Evaluate the Economic Benefits of Investing in Early Warning System for Floods Management

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Abstract:- This study evaluated the economic benefits of early Warning services for floods in Rubavu district, in Rwanda, focusing on gender distribution, awareness, satisfaction, and perceived economic advantages. Survey data from 180 respondents indicated high awareness among both genders, with generally satisfactory perceptions of existing systems. Economic benefits included job creation and business protection, with positive technological perceptions correlating with higher perceived benefits. Recommendations included funding allocation, collaboration, research, and community engagement to enhance system effectiveness. The research aimed to assess the economic advantages of investing in flood early warning systems in Rubavu District, proposing strategies for funding alongside climate change adaptation. It marked the first empirical investigation into the correlation between investment, flood-related losses, and socio-economic development across various economies. Methodological instruments such as questionnaires, interviews, GIS, remote sensing, and statistical analysis were employed. The study found a positive relationship between investment and flood-related losses, supported by a statistically significant p-value of 0.0379. This indicates ample evidence for correlation between the variables. Thus, the study emphasized the importance of early notice systems in vindicating flood economic impressions and advocated for concerted efforts to maximize socio-economic benefits in Rubavu district.

Keywords:- Investment, Early Warning Systems, Flooding and Economic Benefits.

I. INTRODUCTION

Early warning systems for floods have been invaluable tools globally, regionally in Africa, and locally in countries like Rwanda due to their ability to provide timely alerts and help mitigate the impacts of floods. Here's how they have been beneficial: at global level in USA, UK, France, Samoa and Bangladesh, early warning systems contribute to global disaster risk reduction efforts by enabling countries to anticipate and prepare for flood events. They facilitate the exchange of information and best practices among countries, helping to improve resilience and response strategies worldwide (Leal Filho, W, et al., 2019).

In Kenya, Seychelles, Senegal, Madagascar, Mauritius and DRC where many districts are susceptible to flooding due to factors like heavy rainfall, poor infrastructure, and

deforestation, early warning systems play a crucial role. These systems enhance regional cooperation and coordination in disaster management by sharing data, technology, and expertise across borders. They assist in minimizing the death and assets by providing caveats to vulnerable societies well in advance, consenting time for evacuation and preparation (Browne, 2021). At the community level in Rwanda, localized early notice systems address the specific needs of at-risk populations by providing timely flood information tailored to their areas. These systems frequently adopt community-based approaches, drawing on local knowledge and resources to improve their effectiveness. By notifying authorities and residents of impending flood risks, these systems enable proactive actions such as evacuations, strengthening infrastructure, and deploying emergency services. Rwanda, renowned as the "terrestrial of a thousand knolls," is a compact, landlocked nation. Encompassing an area of 26,338 square kilometers and with an estimated population of 14,188,378 in 2023, Rwanda stands as densely inhabited nation, with roughly 571 inhabitants per square kilometer (Wagesho, N., & Claire, M. , 2016). The majority of its population, approximately 82%, resides in rural regions and heavily depends on subsistence farming, often on steep hillside plots reaching elevations of up to 3,500 meters. Many of these small-scale farmers cultivate plots as tiny as 0.33 hectares, confronting additional hardships stemming from environmental threats that exacerbate their living conditions. (Worldometer, 2023).

Through a thorough examination of Rwanda-specific data and experiences, this study intentions to offer treasured insights into crucial that early warning services play a role in minimizing disaster menaces and promoting economic sustainability. In the subsequent sections of this thesis, I explored the methodologies utilized, the results obtained, and the policy implications arising from this inquiry, thus mainly Research was Intended to assess and analyze the economic advantages of investing in Early Warning Systems for flood mitigation, with a central focus on reducing property damage, human casualties, and post-flooding expenses within the specific context and elucidating the tangible economic benefits associated with investing in early warning systems for flood management in Rwanda (Wabanhu, 2017).

II. THE RESEARCH METHODOLOGY

Total sample size in this research was 180 participants calculated using the Slovin's formula (1960). It was calculated based on target population (102,137) populations located in Sectors of Rubavu District. The study followed

Stratified Sampling by dividing the population of Rubavu district into strata based on relevant factors such as socioeconomic status, proximity to water bodies, and historical flood risk. Then, randomly selecting participants from each stratum to ensure representation across different risk levels.

