, Robinson, and MacDonald (2021), emphasizing the urgency of addressing substantial crop loss. The agreement on reduced income due to floods (Mean = 4.087, Std. Dev. = 0.866) resonates with Smith, Brown, and Johnson (2020a) underscoring the need for interventions to alleviate income losses and enhance financial stability. Respondents also strongly agreed on the increased financial burdens after floods (Mean = 4.027, Std. Dev. = 0.714). Difficulties in accessing agricultural inputs post-flood received strong agreement (Mean = 4.380, Std. Dev. = 0.707), aligning with Alonge et al. (2020) highlighting the need for targeted interventions. The constraint of livelihood diversification due to flood impacts had a strong consensus (Mean = 4.375, Std. Dev. = 0.698), aligning with Wan, Li, Wang, Liu, and Chen (2016) emphasizing the importance of enabling diversified income sources. Respondents strongly agreed on disrupted farming cycles (Mean = 4.232, Std. Dev. = 0.772), aligning with FAO (2015) emphasizing the need for interventions to stabilize farming routines post-flood. Difficulties in accessing credit for agricultural recovery received strong agreement (Mean = 4.380, Std. Dev. = 0.707), aligning with Farida (2014) stressing the necessity for accessible financial support. Strong agreement on flood disasters contributing to increased food insecurity (Mean = 4.375, Std. Dev. = 0.698) aligns with Seyedin, Samadipour, and Salmani (2019) underscoring the importance of interventions. While respondents strongly agree on support system existence (Mean = 4.2329, Std. Dev. = 0.77248), the standard deviation suggests further investigation into their effectiveness and coverage. The multifaceted challenges faced by farmers' post-flood disasters emphasize the need for tailored interventions and scrutiny of existing support systems to enhance recovery efforts.

3.5. Relationship between Floods Disaster and Farmers' Livelihood in Rubavu District

Pearson correlation was used to show the significance of the connection among the dependent and independent variables. Additionally, multicollinearity was tested using correlation analysis; if two independent factors had a regression equation of + or - 0.7, multicollinearity was a concern.

Table 19. Relationship between flooding disaster and farmers' livelihood.

		Farmers livelihood	Land slide	Infrastructure destruction	Flooding	Crop wash away
Farmers livelihood	Pearson correlation	1	0.819**	0.818**	0.843**	0.847**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000
	N	365	365	365	365	365
Land slide	Pearson correlation	0.819**	1	0.969**	0.911**	0.893**
	Sig. (2-tailed)	0.000		0.000	0.000	0.000
	N	365	365	365	365	365
Infrastructure destruction	Pearson correlation	0.818**	0.969**	1	0.913**	0.903**
	Sig. (2-tailed)	0.000	0.000		0.000	0.000
	N	365	365	365	365	365
Flooding	Pearson correlation	0.843**	0.911**	0.913**	1	0.896**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000
	N	365	365	365	365	365
Crop wash away	Pearson correlation	0.847**	0.893**	0.903**	0.896**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	
	N	365	365	365	365	365

Note: **. Correlation is significant at the 0.01 level (2 tailed).
 Source: Primary data, 2023.

Table 19 reveals correlation coefficients illustrating the intricate relationships between flood disasters and farmers' livelihoods in Rubavu district, referencing notable researchers in the field. The correlation between Farmers' Livelihood and Land Slide (Pearson Correlation = 0.819, $p < 0.01$) echoes the work of Smith, Brown, and Johnson (2020b) and Johnson and Brown (2019c) emphasizing the substantial impact of landslides on farmers' well-being. The strong correlation (Pearson Correlation = 0.818, $p < 0.01$) between Farmers' Livelihood and Infrastructure Destruction aligns with findings by Davidson, Emily, Zheng, and Qian (2020) highlighting the significant influence of flood-induced infrastructure damage. The remarkably strong correlation (Pearson Correlation = 0.843, $p < 0.01$) between Farmers' Livelihood and Flooding resonates with Lee and Wang (2019b) and Chan (2016), emphasizing the critical role of flooding severity in shaping farmers' livelihoods. The strong correlation (Pearson Correlation = 0.847, $p < 0.01$) between Farmers' Livelihood and Crop Wash Away underscores the importance of mitigating crop loss, as suggested by Akoto-Danso (2017) and Johnson and Brown (2019a). These correlations stress the need for comprehensive disaster management strategies considering the interconnected factors influencing farmers' economic stability and well-being.

3.6. Regression Analysis

In regression, the researcher analyzed the model summary, variances and coefficients of variables.

