International Journal of Disaster Response and Emergency Management
Volume 4 • Issue 2 • July-December 2021

Climate Variability and Its Associated Community Losses in Gicumbi District, Northern Rwanda

Lamek Nahayo, University of Lay Adventists of Kigali, Rwanda
Lanhai Li, Xinjiang Institute of Ecology and Geography, China
Christophe Mupenzi, University of Lay Adventists of Kigali, Rwanda

ABSTRACT

Climate change causes loss on lives and livelihoods while regular update strengthens resilience. This study aimed to analyze the rainfall variability impact on livelihoods in Northern Rwanda. The data on community losses due to rainfall variability were considered from 2013 to 2019. The GIS and SPSS helped the data analysis process. The results showed high mean monthly rainfall (119.345 and 90.05 mm) in 2013 and 2017, respectively. This caused landslide, flood, rainstorms, windstorms, lightning, and hailstorms occurrence, which killed/injured people, damaged houses and cropland, livestock loss, and destruction of infrastructures. The correlation analysis indicated a statistically significant p-value of 0.0151 lower than 0.05 and approved that rainfall variability negatively impacts livelihoods. This study can enable policymakers to better understand how changes in rainfall impact livelihoods and strategic measures to adopt for climate variability and climate change adaptation.

KEYWORDS

Climate Variability, Gicumbi District, Livelihoods, Rainfall, Rwanda

1. INTRODUCTION

The weather and climate of African continent are changing differently and major concerns are attributed to the fact that intense rainfall is under record in some places while other areas are projected to registering drying scenarios (Osabuohien et al. 2020; Gonzalez et al. 2018). The recorded global greenhouse gas emissions are putting the world on a path toward unacceptable warming, with serious implications for development prospects in Africa (Bang and Few 2012). It is reported that limiting warming to 1.5° C is possible by ensuring unprecedented changes. The Inter-Governmental Panel on Climate Change (IPCC 2014; Norbu et al. 2008) states that this can only be possible by considering all transition occurring in land, energy, industry, buildings, transport, and cities (IPCC 2014).

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 place to become much wetter and dry places will be much drier (Dami et al. 2017; Fosu-Mensah et al. 2012).

DOI: 10.4018/IJDREM.2021070103

The rainfall and temperature patterns resulting from the changing climate generate risks such as droughts, Tsunamis, water borne diseases, heatwaves, storm winds, and floods. These risks are severely causing immense losses among the communities, primarily poor people due to lack of risk awareness, adaptation and financial capabilities (Bang and Few 2012; Huong et al. 2018; Orencio and Fujii 2014; Mızrak and Aslan 2020).

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 of the community (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). More losses are mainly registered in the north-western parts of Rwanda including the Gicumbi district (Wagesho and Claire 2016; Rugigana et al. 2013).

Existing government reports on climate change and its impact on livelihoods highlighted that the northern Rwanda is under threat of disasters, mainly flood and landslide resulting from change in rainfall intensity which in turn affects people's livelihoods, and Gicumbi district was among the largely affected areas (MIDIMAR 2017, 2014; DDP 2013). This expresses a necessity of conducting an academic research on this matter to indicate the impact of climate variability on community livelihoods in Gicumbi district of the northern Rwanda. Therefore, the objective of this study was to analyze the impact of climate variability mainly rainfall on community livelihoods. The authors believe that the findings of this research will enable policy makers to better understand rainfall variability, the recorded community losses associated to climate variability and the best practices which can be adopted in the study area for adaptation to the changing climate.

2. METHODOLOGY

2.1 Description of Study Area

This study considered Gicumbi district located in Northern province of Rwanda as target area. The District spreads over an area of 829.55 km^2 with 418 residents per square kilometer. The district is composed of 21 sectors, 109 cells and 630 villages and its residents are more rural than urban. The district (Figure 1) is bordered to the North by the District of Nyagatare, the Ugandan boarder and by the District of Burera. To its South, there is Rwamagana District of the Eastern province and Gasabo district of the City of Kigali. There are districts of Gasabo, Rulindo and Burera to its western side while to its East, the district is bordered by the districts of Nyagatare and Gatsibo (DDP 2013).

