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CLIMATE CHANGE VULNERABILITY IN RWANDA, EAST AFRICA

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ABSTRACT

This study aims to spatially assess the flood vulnerability then suggests appropriate vulnerability lessening and adaptation mechanisms in Rwanda. Six vulnerability factors namely the rainfall and temperature, total population, access to communication tools, poverty level and number of schools were analyzed. The Weighting Linear Combination (WLC) method in ArcGIS is used to analyze these factors and spread the resulting flood vulnerability countrywide. The results showed high flood vulnerability within the northern, western and southern provinces and Kigali city of Rwanda. This vulnerability is likely to rise due to the noticed low possession of communication tools and education delivery, which could help to enhance the risk awareness and preparedness among the vulnerable communities. The results of this study can help policy makers to understand the required community's vulnerability lessening measures and ensure spread of mitigation and adaptation policies as per vulnerability extent within Rwanda.

Contribution/Originality: The paper primary contribution is finding that climate change risk, mainly the flooding are gradually causing severe losses and damages in Rwanda. Thus, the mapped flood vulnerability can be useful to policy makers to better recognize the required vulnerability lessening policies based on the actual circumstances.

1. INTRODUCTION

Under climate change, it is predicted that the temperature and precipitation will rise by about 2°C, and 1 to 2%, respectively, in the next decades, and this consequently, will cause wet places to become much wetter and dry places will be much drier (Fosu-Mensah *et al.*, 2012; Dami *et al.*, 2017). The changing climate risks such as droughts, Tsunamis, water borne diseases, heatwaves, storm winds, floods, landslides, etc., caused by rainfall and temperature patterns are severely causing immense losses among the communities. The poor and vulnerable people are largely affected primarily due to lack of risk awareness, adaptation and financial capabilities (Hirabayashi *et al.*, 2013; Oruonye and Ahmed, 2017; Ullah *et al.*, 2018).Within the East Africa, where Rwanda is located, more than 90 percent of the recorded natural disasters are hydro-meteorological caused by climate change causing serve losses and other negative impacts on the socio-economic and environmental wellbeing (Sowers *et al*., 2011; Chaudhury *et al*., 2013).

In Rwanda, climate change generated heavy rains, drought, flood, landslides, cropland damage and famine, which as reported, between 1980 and 2017 affected more than one million people (killed, injured and homeless), damaged more than 15,000 ha of cropland and 23,000 houses were destroyed (MIDIMAR, 2017).Nevertheless, in Rwanda, as previously reported, Nahayo *et al.* (2018) the delivery of disaster resilience education is not reaching the whole population. These are predominantly young (more than 30 percent of the total population) reported to rapidly grow and likely settling in disaster risk prone zones. This is associated with unavailable and/or limited data and studies on disasters, climate monitoring and update provision, lack of early warning and information sharing at local levels along with limited financial capabilities for the adaptation (Beswick, 2014; Asumadu-Sarkodie *et al*., 2015).

Thus, appropriate climate change risk awareness, mitigation and adaptation capabilities starting from local levels would be useful in enhancing the community's wellbeing and ensuring sustainable development. Therefore, this study considered the flood, one of the major climate change resulting disasters under record in Rwanda in order to indicate the extent of each region's vulnerability and suggest relevant vulnerability lessening measures to undertake in Rwanda.

2. METHODS AND MATERIALS

2.1. Description of the Study Area

Rwanda is a poor and densely populated East African country with a green and mountainous landscape. The country Figure 1.a is bordered by the Democratic Republic of Congo in the west, Uganda in the North, Burundi in the south and Tanzania in the east. Rwanda has two rainy seasons: the first starts from March and ends in May and the last begins from late September to early December. The average monthly rainfall is about 110-200 mm. There are two dry seasons: the first and short dry season starts from late December to the end of February, while the longer one lasts from June to early September, with an average temperature ranging between 19 to 27°C (Colón-González *et al*., 2016). In Rwanda, it is reported that global warming is causing unequal rainfall distribution associated with its high population density practicing subsistence agriculture (about 80%) on steep slope land (around 60% of the total land), which easily cause erosion and trigger hydrological disasters such as slope wash, debris flow and mudflow, while the landslides and floods are the major concerns among others (Nahayo *et al*., 2017; Nsengiyumva *et al*., 2018).

