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Disaster Risk Management of Higher Risk Areas on Floods and Landslides in Rwanda

Venuste Kabalisa
kabaveste@gmail.com
Dalian University of Technology, Dalian, China

Mugisha Francis Kagambira
francismugisha40@yahoo.com
University of Rwanda, Kigali, Rwanda

ABSTRACT

Due to the country's geography, several areas in Rwanda are in high-risk zones. Recently, disasters like floods and landslides have the potential to hinder economic progress due to damaged infrastructure, relocation, and loss of life. Furthermore, climate change and the occurrence of more severe weather patterns have grown in recent years. According to data from the Ministry of Disaster Management and Refugees (MIDMAR), rainfall in central and northern-western Rwanda killed over 80 people between January and May of this year, while injuring 74 more. At least 28 persons were killed as a result of severe rain that caused flooding along the Sebeya River and other locations where people live on high slopes. In addition, 898 buildings were damaged, and nearly 1,500 hectares of crops were affected within the same time period. Rwanda, sometimes known as "the country of a thousand hills," is one of Africa's most densely inhabited countries. As a result, population growth has put pressure on land usage, leading in the establishment of human settlements in places prone to flooding and landslides. More places in Rwanda are vulnerable to floods and landslides owing to factors such as geography, land use type, a lack of proper information, and others. As disaster risk management is a global issue, knowledge about disaster-prone locations in Rwanda may be seen as an extra instrument for acquiring precise information, thus contributing to successful disaster risk management. It is in this regard that this work was conducted to provide information on disaster risk of floods and landslides and their management options in Rwanda. The result revealed that Flood-prone and landslide-prone zones are concentrated in the North-Western while floods had affected the country more than landslides.

Keywords: *Disaster, Risk Areas, Floods, Landslides*

1. INTRODUCTION

1.1. Disaster risk Context in Rwanda

Rwanda has seen a number of natural and man-made disasters, which have resulted in the loss of lives and property, as well as the relocation of people (MIDMAR, 2012). Famine caused by drought, traffic accidents, earthquakes, epidemics, and floods, landslides, environmental degradation, technical accidents, fires and lightning have been prevalent. According to MIDMAR (2012), natural hazards in Rwanda are divided into two categories: I) hydro meteorological, which includes floods, landslides, and droughts, and (ii) geological, which includes earthquakes and volcanic eruptions. In terms of the number of persons impacted, floods and landslides have produced the most devastating disasters. As a result, this paper concentrated on the specific situation of floods and landslides in Rwanda.

Rwanda has become one of the Sub-Saharan African countries most prone to disasters, notably landslides and floods, due to its geographical location and meteorological profile. Many of the disasters highlighted in this study are inextricably tied to the country's geographic characteristics, history, and socio-cultural features. Rwanda experiences disaster cases resulting from natural hazards including flooding, landslides, heavy rains and storms (Tsinda et al., 2019). Geographic factors such as steep slopes and others are among the factors of catastrophe vulnerability.

According to MIDMAR report (2011), Flooding was triggered by heavy rains in northeastern Rwanda, killing at least 10 people and displacing hundreds more. Floods in the western region damaged 354 dwellings and 3,000 hectares of crops in 2011, prompting farmers to seek refuge on higher ground.

The city of Kigali, especially in the past two decades, has experienced rapid expansion; population growth (mainly in 2006) has led to local government rearrangement, with numerous districts from rural regions being joined to the City (Baffoe et al., 2020; Sano, 2012). However, since 2006, the total area of the city has not changed from 370 square km^2, while the population has increased from approximately 900,000 in 2006 to 1.318

million in 2015, and disaster risks and losses have been registered accordingly.

According to the Government of Rwanda (2017), in May 2016, the city of Kigali suffered heavy rains, causing floods and landslides, destroying roads, transportation infrastructure and cutting off the supply of drinking water. Part of the road was completely blocked due to landslides, and the Kigali-Muhanga and Kigali-Musanze roads were closed to avoid the risk of people traveling. In addition, the water supply in some areas of Kigali was interrupted due to flooding caused by heavy rains. Water and Sanitation Corporation Limited (WASAC) reported that it has suspended water treatment at the NZOVE treatment plant (located in Kigali) due to "high water turbidity" caused by heavy rain (Floodlist, 2016). The main reason is related to the location pattern of the city. It is located in a mountainous area and rainwater easily flow downhills, causing floods and mudslides, rapid migration from rural to urban areas and settlement of residents in flooded areas, extreme rainstorms, changes in hydrological conditions and river bank flooding, and Residents lack the main skills for disaster preparedness, risk reduction and limited adaptability.