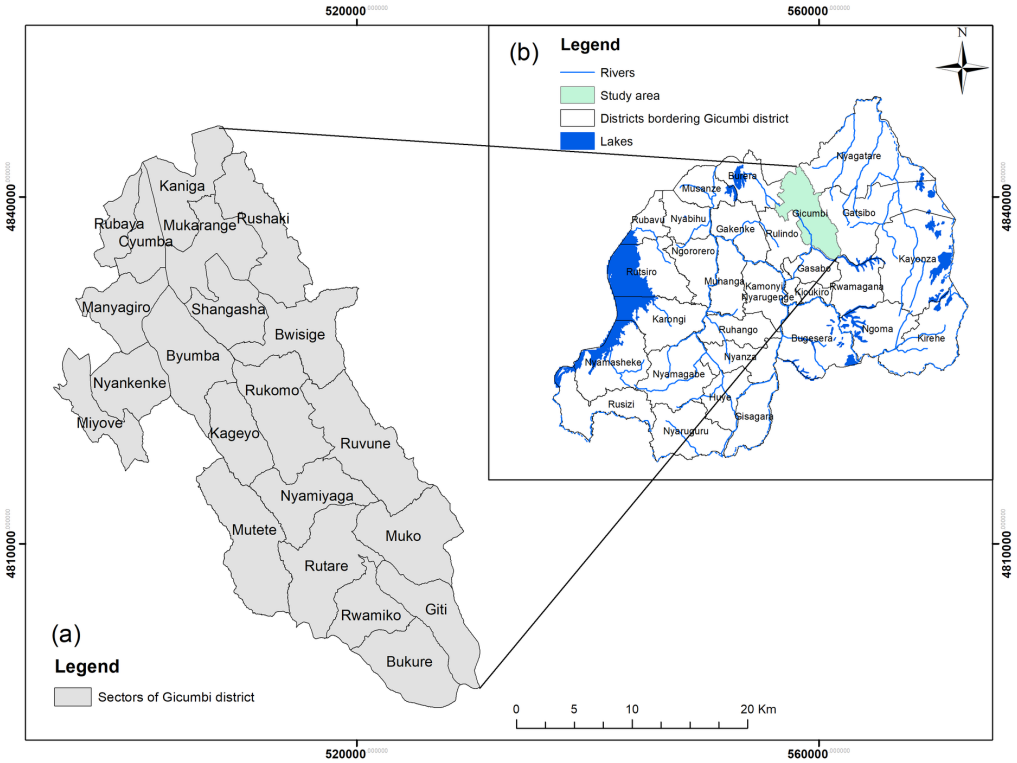
Gicumbi is characterized by a relief with steep slopes and a mountainous topography character. The plateau is surrounded by steep ravines with small valleys segmented by multiple swamps. And 90% of the area is in the mountains characterized by lateritic soils and granites which results in the soil erosion during the long rain season (DDP 2013). The district has two rainy seasons and two dry seasons. Ordinary the minor rainy season begins in September to December and the short dry season extends from January to February. The long rainy season extends from March to May when the long dry season begins June to August. The rainfall ranges between 1,200 mm to 1,500 mm (DDP 2013).

In Gicumbi district, during heavy rains immense losses on community livelihoods are recorded resulting from occurrence of disasters caused by changes on rainfall intensity and frequency. This expresses the need of assessing how rainfall impact on community livelihood sin this area and best of ways of adaptation.

2.2 Data Collection and Analysis

This study adopted the quantitative research design by merely using secondary data on climate variability mainly changes on frequency and intensity of rainfall, its related risk and the resulting impact

Figure 1. Map indicating the (a) sectors of Gicumbi district and (b) its bordering districts of Rwanda



on community livelihoods. The employed secondary data on both rainfall variability and community livelihoods ranged from 2013 to 2019. Figure 2 details the adopted methodological framework.

2.2.1 Climate Variability Factors

The data on climate variability merely considered rainfall variability ranging from 2013 to 2019 in Gicumbi district, northern Rwanda.

The statistical data on rainfall recorded by six meteorological stations located in the study area (Mirindi, Nyabishambi, Rwesero, Karambo, Byumba and Cyohoha) were utilized to indicate the spatial variation of rainfall within the study area.