In this Research, data collection Engaged the usage of questionnaires, interviews, as well as GIS and remote sensing techniques. Surveys informed the design of the questionnaires, while interviews provided qualitative insights (Bluemke, et al., 2017). Questionnaires were distributed to residents of Rubavu district to gather quantitative data on their experiences, perceptions, and economic impacts related to floods, as well as their opinions on early warning systems. Types of Information/Data Collected: Demographic information (age, gender, occupation, etc.), Economic losses incurred due to past floods (property damage, income loss, etc.). Perception of flood risk and preparedness measures. Willingness to pay for early warning systems. Desired features of early warning systems. Previous experience with flood warnings and responses (Berz, 2000).

I used GIS and remote sensing techniques to analyze spatial data related to flood risk, vulnerability, and historical flood events in Rubavu district, Identification of flood-prone areas within the district. Mapping of critical infrastructure (roads, bridges, hospitals, etc.) at risk from floods, Assessment of land use patterns and their impact on flood susceptibility. Integration of topographic and hydrological data to model flood scenarios (Loli, M., et al, 2022).

Statistical methods were applied to analyze quantitative data, whereas thematic analysis is employed to scrutinize qualitative data, uncovering patterns and themes within the framework of weighing the commercial advantages of investing in early warning systems for floods in the Rubavu district. This process aimed to evaluate the accuracy of particular assertions or presumptions through data examination. GIS tools were used to analyze spatial relationships, calculate flood risk indices, and identify vulnerable areas. Inferential statistics: Statistical tests (e.g. chi-square tests) was performed to assess relationships and differences between variables (Cooksey, R. W., & Cooksey, R. W., 2020).
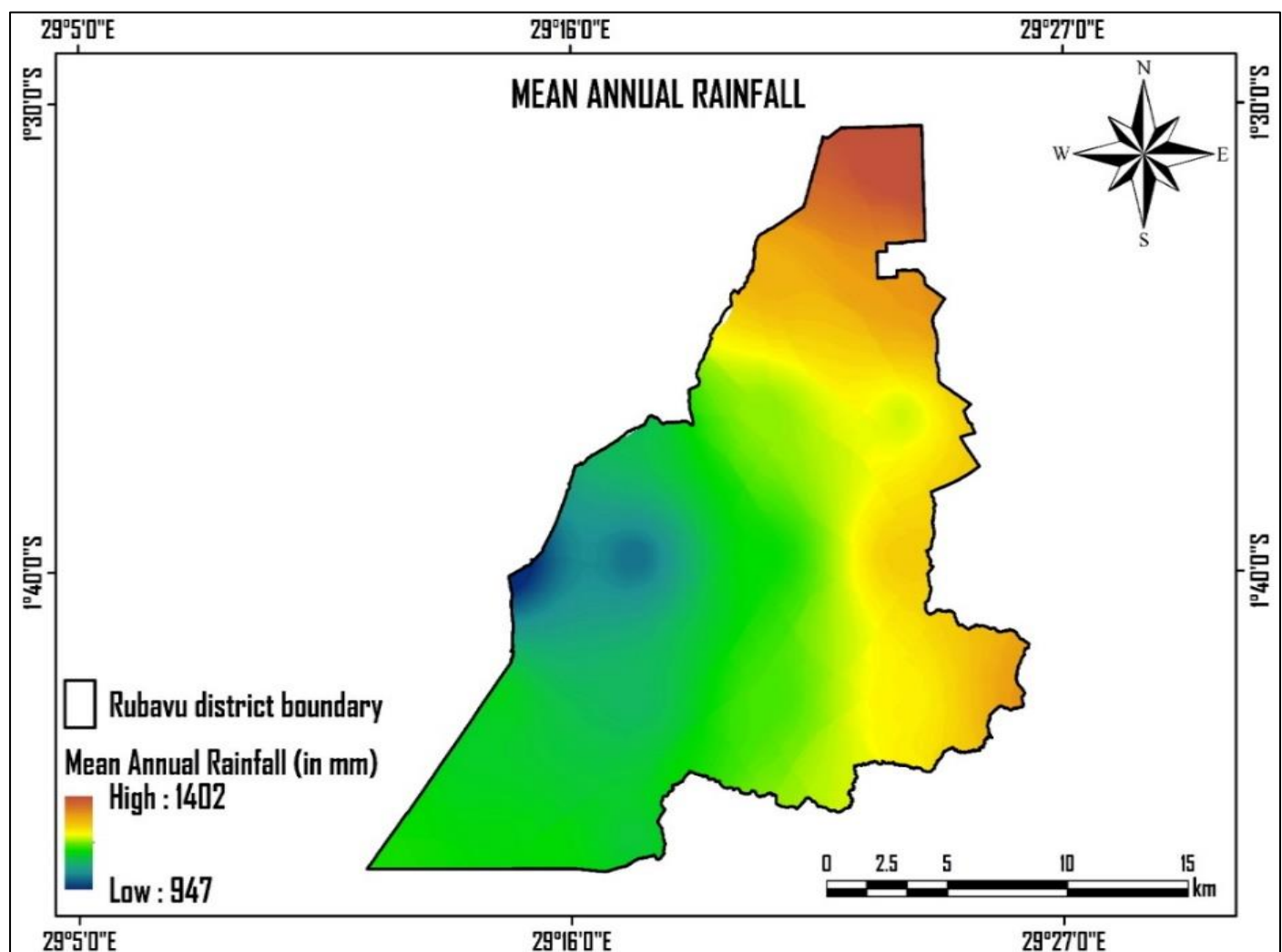
➤ *The Annual Rainfall of Rubavu District*