1.2. Floods and Landslides in Rwanda

1.2.1. Floods: Floods are typical in Rwanda, although their frequency has grown during the last two decades. Incidences in 2005 and 2007, in Musanze and Rubavu, caused the damage of infrastructure, agricultural losses, led to environmental degradation, population displacement and fatalities. Floods in Rwanda are mostly caused by heavy rain, which generates quick and unpredictable surges in the flow of rivers downstream (MIDMAR, 2016). Floods are classified into two types: i) localised floods produced by unusually strong rainfall and run-offs, and (ii) extensive floods caused by overflowing rivers and their tributaries. Floods can also trigger outbreaks of waterborne diseases and malaria, hence compounding communities to health hazards. They also cause physical damage by washing away structures, crops, animals and submerging human settlements. The impact of floods can be minimized by forecasting, studying seasonal patterns as well as the construction and maintenance of sufficient drainage systems. Floods can be properly managed through flood plan mapping and survey by air and land. Rwanda experiences both slow and rapid onset floods. They are common in North and Western parts of Rwanda (Claude et al., 2020).

1.2.2. Landslide and Mudslide: Landslides and mudslides are rapid movements of mass muddy rocks formed from loose soil and water. They usually result in migration of soil and sediments following heavy rains or upland sewage flowing through cracked bedrock or earthquakes (Claude et al., 2020). Predicting landslides and landslides is very difficult, but their frequency and extent can be estimated using information about the area's geology, topography, climate and vegetation cover and traditional knowledge. Settling in communities on steep slopes and other unmanaged land use practices increases the likelihood of landslides or mudslides spreading. The regions affected mainly on the land side are the northern, southern and western parts of the country (Nsengiyumva et al., 2019). For example, in 2010 and 2011, heavy rains were rampant in some parts of the country of Rwanda, resulting in several landslides and mudslides. These include outbreaks in Musanze, Rusizi, Rustiro, Nyabihu and Burera regions, resulting in destruction of houses and crops and loss of life. The remainder of this paper is structured as follows: Section 2 describes flood risk analysis: Conceptual frame and analysis procedure; Section 3 Disaster Risk Reduction Strategy in Rwanda. Finally, Section 4 ends the paper with concluding remarks.

2. FLOODS AND LANDSLIDES HAZARD IDENTIFICATION PROCESS

Identification entails identifying the danger in its local context and providing a description and historical background of potential environmental risks that may affect the community. This technique clarifies the degree of a hazard that may endanger the human, constructed, or natural surroundings. Thorough historical data on all hazards is crucial for understanding how hazards have impacted communities in the past and how they may affect communities in the future. As a result, the risk-specific procedure involves a study of past catastrophes in the community as well as the potential of future catastrophes. It is underlined that even slight hazards might result in significant secondary consequences. Risk is a part of our lives and all communities face different types of risk (Smith, 2004).

Our ability to mitigate the negative effects of disasters is dependent on human adaptation to natural occurrences, which includes building rules, land use control, and the design of vital infrastructure. Human adaptive activities impact our resilience, or capability to tolerate or recover from a disaster. As a result, we must study our environmental, human, economic, and built systems to fully comprehend what steps may be adopted to lessen our susceptibility and increase our resilience to natural disasters. The identification of the threats to our communities and organizations is critical to this process. The identification of hazards highlights natural and man-made phenomena that endanger a community. This process provides information that reveals the community's ability to respond to disasters. It provides an opportunity to characterize the physical characteristics of the building, the social characteristics of the community, and the responsiveness of the area. Hazard identification can be used directly in preparatory activities to clarify risk areas for response. Comprehensive identification of risks can support risk management policies and programs and determine the benefits of alternative strategies to reduce susceptibility (Mall et al., 2019). Floods and landslides are certainly on the increase as a result of many triggering variables. Aside from natural triggering factors like severe rainfall, deforestation, land use change, and so on, experts also include man made triggering causes. Land use change is the most significant anthropogenic influence. Therefore, the combination of natural and anthropogenic factors increases the risk of floods and landslides worldwide.