2.2. Datasets

2.2.1. Flood Inventory

The authors employed long term (1980-2017) flood hazard recorded in Rwanda provided by the GRDP (2017) and Rwandan Ministry of Disaster Management (MIDIMAR, 2017). This distribution Figure 1. b and c was performed based on people affected (killed, injured and homeless), damaged cropland, destroyed houses and lost livestock and their occurrence frequency in Rwanda.

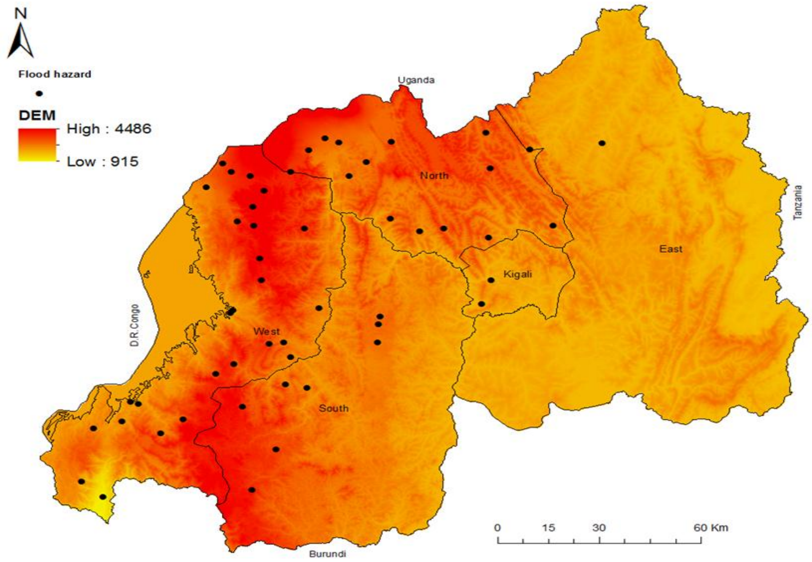
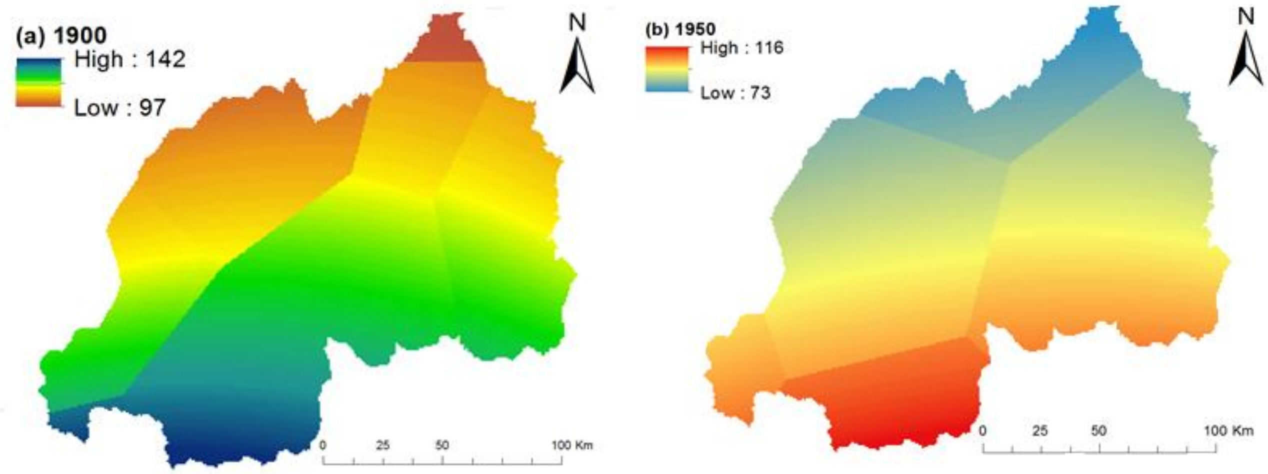


Figure-1. Geographical location of Rwanda its previous spatial flood hazard distribution.