Fig 1 The Mean Annual Rainfall of Rubavu District
Sources: Primary Data,2024

The range of annual rainfall in Rubavu district, spanning from 947mm to 1402mm, indicates varying precipitation levels across the region. This suggests that different areas within the district experience different amounts of rainfall annually. While areas with lower rainfall amounts (947mm) considered relatively drier compared to those with higher rainfall amounts (1402mm), heavy rainfall events in regions with higher precipitation levels can increase the risk of flooding. Intense rainfall exceeding the soil's ability to absorb water or overwhelming drainage systems lead to surface runoff, flooding of low-lying areas, and flash flooding. Based

on information gleaned from elevation maps, flood hotspot data, and annual rainfall maps, it is evident that flooding and heavy rainfall occur in Rubavu due to topographical and climatic conditions. This underscores the necessity for investment in early warning systems for floods. Such investment aims to mitigate property damage, save lives, decrease maintenance costs, and potentially yield profits by establishing early warning systems for floods. This initiative would involve collaboration among various stakeholders and development partners (Hasan, 2018).
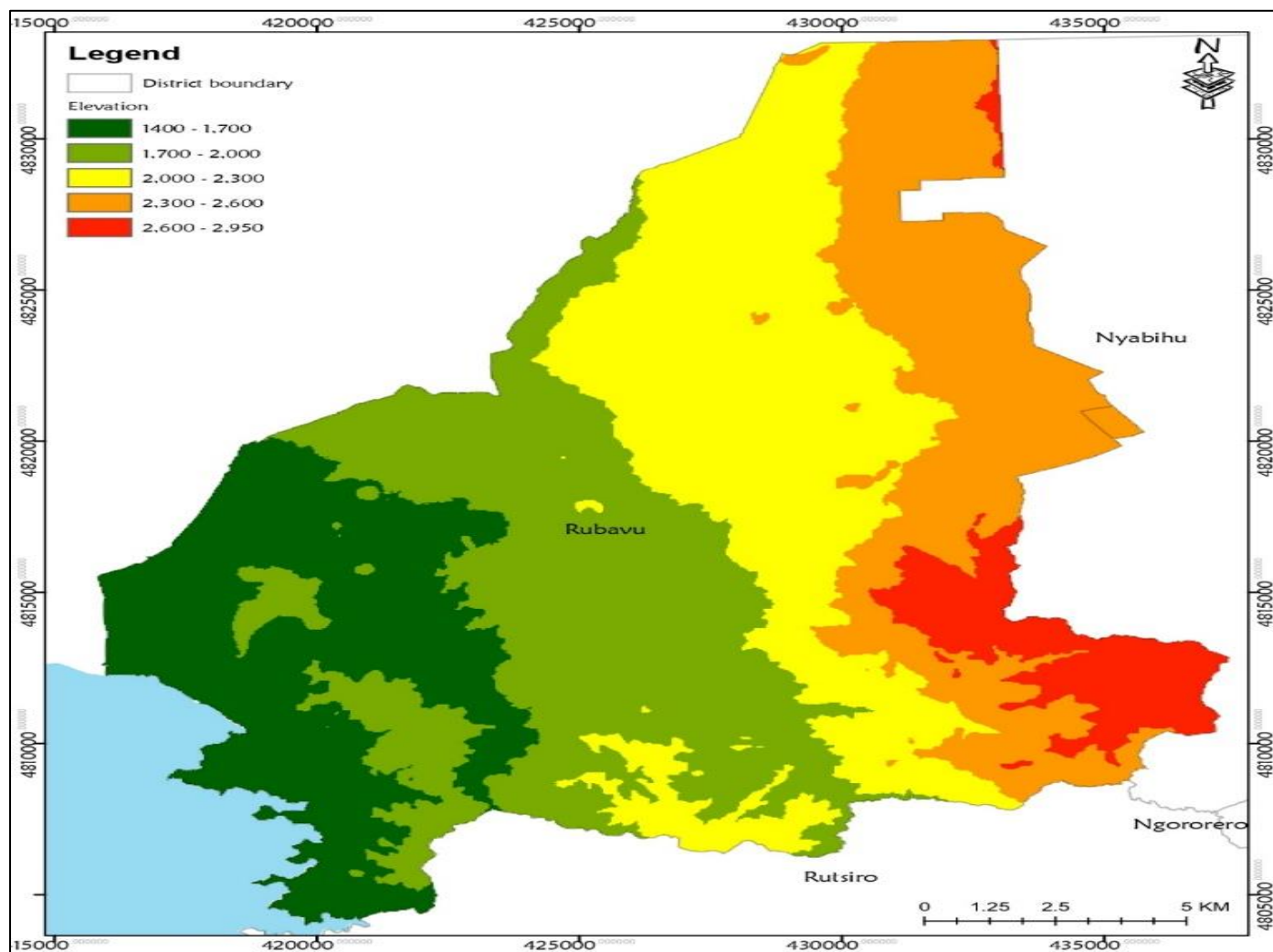