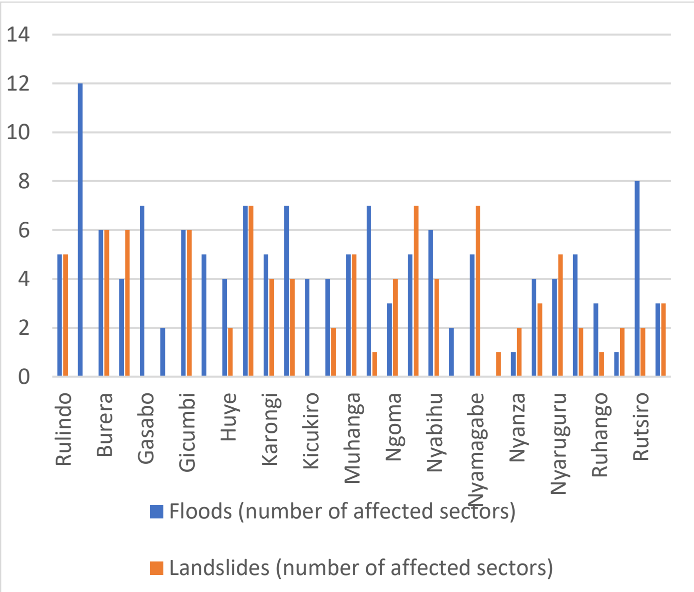


Fig. 1: Floods and Landslides per district in Rwanda (2010-2011)

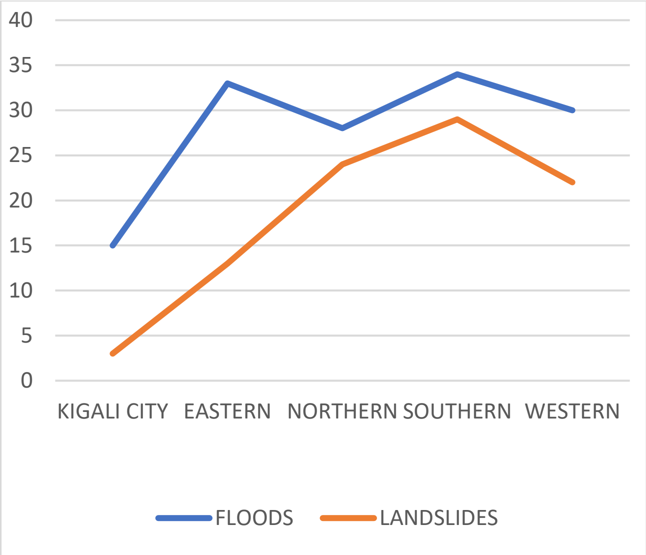


Fig. 2: ***landslide and floods per province (in terms of prone sectors)*****; Source: MIDIMAR Survey, 2011**

The amount of exposure varies by province, ranging from floods to landslides. In general, flooded areas predominate landslide-affected zones. Bugesera District has raised the amount of flood proneness in the Eastern province, with practically all sectors frequently flooding due to the Nyabarongo River. In fact, some regions are extremely vulnerable to floods and landslides, but the vulnerabilities vary from region to region due to various factors.