2.2.2. Climate Factors

This study employed long term (1900-2017) climate factors consisting of the mean monthly rainfall (mm) and maximum temperature (^{0}C) to indicate their long term spatial and temporal patterns over Rwanda. Both temperature and rainfall were chosen among climate factors, due to the reason that they are the main causes of rainfall patterns which cause flood in Rwanda. These data were acquired from the Climate Hazards group Infrared Precipitation with Stations (CHIRPS) (Funk *et al.*, 2015) and ORNL (2017) attributed Active Archive Center (ORNL/DAAC), one of the National Aeronautics and Space Administration (NASA) Earth Observing System Data and Information System (EOSDIS) data centers managed by the Earth Science Data and Information System (ESDIS) Project.



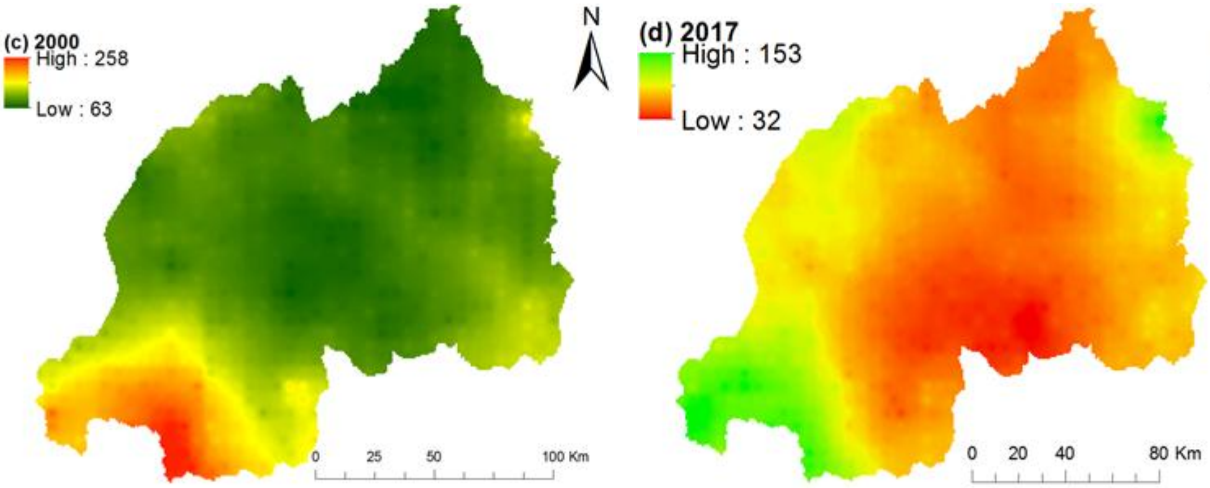


Figure-2. Spatial rainfall distribution over Rwanda, where in 1900 (a) the rainfall was high (142 mm) in the southwestern parts compared to other parts of the country and in 1950 (b) the same rainfall scenario was recorded. However, the rainfall reduced from 142 mm to 116 mm in 1900 and 1950, respectively. While in 2000 (c), the rainfall was not only high in the Southwest but also spread toward the eastern region, with record increasing up to about 259 mm, and the scenario continued in 2017(d) despite the decreasing record (153 mm).