Fig 2 The Elevation Map of Rubavu District
Sources: Primary data, 2024

➤ *The Elevations of Rubavu District.*
According to the Map of Elevation Above shows that in Rubavu District there is Orographic Effects: Areas at higher elevations (closer to 3000 meters) may experience orographic rainfall, where humid air is enforced to upsurge over the elevated land. As the air ascends, it cools and condenses, leading to enhanced cloud development and potentially heavier rainfall. This upshot in increased overflow and the potential for flooding in downstream areas (Grigoriy, 2018). Drainage Patterns: Higher elevations often serve as the source of rivers and streams that flow downstream towards lower-lying areas. During heavy rainfall events, runoff from these

higher elevations can increase significantly, leading to higher water levels in rivers and streams downstream. This can result in flooding in areas located at lower elevations (Merz, B., etal , 2021).

Slope Stability: Areas with steep slopes, which are often found at higher elevations, may be more susceptible to landslides and slope failures during heavy rainfall events. The combination of saturated soil and steep slopes can increase the risk of mass movements, leading to debris flows and landslides that can block rivers and exacerbate flooding downstream (Jakob, 2022).Vulnerability of Low-Lying

Areas: While higher elevations may experience increased rainfall and runoff, lower-lying areas are typically more vulnerable to flooding due to their proximity to rivers, streams, and other water bodies. Heavy rainfall events can lead to rapid inundation of these areas, causing property damage and posing risks to human safety (Wilby, R. L., & Keenan, R., 2012).