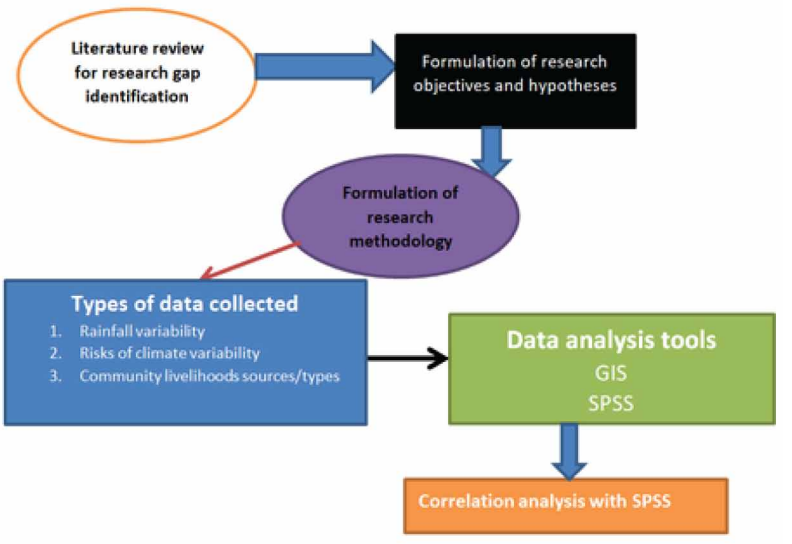
2.2.2 Community Livelihoods Losses

In order to better understand how climate variability impacts on community livelihoods, the authors consulted different sources to find out the risks of climate variability which have been registered in Gicumbi district within the considered period of study (2013-2019).

The review of the literature showed among others, malaria and disasters like flood, landslide, hailstorms, rainstorms, and windstorms. The authors employed these risks based on the fact that several reports and studies conducted in Gicumbi district highlighted them as the major risks associated to climate variability and climate change in Gicumbi district (Bizimana et al. 2015; MIDIMAR 2014; Habimana et al. 2016).

However, due to data availability, the authors only employed disasters losses. These included number of death and injuries, houses damaged, hectares of cropland damaged, lost livestock, and

Figure 2. Research methodological flowchart



destroyed infrastructures mainly classrooms, roads, bridges, markets, health centers, administrative offices, water supply and electricity lines. These datasets were collected from different studies which were conducted in the study area (Bizimana and Sönmez 2015; Bosco et al. 2018), Gicumbi District Development Plan (DDP 2013) and the Rwanda's Ministry in Charge of Emergency Management (MINEMA 2020).

2.3 Data Analysis

The authors distributed the average monthly rainfall across the study area by using the IDW (interpolation) and the extraction by mask techniques in the Spatial Analysis Tools of GIS in order to spatially differentiate the recorded rainfall variability (mm) across each sector of Gicumbi district.

The Microsoft Excel presented the recorded community disaster losses and the Pearson Correlation of SPSS tested whether there is a statistically significant correlation between rainfall/temperature variability and community livelihoods or not in Gicumbi district.

3. RESULTS

3.1 Climate Variability in Gicumbi District

The results in Figure 3 (a) demonstrated that the average monthly rainfall recorded over Gicumbi district was differently distributed across its sectors. In 2013, Miyove, Nyankenke, Manyagiro, Cyumba and Rubaya sectors recorded a high monthly rainfall of 139.6 mm. The same Figure 3 (b) demonstrated that in 2014, the record of rainfall reduced compared to that of 2013. The highest record was 68.3 mm/month within Rutare and Nyamiyaga sectors.

Nevertheless, the record of monthly rainfall in 2015 revealed an increasing rainfall compared to that of 2014. The results in Figure 4 (a) showed that the highest average monthly rainfall was 74.2 mm in Kageyo and Manyagiro sectors. Compared to the record of 2015, as illustrated in Figure 4.b, the average monthly rainfall of 2016 (67.7 mm) was lower than that of 2015 and was mainly registered by the Miyove, Manyuagiro and Cyumba sectors.