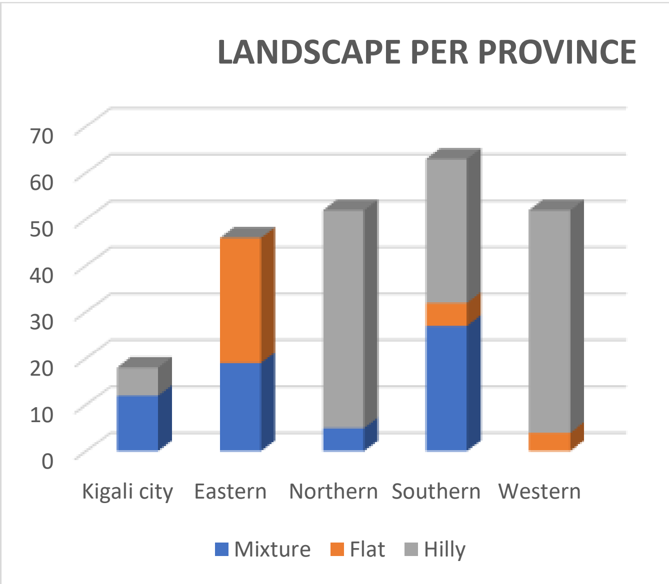


Fig. 3: Landscape type per Province; source: MIDIMAR/RPA, 2011

Landslides are more likely in steep terrain, whereas floods are more frequent in low-lying areas. However, because of the complexities of the geotechnical parameters that affect flood and landslide risk, extreme caution should be taken. Geologists need to investigate soil conditions, slopes, drainage, climate, prevalence of earthquakes and volcanic eruptions, erosion, industry-induced vibrations, construction and other topographic changes for prediction (Nsengiyumva et al., 2019). Important factors that can help you understand landslides include: include (1) areas that appear to have failed due to landslides, including debris flows and cut-and-fill failures; (2) areas that have the potential for landslides, by correlating Some of the major elements that lead to landslides include steep slopes, geologic units that lose strength when saturated, and poorly drained rock or soil with landslide history; and (3) places where landslides have happened in the past., are likely to occur now, and could occur in the future.

Fig. 4: Picture taken in Nyabihu District (flooding area), 2011

The photo above depicts some areas affected by landslides and floods in the Nyabihu District. The situation is not only the loss of infrastructure, facilities, etc., but also other related problems can occur. For example, if an educational facility is destroyed, students can suspend or continue studying but in very bad condition (exposed to the sun and rain). During the rainy season, students are discouraged because they need to study less time than usual. Therefore, the quality of education is reduced. In addition, this destroyed facility will need to be rebuilt or rebuilt. Furthermore, this damaged infrastructure would need to be rebuilt or restored, necessitating a large investment from the government rather than investing in other development efforts.

3. FLOOD RISK ANALYSIS: CONCEPTUAL FRAME AND ANALYTIC STEPS

3.1 Analytical component of flood risk analysis

Flood hazard, flood exposure, flood vulnerability, and flood risk are the core principles driving this research. Although these names are frequently used interchangeably, they represent different ideas. The flood hazard reflects the likelihood and severity of a flood of a specific magnitude occurring. Flood hazard indicates the probability and severity of a flood of a particular size. Flood exposure indicates the location of property, buildings, economic activity, infrastructure and population in relation to flood hazards. Flood vulnerabilities include physical, social, economic and environmental factors that increase susceptibility to flood hazards. Flood risk represents expected loss or damage to property, loss of life, and disruption of economic activity due to flooding. Flood risk depends on the flood hazard, exposure, and vulnerability. For example, there are all the risks and exposures of a building located on a floodplain, but there is no risk of flooding because there is no vulnerability if the building is completely resistant to flooding.

Disaster management experts continuously investigate the causes of floods using the following questions: What can go wrong in the case of a flood? How likely is it to happen? If that happened, what would the outcome be? What can be done to eliminate the occurrence of flooding or reduce the risk of flooding? Geographers are interested in spatial questions such as: Where do floods occur? How likely is a flood risk here? What is the geographic scope and impact of the event in the case of a flood? How can you manage the space to mitigate flood risk? Answers to this question can help identify effective planning strategies to mitigate flood risk (Vose, 2008).

Various frameworks have been developed to identify flood hazards and risks. One such study used flood risk, exposure, vulnerability and capacity indicators to analyze flood risk in the Volga River basin, Russia.

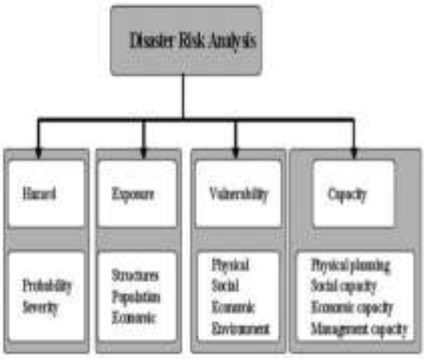
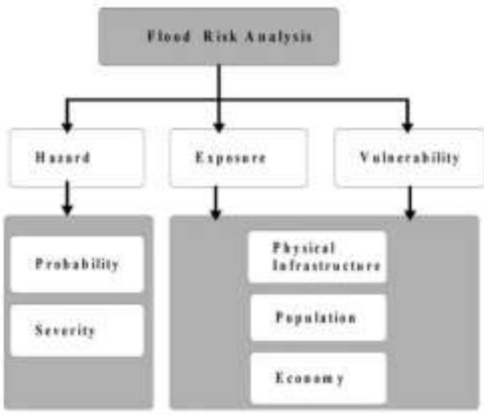