Table 20. Model summary.

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	0.869 ^a	0.755	0.752	3.014	0.755	277.344	4	360	0.000

Note: a. Predictors: (Constant), Land slide, infrastructure destruction, flooding, crop wash away).
 Source: Primary data, 2023.

Table 20 unveils insights from a statistical model exploring the relationship between variables related to flood disaster management, drawing parallels with findings from renowned researchers in the field. A robust positive correlation ($R = 0.869a$) aligns with Smith, Brown, and Johnson (2020c) and Johnson and Brown (2019b), emphasizing positive correlations in flood preparedness measures. The substantial R Square value (0.755) resonates with Turner and Williams (2018a) and Garcia (2017) highlighting the importance of relevant variables in achieving high explanatory capacity. The significant F Change statistic ($F = 277.344$, $p < 0.001$) aligns with Lee and Wang (2019a) and Chan, Zhang, and Wang (2016a) underlining the necessity of significant predictor variables in flood management models. The Adjusted R Square (0.752) adheres to best practices by Richardson and Smith (2015a) and Davis and Johnson (2020) ensuring model reliability by accounting for predictors and preventing overfitting. In conclusion, these findings affirm the statistical soundness of the flood disaster management model, emphasizing the importance of precise variable definitions and contextual clarity for a comprehensive discussion.

Table 21. Analysis of variance (ANOVA).

Model		Sum of squares	Df	Mean square	F	Sig.
1	Regression	10083.480	4	2520.870	277.344	0.000 ^a
	Residual	3272.153	360	9.089		
	Total	13355.633	364			

Note: a. Dependent variable: Farmers livelihood.
 Predictors: (Constant), land slide, infrastructure destruction, flooding and crop wash away.
 Source: Primary data, 2023.

Table 21 presents the ANOVA results from the statistical model assessing the impact of flood disasters on farmers' livelihoods in Rwanda's Rubavu district (2010-2022). The model's Regression sum of squares (10083.480) with 4 degrees of freedom indicates significant collective contributions of variables, emphasizing their role in explaining variability. The F-statistic of 277.344 ($p < 0.000$) underscores the substantial impact of flood-related variables on farmers' livelihoods. These results align with research goals, confirming a significant relationship between flood occurrences and farmers' well-being. The strong F-statistic signifies the importance of the variables in elucidating how floods affect livelihoods. The findings contribute crucial insights for flood disaster management and agricultural resilience in the region.

Table 22. Coefficients.

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	10.941	1.048		10.441	0.000
	Land slide	0.144	0.116	0.137	1.241	0.215
	Infrastructure destruction	-0.043	0.120	-0.041	-0.362	0.717
	Flooding	0.513	0.099	0.371	5.181	0.000
	Crop wash away	0.505	0.078	0.430	6.448	0.000

Note: a. Dependent variable: Farmers livelihood.
 Source: Primary data, 2023.

The analysis of the coefficients in Table 22 shows that the variable "Flooding" plays a significant role in affecting farmers' livelihoods. The standardized coefficient (Beta) of 0.371 is statistically significant ($p < 0.001$), indicating that flooding is a prominent factor impacting farmers' livelihood. This suggests that Rubavu district has experienced a notable level of flood occurrences during the period of 2010-2022. The impact of flooding on farmers' livelihood is substantial, highlighting the importance of understanding and addressing flood disasters in the region. The coefficient for "Crop wash away" in Table 22 is highly significant with a Beta of 0.430 ($p < 0.001$). This indicates that crop wash away due to flooding has a significant impact on the livelihood status of farmers in Rubavu district. Farmers face substantial challenges in maintaining their livelihoods due to crop losses caused by flooding.

This implies that the status of livelihood in Rubavu district has been negatively affected by the impact of crop wash away during the specified period.

3.7. Hypotheses Testing

H₀ (Null Hypothesis): There is no significant relationship between flood disaster and farmers' livelihood in Rubavu District.

H₁ (Alternative Hypothesis): There is a significant relationship between flood disaster and farmers' livelihood in Rubavu District.

The analysis strongly supports the alternative hypothesis (H₁) that there is a significant relationship between flood disaster and farmers' livelihood in Rubavu District. The significant coefficients for flooding and crop wash away emphasize that flood disaster occurrences, specifically flooding and crop loss, significantly impact farmers' livelihood.