Figure 3. Average monthly rainfall of (a) 2013 and (b) 2014 in Gicumbi district

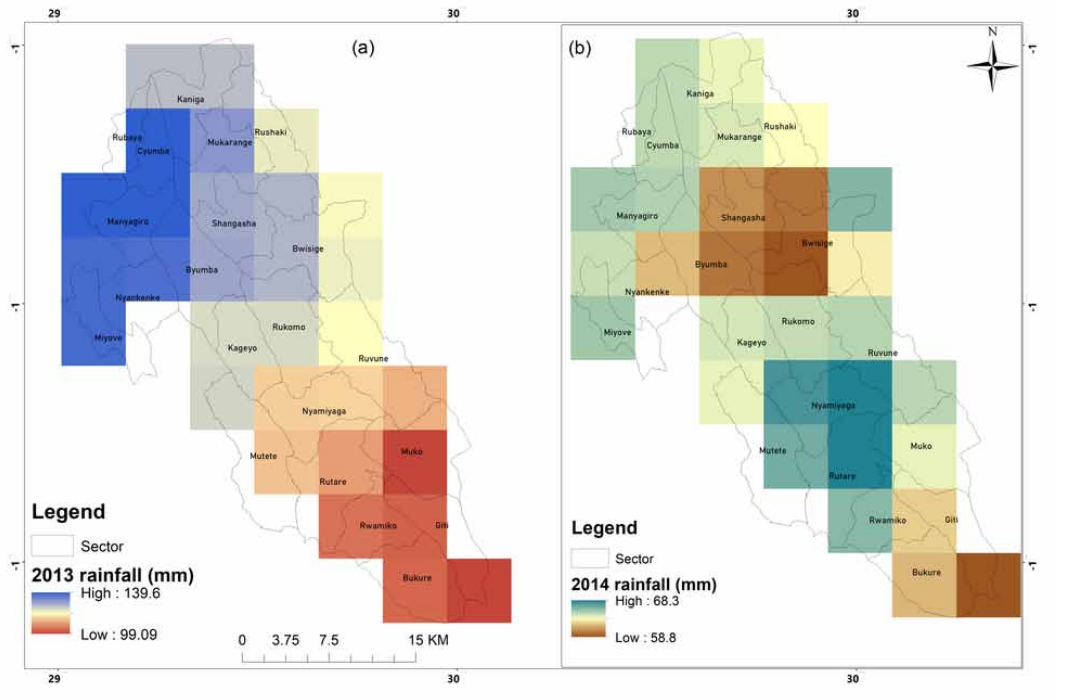
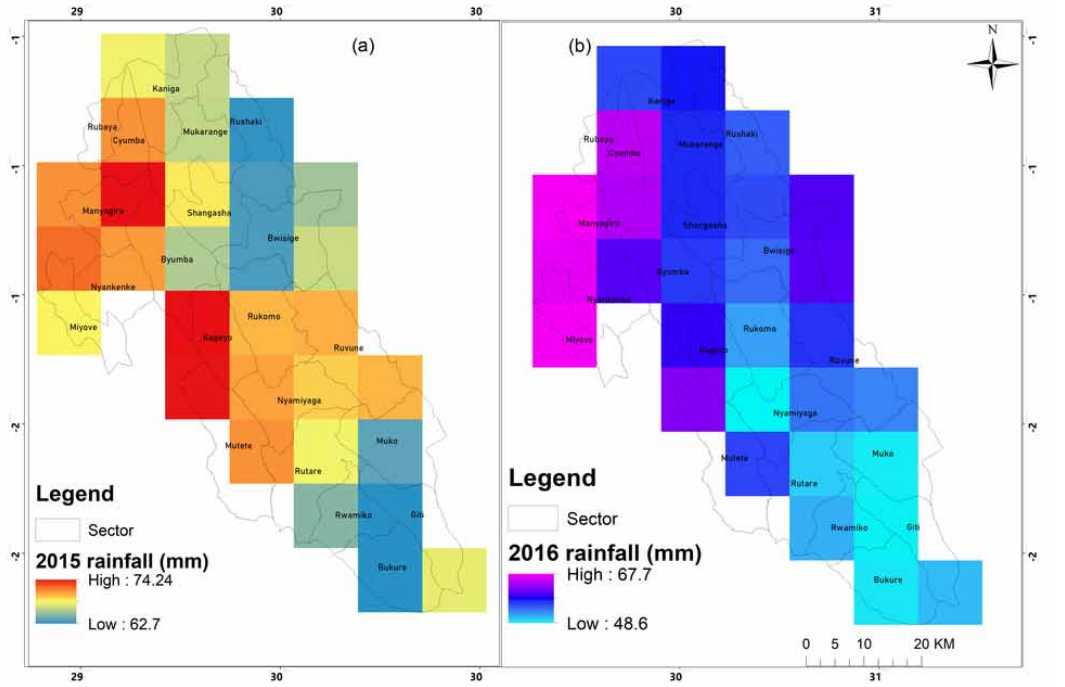


Figure 4. Average monthly rainfall of (a) 2015 and (b) 2016 in Gicumbi district



The results in Figure 5 (a) showed high monthly rainfall record across sectors of Gicumbi district in 2017. The highest record reached 109.2 mm in Miyove, Kageyo, Byumba, Manyagiro and Nyankenke sectors. However, in 2018, the record again reduced compared to that of 2017. The results in Figure 5 (b) indicated that 67.3 mm was the highest monthly rainfall noticed particularly within Miyove sector. The lowest rainfall fell up to 48 mm in Giti, Muko, Bukure, Rwamiko and Rutare sectors.