Fig. 5: Framework for flood risk analysis Source: Modified from UNU-IEHS and NNSUACE, 2006



The heaviness of flooding is characterized by water levels, flood duration and speed, while the likelihood relates to flood frequencies. Similarly, the catastrophic management program of the United Nations Commission for Human Settlement has proposed the following indicators: flood rate, sediment load, water volume, time and affected areas (UNCHS Habitat 2001). As can be seen above, an approach to flood analysis, mainly based on physical properties (depth, time, speed, frequency, flood size and sediment load) and a different approach to reaction variables (warning time, readiness, rate of rise and access).

3.2. Reaction to risk

Reactions to natural hazards vary based on past event experiences, perceived risks, personality, degree of reliance on resources, communication and interpretational difficulties. The way hazards are framed has a very large influence on how responses developed. In the case of migrants, 'displaced' groups have typically been connected with resourcefulness. (McMichael et al., 2012), a longer phenomenon does not only regulate its own living, but also contributes to the opportunity of the host community. In the variation of the perspective, at an institutional level, are the deeper challenges in moral, political and scientific decisions that relate to the effects of an environmental shock and a certain to their appearance. Participation conditions in these reactions and adequate guidelines changes to various contexts and institutional links to the event (VOSE, 2008).

It is crucial to note here that displaced persons who are economically disadvantaged sometimes congregate or are clustered in regions of increased environmental risk. The disadvantaged population seems to be more subject to environmental risks, hence reducing vulnerability and poverty mitigates disaster effects. The relationship between poverty and environmental impacts led to increased convergence of identifiers of catastrophic risks, also highlighted by the Hyogo Agreement in 2005, which is emphasized by the playback targets Millennium development Goals, and climate change adaptation.

3.3. Risk Management Options

After you've identified the risks involved to your organization, you must sit down and evaluate each risk based on its likelihood of becoming a reality and the impact it will have on the business if it does. Classify each risk's impact and probability as high, medium, or low. (Akintoye & MacLeod, 1997, VOSE, 2008).

High effect, a high probability risk should be processed first, while the risk of low probability and low impact can be handled for the last time. Consider how much time, money, and effort will be required to adequately manage each risk. Risk management options may be classified into various categories.

3.3.1. Acceptance (Do nothing): No action is taken to reduce the risk or one's exposure to it. Appropriate for risks when the expense of control exceeds the risk. It is often good for low-probability, low-impact risks and opportunities, of which one should have a long list, but you may be overlooking certain high-value risk reduction or avoidance alternatives, particularly if they handle many hazards at once.

3.3.2. Increase: You may realize that you are already using significant efforts to manage a risk that is disproportionate in comparison to the degree of protection it provides. In such instances, it is sensible to lower the amount of protection and reallocate resources to other risks, resulting in greater overall risk efficiency. For example, cease the need to test all slaughtered cows for BSE and reinvest the savings on hospital upgrades.

3.3.3. Get more information: A risk management can explain the degree of uncertainty in the decision problem (here we use uncertainty as distinct from inherent randomness). Acquiring more knowledge may frequently minimize uncertainty (whereas randomness cannot). As a result, a decision-maker might judge that there is too much uncertainty to make a serious judgment and request that further data be gathered. Using a risk analysis model, the risk analyst can recommend the most cost-effective approach of gathering more data required to attain the requisite degree of precision. Arguments about the value of information can be used to determine how much, if any, further information should be gathered.

3.3.4. Avoidance (Exclusion): This requires modifying an operating technique, a project plan, an investment strategy etc. to ensure that the risk identified is no longer applicable. Avoidance is generally used for risk of high likelihood, high effect. Example: instead of the innovative technique initially planned, utilize a tested technology. Note that there may be a very real danger that your plans may change, by creating new (and maybe even more critical) hazards.

3.3.5. Reduction (Mitigation): Reduction includes a number of methods that may be used in combination to lower the likelihood of risk, its impact or both. Examples are: redundancy building (standby equipment, backup computer at different location); greater quality testing or inspections; greater training for staff. Reduction techniques must be employed for all risk levels, where the residual risk is not of very high importance and where the benefits surpass the cost of the reduction.