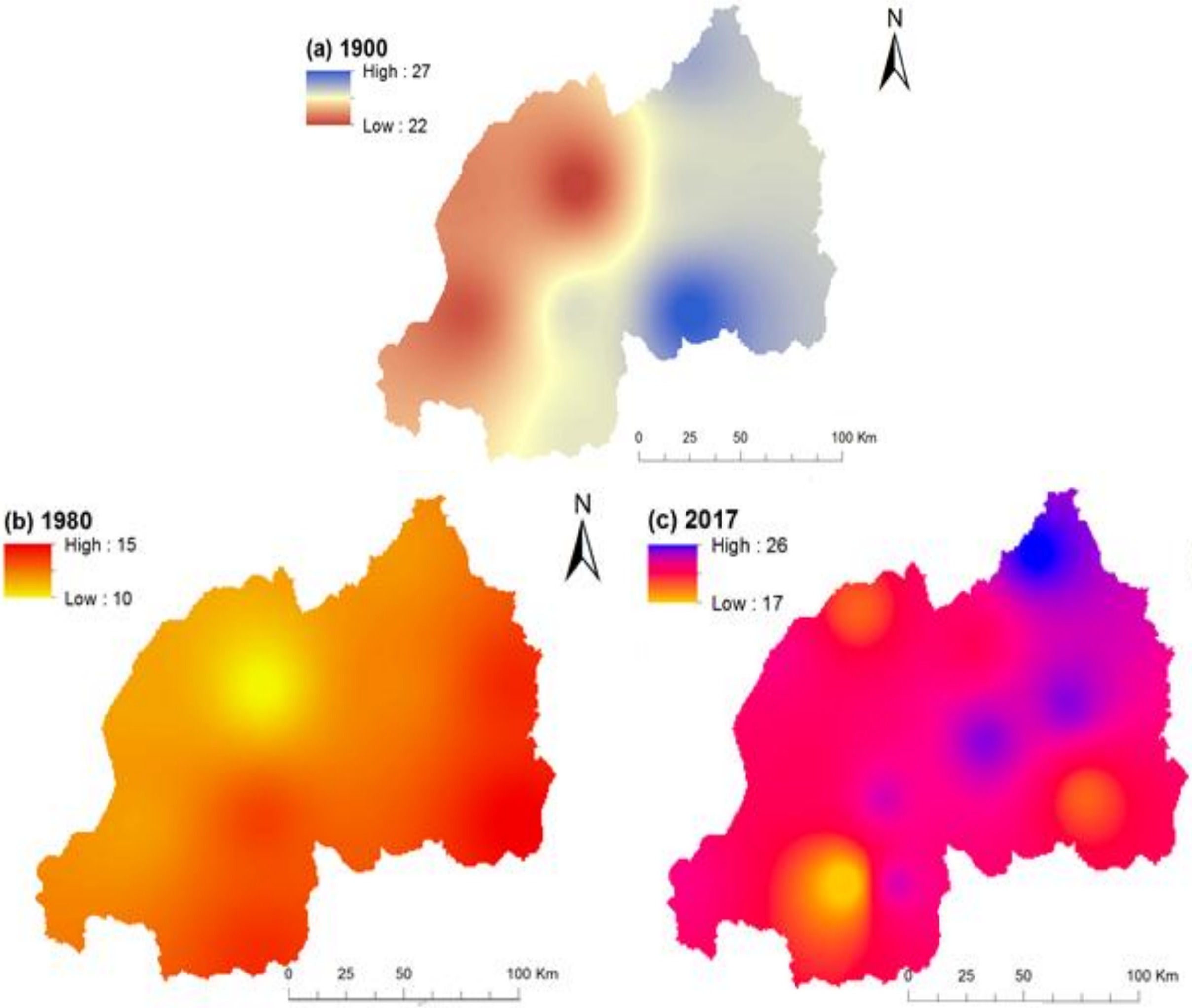


Figure-3. Spatial temperature variation in Rwanda shows that there have been raising trends countrywide, the coolest regions (northwestern) are becoming warmer and the maximum temperature increased compared to previous decades as revealed by the maximum temperature of the years of 1910 and 1980 (27 and 14^{o}C, respectively) which became 26^{0}C in 2017.

2.2.3. Socio-Economic Factors

The socio-economic factors employed by this study were provided by the NISR (2017). They included the total population, poverty level, possession of communication tools (radio, television and telephones) along with the number of schools. These factors were specifically chosen to be employed because they are among the factors which characterize the community's socio-economic function. For example, poor and/or absolute lack of communication tools (telephones, radio and television) indicates that a community is likely exposed to several risks due to lack of and/or limited access to news. Similarly, poverty strengthens or weakens the community's capacity to use strong materials and build sturdy infrastructures like houses, bridges and roads, while the availability of schools expresses the extent to which the community can be easily provided with necessary education, and ability to read and/or transmit a message to others in case of risk information sharing and/or early warning.