➤ *Flood Hotspots in Rubavu District*

Hotspot flooding refers to specific areas or locations that are particularly prone to experiencing frequent or severe flooding events.
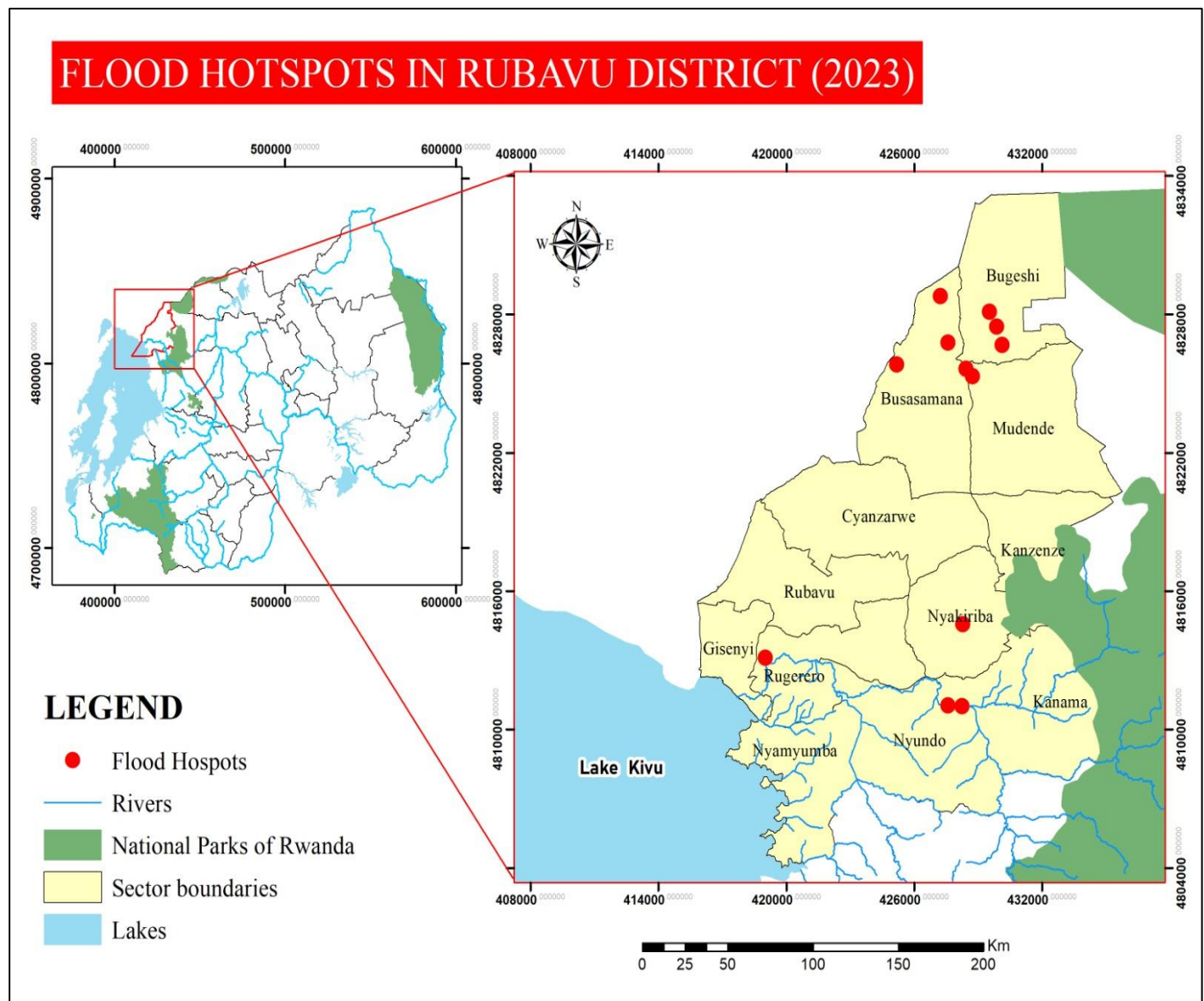

Fig 3 Floods Hotspots in Rubavu District
Sources: Primary data, 2024

These areas are often characterized by a combination of factors that make them more susceptible to flooding compared to surrounding areas. Some common factors contributing to hotspot flooding include: Geographic Features: Certain geographic features such as low-lying terrain, proximity to rivers, streams, or coastlines, and natural drainage patterns can increase the likelihood of flooding in specific areas. Urbanization: Rapid urbanization and inadequate infrastructure can exacerbate flooding in urban areas by reducing natural water absorption and increasing runoff. Land Use Changes: Changes in land use, such as deforestation, agricultural expansion, or the construction of impervious surfaces like roads and buildings, can alter natural drainage patterns and contribute to increased flooding risk (Wheater, H., & Evans, E. , 2009).Climate Change: Climate change result to more frequent occurrences and intense rainfall events, expanding sea levels, and changes in precipitation patterns, all of which can contribute to increased flooding risk in certain areas. Infrastructure Vulnerability: Aging or poorly maintained infrastructure, such as drainage systems, levees, and flood barriers, can increase the susceptibility of certain areas to flooding (Sohn, W., et al, 2020).