3.3.6. Risk Reserve: The reaction of Management to the identified risk is to add a certain reserve (buffer) if it occurs. Appropriate for small to medium-sized hazards. Examples include: allocating more funding to a project; allocating additional time to finish a project; having cash reserves; more goods in stores for a vacation weekend.

3.3.7. Risk transfer: This includes manipulating the problem so that to transfer the risk from one party to another. A popular way to transfer risk is through contracts where a certain type of penalty is incorporated in the performance of a contractor.

3.4. Assessing Risk Management Options

Many factors must be considered by the management when analyzing the various choices for dealing with a defined risk issue: Is there adequate reliance on the risk evaluation of quality? How sensible is each option's rating in order to model uncertainties? How do the expenses of each risk management strategy benefit? What are the benefits? Is there any secondary risk related with the risk management approach chosen? How feasible will it be to carry out the risk management option? Is the risk assessment of high enough quality to be depended on? How sensitive is each option's rating to model uncertainties?

On this last point, we nearly always wish for more data or greater confidence about the nature of the problem: we want the distribution of what will happen in the future to be as small as possible.

3.5. Software tools and the models they build

3.5 1. Spreadsheet: Spreadsheets, and by that, I mean Excel these days, are the most natural and first choice for most people because it is perceived that producing a risk analysis model requires relatively little additional knowledge. In a few seconds and a few more button clicks, you may run a simulation and examine the distribution results. Excel Monte Carlo simulation software tools have focused heavily on graphical interfaces to make risk analysis modeling simple: combine that with the ability to track formulae across spreadsheets, embed graphs and format sheets in a variety of ways, and with VBA and data importing capabilities, and it's easy to see why Excel is so popular.

3.5.2 Influence diagram: Influence diagrams are popular because they effectively replicate the mathematics that can be built in a spreadsheet, but the modeling environment is very different. the most often used influence diagram tool. Variables (referred to as nodes) are represented as graphical objects (circles, squares, etc.) and are linked together by arrows (referred to as arcs) that indicate the direction of interaction between these variables.

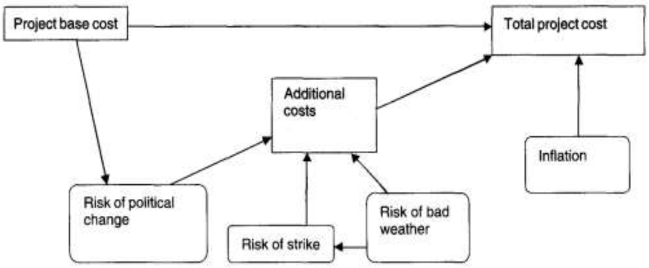


Fig. 6: Example of a simple influence diagram.

The visual result is a network that shows the viewer which variable affects which variable, but such a picture is soon very complex, so you can imagine creating a sub-model.

3.5.3 Event Tree: Event Tree Provides a way to build a series of probabilistic events with their probabilities and effects. They are likely the most helpful approach for representing a probabilistic sequence since they are highly straightforward, the mathematics for combining the probabilities is simple, and the diagram aids in ensuring the essential discipline. (Ezell et al., 2010; Pribadi 1991). Events are built from tree nodes (boxes) and arcs (arrows).

Example of a simple event tree.

Se = P (test positive for disease given the animal is infected)
Sp = P (test negative for disease given the animal is not infected)
Thus, following the rules of conditional probability algebra, we can say, for example:
P (anima1 is infected and tests positive) = p*Se
P (anima1 is infected and tests negative) = p*(l - Se)
P (anima1 tests positive) = p*Se + (1 - p) *(l - SP)

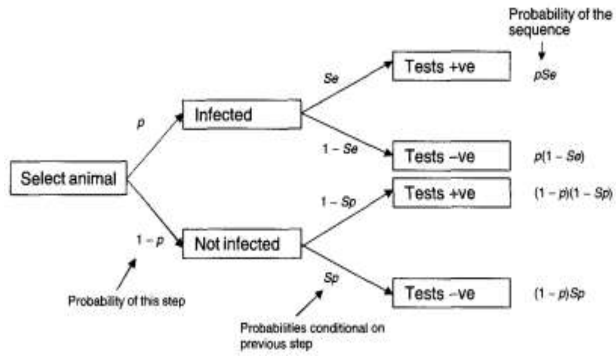


Fig. 7: Example of a simple event tree.