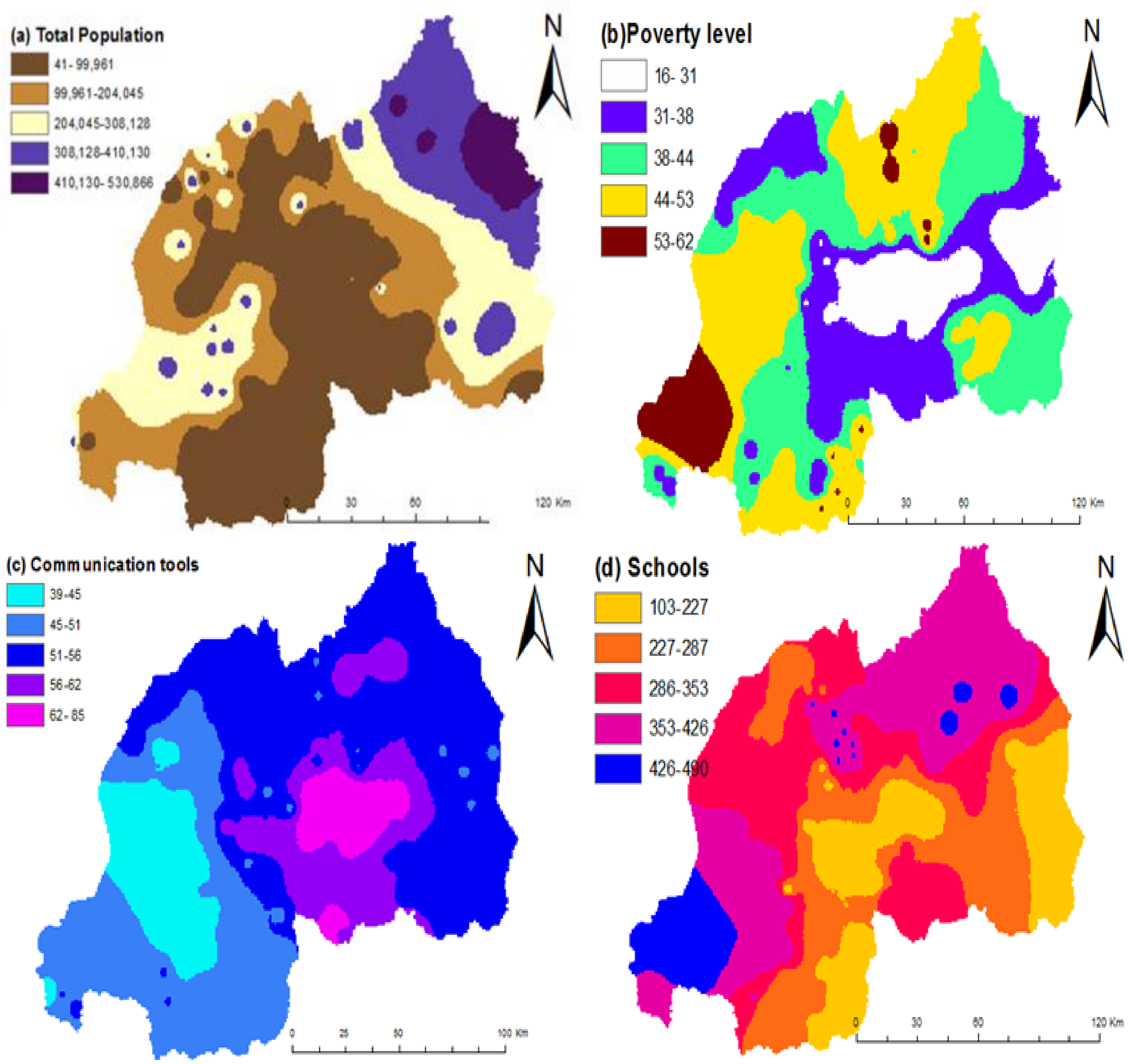


Figure-4. Spatial Distribution of the (a) total population, (b) poverty level, (c) communication tools (mobile phone, radio and television) and (d) the schools (primary, secondary and adult literacy centers) in Rwanda.