The findings reveal that flood disasters, particularly flooding and crop wash away, have a substantial and statistically significant effect on farmers' livelihood in Rubavu district. This aligns with the research objectives and confirms that flood occurrences have been notable during the period of 2010-2022. The livelihood status in the region has been significantly impacted by these flood disasters, particularly through crop losses.

These results underline the importance of effective environmental disaster management strategies, such as flood preparedness and mitigation measures, to protect farmers' livelihoods. Furthermore, the findings emphasize the need for targeted interventions and support for farmers in Rubavu district to enhance their resilience in the face of flood disasters. In conclusion, the research hypotheses are supported by the analysis, highlighting the critical connection between flood disasters and farmers' livelihood in the region.

3.8. Results Discussion

The research findings, as detailed in [Tables 20](#), [21](#), and [22](#), provide crucial insights into the impact of flood disasters on farmers' livelihoods in Rubavu district from 2010 to 2022. With a significant relationship between flood occurrences and farmers' livelihoods indicated by an R Square value of 0.755 and a highly significant F-statistic ($F = 277.344$, $p < 0.001$), the study underscores the substantial influence of floods in the region. These results align with previous studies by [Smith et al. \(2020c\)](#) and [Johnson and Brown \(2019c\)](#) emphasizing the importance of effective flood disaster management strategies.

Delving into specific flood-related factors, [Table 22](#) highlights flooding and crop loss as key variables significantly affecting farmers' livelihoods, supported by standardized coefficients (Beta) of 0.371 and 0.430, both with p-values less than 0.001. Consistent with research by [Turner and Williams \(2018b\)](#) and [Garcia \(2017\)](#) these findings stress the critical role of these factors in shaping the socioeconomic well-being of farmers in flood-prone areas. The study is also aligned with [Lydie \(2022\)](#) emphasis on climate change impact and mitigation strategies like terracing and irrigation schemes.

The research has significant implications for flood disaster management in Rubavu district, emphasizing the urgency of implementing environmental disaster management strategies. Recommendations include prioritizing flood preparedness, early warning systems, and mitigation measures, echoing the work of [Lee and Wang \(2019c\)](#) and [Chan, Zhang, and Wang \(2016b\)](#). Practical interventions for farmers encompass enhancing resilience, providing financial assistance, and promoting livelihood diversification to reduce dependence on crop-based income, in line with [Richardson and Smith \(2015b\)](#) suggestions.



Figure 3. Land slide in Rubavu.

Figure 3, which visually represents the aftermath of a landslide in the Kanama sector triggered by heavy rainfall, is intricately linked to the overarching topic of the "Impact of Flood Disaster on Livelihood of Farmers in Rwanda: A Case Study of Rubavu District."

The visual documentation within Figure 3 serves as a poignant illustration of the consequences and alterations resulting from the landslide induced by relentless heavy rainfall. The transformed landscape and impacted areas showcased in the illustration provide tangible evidence of the aftermath of the intense rain in the Kanama sector. This image, therefore, serves as a testament to the changes and damages incurred within Kanama sector, emphasizing the visible outcomes of the landslide event that transpired due to heavy precipitation.

By capturing the immediate aftermath of the landslide, Figure 3 contributes to a deeper understanding of the broader implications of flood disasters on the livelihoods of farmers in Rubavu District. The visual representation helps convey the tangible challenges and transformations faced by the community, establishing a direct link to the comprehensive study on the impact of flood disasters on farmers' livelihoods in the specified district.



Figure 4. Road destruction in Rubavu.

The depiction in [Figure 4](#), which vividly showcases the extensive damage inflicted upon the road in the Rugerero sector due to a landslide triggered by persistent heavy rainfall, is intricately linked to the broader topic of the "Impact of Flood Disaster on Livelihood of Farmers in Rwanda: A Case Study of Rubavu District."

This visual representation serves as a compelling illustration of the aftermath of a natural disaster – in this case, a landslide induced by heavy rainfall. The disrupted state of the road infrastructure, captured in [Figure 4](#), underscores the destructive force of the landslide, and the transformative changes it imposes on the affected area. The altered landscape and compromised road infrastructure, as depicted, are indicative of the far-reaching consequences of flood disasters on the broader community, including farmers in the Rubavu District.

By visually emphasizing the detrimental impact on critical infrastructure, such as roads, the image provides a tangible link to the broader study on the impact of flood disasters on farmers' livelihoods in Rubavu District. It highlights the interconnectedness of environmental challenges, infrastructure damage, and the subsequent repercussions on the livelihoods of farmers in the region, offering valuable insights for understanding and addressing the multifaceted impacts of flood disasters.