➤ *Investment in Early Warning Systems in Rubavu District*

Table 1 Awareness of Existing in Early Warning Systems for Floods in Rubavu District

Aware of present of Early warning systems for Floods in Rubavu District	FREQ	PERCENTAGES
NO	30	16.7
YES	150	83.3
Grand Total	180	100

Sources: Primary data,2024

Out of the respondents surveyed, 150 individuals were knowledgeable about the presence of Early Warning Systems for floods, comprising 83.3% of the total respondents. Meanwhile, 30 respondents claimed ignorance regarding Early Warning Systems, making up 16.7% of the respondents.

Table 2 Out of the Respondents Surveyed

Satisfaction to Early Warning System	Freq.	Percent	Cum.
Satisfied	130	72.22	72.22
Dissatisfied	50	27.78	100.00
Total	180	100.00	

Sources: Primary data, 2024

Out of a total of 180 respondents, 130 expressed satisfactions with the Current Early Warning Services, accounting for 72.22% of the total and contributing to a cumulative percentage of 72.22%. Conversely, 50 respondents reported dissatisfaction, making up 27.78% of the total.

Table 3 Out of a Total of 180 Respondents

Gender of respondents	Satisfaction to early warning system		
	Satisfied	Dissatisfied	Total
Female	80	0	80
%	100.00	0.00	100.00
	61.54	0.00	44.44
Male	50	50	100
	50.00	50.00	100.00
	38.46	100.00	55.56
Total	130	50	180
	72.22	27.78	100.00
	100.00	100.00	100.00

Sources: Primary data, 2024

In the first row, there were 80 females who expressed satisfaction with the current early warning systems for floods and none reported dissatisfaction. Among males, 50 were satisfied while another 50 were dissatisfied with the systems.

Table 4 The Current Early Warning Systems for Floods

Gender of respondents	Economic benefit of investing in early warning systems for floods		
	Job opportunities	Protection of Businesses and Economic Activities	Total
Female	40	40	80
% in low	50.00	50.00	100.00
% in Column of Fem	40.00	50.00	44.44
Male	60	40	100
%	65.00	35.00	100.00
% in Column of Male	60.00	50.00	55.56
Total	100	80	180
%	55.56	44.44	100.00
%	100.00	100.00	100.00

Sources: Primary data, 2024

In terms of frequencies, investing in early warning systems for floods resulted in the creation of employment opportunities. Among males, 55.56% secured jobs, while among females, 44.44% obtained employment, contributing to the protection of businesses and economic activities.

> *Relationship between Technological Perceptions with Benefit of Investing in Early Warning Systems.*

Table 5 Relationship between Technological Perceptions with Benefit of Investing in Early Warning Systems

Technological perceptions towards early warning systems	Economic benefit of investing in early warning systems for floods		
	Job opportunities	Protection of Businesses and Economic Activities	Total
Yes	70	30	100
No	30	50	80
Total	100	80	180
Pearson Chi2 = 0.041 Prob = 0.0379			

Sources: Primary data,2024

Here is a Positive Relationship meanwhile the p-value (0.0379) is less than the conventional significance level of 0.05. This indicates ample evidence to establish a statistically significant association between the two categorical variables. Consequently, it is justified to assert that the two variables are correlated based on the available data.

Based on the provided tables and analysis, let's discuss the results and compare them with relevant theories and literature regarding the economic profits of investment in early warning systems for floods in Rubavu district: Tabulation of Gender by Benefits of Investing in Early Warning Systems:

The table presents a breakdown of the economic gain of investing in early warning systems, specifically in terms of job opportunities and protection of businesses and economic activities, by gender. Among females, 50% perceived job opportunities and 50% perceived protection of businesses and economic activities. Among males, a higher percentage (60%) perceived job opportunities compared to protection of businesses and economic activities (40%).

This suggests that there is variation in perceptions of economic benefits between genders, with males showing a slightly higher inclination towards job opportunities resulting from investing in early warning systems.

Relationship between Technological Perceptions with Benefit of Investing in Early Warning Systems: This table examines the relationship between technological perceptions towards early warning systems and the perceived economic benefits. Among those who have positive technological perceptions towards early warning systems, 70% perceived job opportunities and 30% perceived protection of businesses and economic activities. Conversely, among those with negative technological perceptions, 30% perceived job opportunities and 50% perceived protection of businesses and economic activities.