2.3. Vulnerability Analysis

The authors estimated the flood vulnerability by using the above vulnerability conditioning factors employed (rainfall, temperature, total population, poverty level, number of schools and possession of communication tools).

The Weighting Linear Combination (WLC) method in ArcGIS was employed. This method was chosen due to its advantage as previous highlighted (Fang *et al.*, 2016; Rahim *et al.*, 2018) that it is comprised of both subjective and quantitative strategies and dependents on the qualitative map combination approach. Thereafter, all layers were reclassified to a typical scale and the vector layers were rasterized. Then the weights of the sub-factors were lineally combined in ArcGIS 10.2 with reference to the following Equation 1 as:

$$TV = \sum_{j=I}^{n} Wjwij \quad (1)$$

Where TV is the total vulnerability, W_i is the weight value for the parameter j, w_{ij} is the rating value/weight of class I in parameter j and n is the number of classes.

The vulnerability was divided into five classes ranging from very low, low, moderate, high and very high vulnerability with values ranging between 0 and 5 based on the experts' knowledge, observation and literature.

3. RESULTS AND DISCUSSION

In Rwanda, climate change is severely impacting on its rainfall and temperature record Figure 2 and Figure 3. This consequently, leads to the occurrence likelihood of flooding and its widespread vulnerability as illustrated in Figure 5.