Finally, with regard to the average monthly rainfall registered in 2019, Figure 6 showed that Miyove, Manyagiro, Nyankenke, Cyumba and Rubaya sectors, at large extent, recorded high monthly rainfall which ranged from 67.7 mm. The lowest monthly rainfall of 48.6 mm was mainly noticed across Muko, Bukure, Rwamiko and Giti sectors of Gicumbi Figure 6.

The average monthly rainfall summarized for every year considered by the current research (2013-2019) indicated that 2013 recorded high monthly rainfall (119.345 mm) followed by the year 2017 which registered a mean monthly rainfall of 90.05 mm (Table 1).

3.1.1 Risks of Climate Variability in Gicumbi District

The results in Table 2 indicated that between 2013 and 2019, rainfall variability led to occurrence of thirty (30) cases of landslide, windstorms, flood, lightning, rainstorm and hailstorms in Gicumbi district. The same Table 3 revealed that the years 2014, 2015, 2017 and 2019 recorded high number of cases.

3.2 Losses on Community Livelihoods

The results in Table 3 indicated that the year 2017 registered a high number of community livelihoods losses which were 885.7 cases. It was noticed that the number of houses and cropland damaged has been increasing over years, their total were 1,013 and 1,318, respectively.

Figure 5. Average monthly rainfall of (a) 2017 and (b) 2018 within Gicumbi district