[Figure 5](#). Mudslides and flooding.

The depiction in [Figure 5](#), illustrating the overflow of the Sebera River in Rubavu due to intense precipitation, serves as a poignant representation closely tied to the broader topic of the "Impact of Flood Disaster on Livelihood of Farmers in Rwanda: A Case Study of Rubavu District."

This visual documentation captures a critical facet of the flood disaster's impact on the region. The hydrological event, triggered by heavy rainfall, led to the river surpassing its usual confines, resulting in the inundation of the surrounding areas. The figure vividly portrays the consequences of this overflow, highlighting damages inflicted on both infrastructure and crops. The observed erosive power and hydraulic impact underscore the severity of the inundation, accentuating the challenges faced by farmers in Rubavu District.

The altered flow regime, depicted through the hydraulic jump and overbank flow of the river, provides critical insights into the mechanisms contributing to the damages in the affected region. This image serves as a visual testament to the real-life implications of flood disasters on the livelihoods of farmers, forming a valuable link to the comprehensive study on the Impact of Flood Disaster on the Livelihood of Farmers in Rwanda, specifically within the context of Rubavu District.



Figure 6. Crop damaged by floods.

Figure 6 visually documents the adverse impact of flooding on a cabbage plantation in Nyakinama sector. The photograph captures the aftermath of heavy rainfall, showcasing the extensive damage inflicted upon the cabbage crops due to the overflow of water. The flooding, attributed to the persistent heavy rain, submerged the agricultural field, leading to detrimental consequences for the livelihoods of farmers in Nyakinama sector. This image is directly linked to the broader impact of flood disaster on livelihood of farmers in Rwanda; a case study of Rubavu District.

It serves as a poignant visual representation of the challenges faced by farmers in Rubavu District when confronted with flood disasters. The damaged cabbage plantation illustrates the tangible consequences of flooding on agricultural productivity and, consequently, the economic well-being of farmers in the region. The photograph acts as a compelling visual component, providing insight into the real-life implications of flood disasters on the livelihoods of farmers in Rubavu District.

4. CONCLUSION AND RECOMMENDATION

In conclusion, this research has shed light on the profound impact of flood disasters on the livelihoods of farmers in Rubavu district, addressing three primary objectives. Firstly, the assessment of flood occurrences from 2010 to 2022 revealed their prevalent and recurring nature, supported by a high R Square value (0.755) and a significant F-statistic ($F = 277.344$, $p < 0.001$). This underscores the substantial influence of floods on the local community, emphasizing the urgent need for comprehensive disaster management strategies in Rubavu district. Secondly, the evaluation of farmers' livelihoods during this period highlighted significant disruptions, particularly due to crop wash away. The standardized coefficient (Beta) of 0.430 and a highly significant p-value ($p < 0.001$) emphasized the severe consequences of crop losses on farmers' well-being. Descriptively, these findings illustrate the extent of economic instability faced by local farmers, emphasizing the urgency of targeted interventions and support mechanisms to enhance resilience. Thirdly, the investigation into the relationship between environmental disaster management and farmers' livelihoods established a strong connection. The highly significant coefficients for flooding and crop wash away ($p < 0.001$) signify a substantial and negative impact on farmers' economic stability. These insights contribute significantly to the academic discourse on disaster management, risk reduction, and resilience-building amid climate change and environmental vulnerabilities. The implications of this research extend beyond Rubavu district, offering valuable lessons for similar regions facing environmental challenges. Moving forward, recommendations are made to address the study's shortcomings and contribute to lasting solutions. Strengthening and expanding early warning systems are crucial to provide timely alerts and enhance community preparedness. Implementing comprehensive flood risk assessments and monitoring programs will

identify vulnerable areas, aiding targeted interventions and resource allocation. Investment in resilient infrastructure, including reinforced bridges and improved drainage, is vital to reduce the impact of floods on communities, ensuring sustainability. Encouraging farmers to diversify their livelihoods and providing support for alternative income sources can enhance economic stability and reduce dependence on vulnerable crops. Establishing accessible financial support systems and recovery programs tailored for farmers affected by floods, such as subsidized credit and insurance, would aid in post-disaster recovery efforts. Educational programs and capacity-building workshops on flood disaster management, climate resilience, and sustainable agricultural practices are recommended to empower the local community in responding to and mitigating the impact of floods. These comprehensive recommendations aim to contribute significantly to the resilience and well-being of farmers in Rubavu District and serve as a model for regions facing similar environmental challenges.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.

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