The tree starts from the left with a node (in the figure above, "animal selection" indicates that in some populations, animals are randomly selected), and the right arrow gives possible results. It shows (here, whether the animal is infected, whether it is a specific disease factor) and its probability (p, the prevalence of animals infected in the population is (1-p)) (Vose, 2008).

3.5.4 Fault Tree: Fault trees begin with the opposite approach to an event tree. An event tree explores potential future outcomes as it progresses from a beginning point. A fault tree begins with the outcome and investigates the various ways it may have occurred. A fault tree is therefore built from the right with the outcome, then proceeds to the left with the potential proximate events that might have caused that result to occur, then continues backwards with the potential events that might have caused the first set of events to occur, and so on.

4. DISASTER RISK REDUCTION STRATEGIES IN RWANDA

The Rwandan government has been supporting disaster risk management activities since 2008. Key areas include strengthening risk identification and developing capabilities for disaster risk management and improving disaster prevention. In 2008, Rwanda supported activities to develop cooperative relationships between East African countries to strengthen disaster risk management capacity and cooperation at the national and regional level. These activities have strengthened the ability of countries to effectively manage risks associated with climate change using regional modeling techniques. In September 2015, the government launched the first Rwanda National Atlas focusing on the risks of drought, earthquakes, floods, landslides and typhoons. The atlas highlights the vulnerabilities and exposures of risks and outlines key mitigation recommendations.

Currently, the Rwanda Government and the Disaster Reduction and Rehabilitation Global Facility are supporting projects in northwestern Rwanda to improve flood risk forecasting and disaster prevention by providing important technical research, training and guidance. Actions are expected to strengthen early warning systems for at-risk communities, and help to develop and implement flood mitigation actions in selected communities and sectors.

The government has intensified efforts to include disaster risk management (DRM) into national policies and long-term development goals. To manage natural and man-made disasters, the Ministry of Disaster Management and Refugee Affairs was founded in 2010. The Government also developed a National Disaster Management Policy, which acts as the country's legislative and institutional framework for DRM, ensuring that operations are coordinated and relationships between the government and stakeholders are promoted (Nipa et al., 2020).

To further develop the DRM agenda, the Government of Rwanda is prioritizing the following:

- Strengthening institutional capacity and coordinating DRM mechanisms between sectors.
- Strengthen disaster preparedness and ensure consistency with local and national disaster management plans.
- Contribute to poverty reduction and sustainable development by establishing DRM policies.
- Flooding is caused by farmers using contour ploughing as much as it is by large-scale dam construction. Drought and flood control intersect in certain ways. Dams can be used to regulate flooding during the rainy season and to alleviate drought during the dry season.
- The monitoring and forecasting of meteorological and hydrological data feeds into early warning systems in order to predict and anticipate drought and floods. This is critical for reducing damage and responding promptly when disasters hit.

In addition, vegetation and tree cover on landslide occurrences; numerous studies have revealed that when trees are planted, landslides are likely to decrease. Tree roots support the soil by growing across failure planes, forming root columns that act as piles, and reducing surface erosion.

5. CONCLUDING REMARKS

Rwanda has experienced a number of natural and man-made catastrophes that have resulted in the loss of lives and property, as well as the relocation of people. The identification of high-risk areas for floods and landslides around the country is part of an attempt to establish a comprehensive disaster prevention, mitigation, readiness, and management framework for the country.

Throughout this study, certain obstacles and possibilities were discovered at the grassroots level, such as the community's difficulty in dealing with natural and man-made disasters, particularly when they occur, such as a lack of effective disaster awareness and public education among the communities. Once disasters strike, there is a lack of understanding and public education for disaster risk reduction, which leads to more fatalities and injuries. It is critical to develop the public education and awareness culture in the field of disaster risk reduction among communities.

Another issue encountered were communities living in extremely vulnerable areas that might impact hazards at a critical moment and result in catastrophes. For instance, some people are still living in various parts of hills, building houses in places characterized by steep slopes and swamps, despite the fact that the aim is to evacuate the community living in disaster high risk zones to places with less natural disaster consequences.

The community needs education for disaster risk reduction in their place for effective disaster management and disaster risk mitigation. Existing response mechanisms for disasters such as community-level landslides and floods are supported by formal institutional, legal and budgetary capacity. It can include emergency planning, equipment and consumable inventory, emergency services and standby arrangement, communication, information management, community training and practice.

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