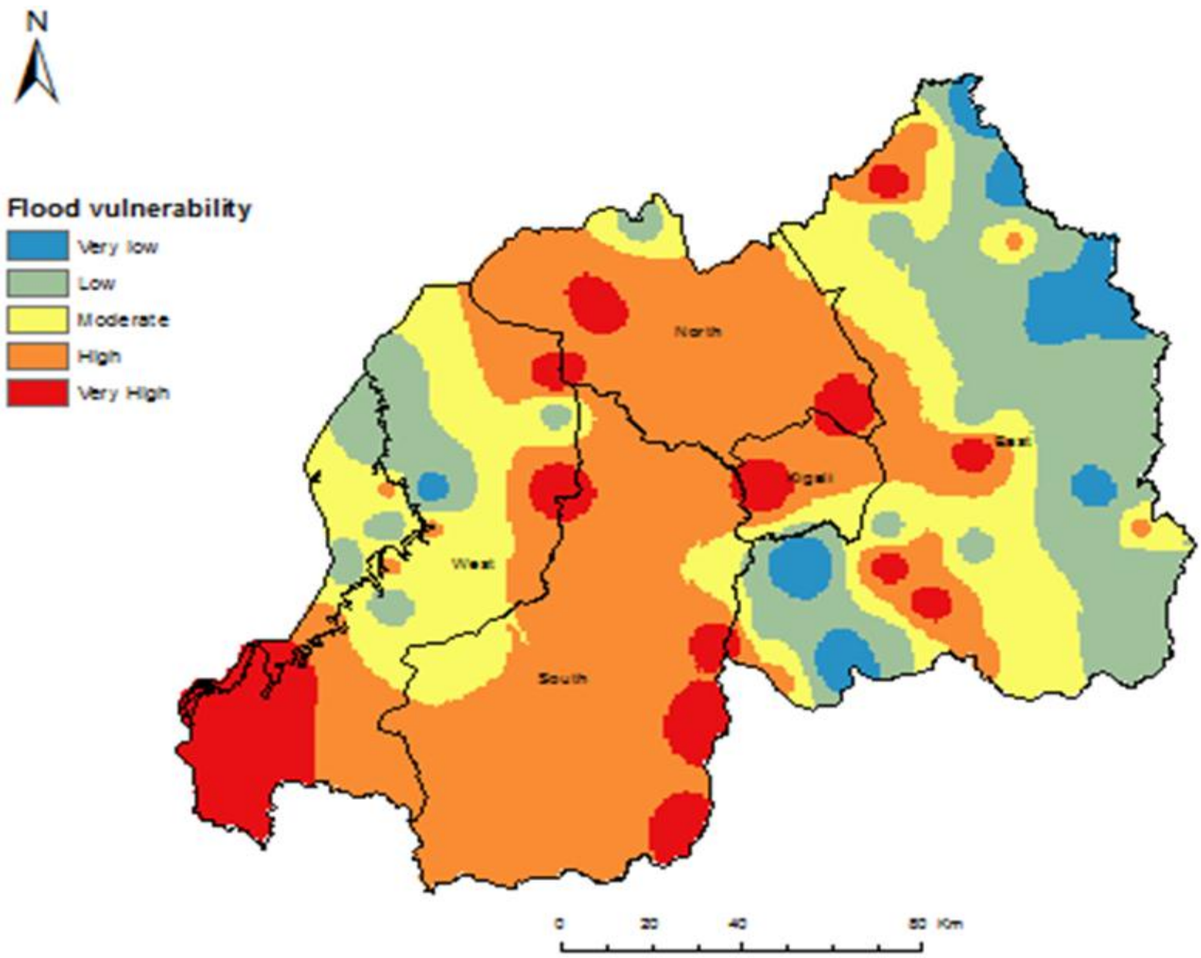


Figure-5. Flood vulnerability is high within the western province and some parts of the southern and northern provinces, and Kigali city, while the Eastern province is less vulnerable to flood.

In addition, this vulnerability would cause many losses due to the reason that, vulnerable provinces are highly populated Figure 4.a, and this calls for approaching the vulnerable population through the community-based disaster risk reduction, a framework where local community acts as decision makers not beneficiaries in order to enhance the community's capacity to cope with, prevent and minimize the loss from flood.

Table-1. Estimated percentage of flood vulnerability per province.

Province	Flood
Eastern	15
Western	19.6
Northern	23.7
Southern	20
Kigali city	22
Total	100

As illustrated in Table 1, the estimated percentage of flood vulnerability is highly within the Northern Province and Kigali city at 23.7 and 22 percent, respectively. Nevertheless, as shown in Figure 4.a, there is high population density inhabiting flood vulnerable zones, but not receiving enough related information Figure 4.c. Hence, within these vulnerable provinces Table 1, the provision of regular training, education and community involvement in risk and vulnerability assessment would help to minimize the vulnerability by enabling the population to analyze the causal factors, lessen people and property's vulnerability and strengthen the awareness and preparedness as well.

Moreover, as long as climate change is predicted to keep under record, it is good to set up appropriate mitigation and adaptation measures, especially within areas with increasing rainfall and temperature trends Figure 2 and 3 and recording high flood vulnerability Figure 5. This again, calls for the government to ensure climate change mitigation efforts and provide sufficient fund for the adaptation and minimize the increasing vulnerability. This can be successful by integrating the climate change into planning and education to help in assessment and evaluation, development of tools for weather monitoring, awareness raising and early warning systems along with mainstreaming the climate change adaptation and disaster risk reduction in science, development and environmental policies.

4. CONCLUSION

The objective of this study was to spatially distribute the flood vulnerability for relevant vulnerability lessening and resilience building measures in Rwanda.The results indicated that the Northern Province and Kigali city are vulnerable to flood than other provinces. The vulnerability is at high extent, triggered by the rapidly growing population, rainfall and temperature patterns, along with lack of information sharing tools among the residents. Based on the findings, for the changing climate risk vulnerability reduction, it is suggested to improve the forecasting capacities, strengthen the community risk awareness and preparedness through its involvement in mitigation, regular training and education along with regular risk vulnerability monitoring, assessment and timely risk information sharing. Finally, it is good to share the responsibility of climate change mitigation, adaption and disaster risk reduction by the public, private and non-governmental organizations.

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