The Pearson Chi2 test indicates a statistically substantial positive relationship between technological perceptions and the perceived economic benefits of investing in early warning systems, by a p-value of 0.0379.

III. DISCUSSION

The positive relationship detected between technological perceptions and perceived economic benefits aligns with theoretical frameworks and findings in the literature. Positive perceptions of technology, such as early warning systems, often lead to greater acceptance and utilization, resulting in enhanced benefits.

Research suggests that trust and confidence in the reliability of early warning services are crucial for their effectiveness in mitigating the impacts of natural disasters like floods. The findings corroborate this by demonstrating that individuals with positive technological perceptions are more likely to perceive economic benefits, such as job opportunities and protection of businesses.

The variation in perceptions between genders highlights the Significance of taking into account of sociocultural influences and gender dynamics in the adoption and perception of technological solutions. Further exploration into the underlying reasons for these differences could provide valuable insights for designing targeted interventions and communication strategies.

Overall, the findings contributed to the up warding form of backup the economic benefits of investing in early warning systems for floods, emphasizing the role of technological perceptions in shaping their outcomes. This underscores the importance of building trust and confidence in these systems to maximize their potential impact on economic resilience and sustainability in Rubavu district and similar contexts.

IV. CONCLUSION

Based on the findings from the evaluation of economic benefits of investing in early warning systems for floods in Rubavu District, the following points are several conclusions and recommendations. **Gender Disparities in Awareness and Satisfaction:** Females comprised 44.4% of the respondents, while males accounted for 55.6%. However, there was no significant difference in satisfaction levels between genders.61.54% of females and 38.46% of males expressed satisfaction with the current early warning systems, indicating a higher satisfaction rate among females. **High Awareness and Satisfaction Levels:** 83.3% of respondents were aware of the existing early warning systems for floods.

72.22% of respondents expressed satisfaction with the current early warning services.

➢ *Economic Benefits and Gender Distribution:*

Investing in early warning systems led to job opportunities and protection of businesses and economic activities. 55.56% of males secured jobs compared to 44.44% of females. Equal proportions of males and females reported protection of businesses and economic activities.

➢ *Positive Relationship between Technological Perceptions and Economic Benefits:*

Here is a statistically significant positive correlation between technological perceptions towards early warning systems and economic benefits. Individuals with positive perceptions towards early warning systems were more likely to benefit from job opportunities and protection of businesses and economic activities. The evaluation of the economic gains of investing in early warning systems for floods in Rubavu District underscores the importance of proactive disaster preparedness and risk mitigation strategies. Through comprehensive analysis, it is evident that such investments yield significant positive outcomes across various sectors of the local economy. Investments in early warning systems contribute to substantial cost savings by reducing damage to critical infrastructure, protecting agricultural assets, and preserving businesses and livelihoods. By providing advance notice of potential flooding events, these systems enable timely interventions, thereby minimizing economic losses associated with property damage, crop failure, and business disruption.

Furthermore, the resilience of key economic sectors such as tourism is strengthened, ensuring continued revenue streams and sustaining local employment opportunities. Lower insurance costs for individuals and businesses in flood-prone areas further enhance economic stability and incentivize investment. Beyond immediate economic benefits, investments in early warning systems also demonstrate a commitment to sustainable development and public safety, fostering a conducive environment for long-term growth and prosperity in Rubavu District. These initiatives not only mitigate the adverse impacts of floods but also contribute to building community resilience and attracting investment opportunities.

The economic profits of investing in early warning systems for floods in Rubavu District are substantial and multifaceted, ranging from direct cost savings to enhanced economic resilience and attractiveness to investors. Such investments are imperative for promoting sustainable development, safeguarding livelihoods, and fostering a resilient and thriving local economy.

To have effective early warning system, the government should ensure that adequate financial resources are allocated to the development, maintenance, and enhancement of early warning systems. Implement measures to improve access to early warning information, especially in remote or marginalized communities, through multiple channels such as mobile alerts, community radio, and social media. Facilitate collaboration between relevant government departments, local authorities, and community organizations to strengthen the effectiveness and sustainability of early warning systems. Incorporate gender-sensitive strategies into policy formulation and implementation to address disparities in awareness, satisfaction, and economic benefits among different gender groups.

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