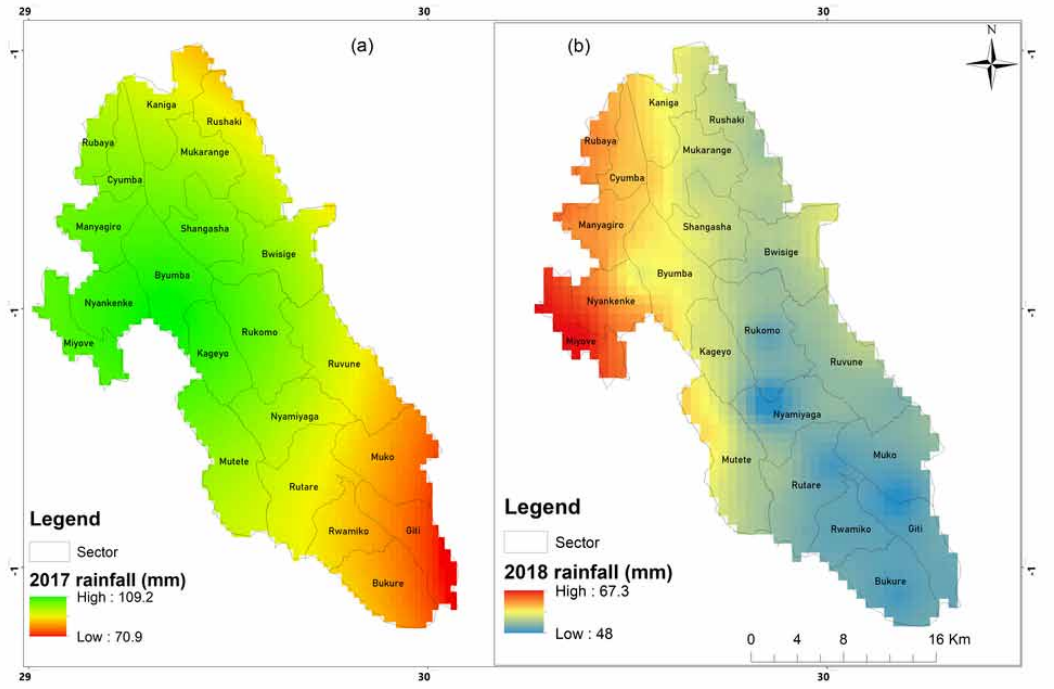


Figure 6. Average monthly rainfall of 2019 in Gicumbi district

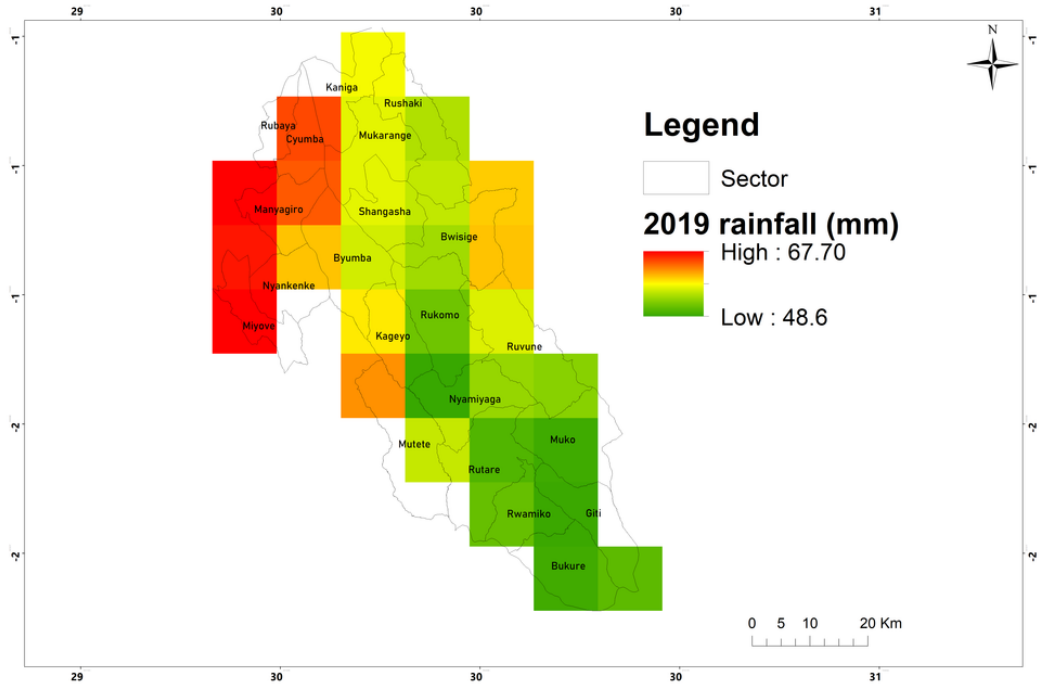


Table 1. Average monthly rainfall between 2013 and 2019

Year	2013	2014	2015	2016	2017	2018	2019
Mean monthly rainfall (mm)	119.34	63.55	68.45	58.15	90.05	57.65	58.15

Table 2. Risks associated to climate variability in Gicumbi district 2013-2019

Risk	Years							
	2013	2014	2015	2016	2017	2018	2019	Total
Flood	0	1	1	0	1	0	0	**3**
Landslide	0	0	0	0	1	1	1	**3**
Rainstorms	1	1	1	1	1	1	1	**7**
Windstorms	1	1	1	1	0	0	1	**5**
Lightning	1	1	1	1	1	1	1	**7**
Hailstorms	1	1	1	0	1	0	1	**5**
Total	**4**	**5**	**5**	**3**	**5**	**3**	**5**	**30**

Table 3. Community livelihood losses from 2013 to 2019

Livelihood losses	Years							
	2013	2014	2015	2016	2017	2018	2019	Total
Death and injuries	1	6	3	6	5	9	8	**38**
House damages	74	82	311	81	123	191	151	**1,013**
Cropland damaged	4.5	496.5	0	0	641.7	28	147.3	**1,318**
Lost livestock	2	1	0	5	101	1	3	**113**
Destroyed infrastructures	1	2	0	7	15	8	5	**38**
Total	**82.5**	**587.5**	**314**	**99**	**885.7**	**237**	**314.3**	**2,520**

Therefore, the results in Table 4 indicated that among the climate variability losses considered by this study, the major losses resulted from the cropland and house damages which ranked 1,418 and 904 cases respectively. In addition, rainstorms and landslide were the major risks which affected people's livelihoods in Gicumbi district. Both risks recorded 1,051 and 635.2 cases, respectively (Table 4).

3.3 Extent to Which Climate Variability Impacts on Livelihoods

The authors applied the Pearson Correlation test of the Statistical Package for Social Science (SPSS) in order to analyze the relationship between rainfall variability and loss on community livelihoods by applying the Pearson correlation analysis. The researcher based on the fact that a p-value smaller than 0.05 indicated a statistically significant association (at 5% level) and a p-value larger than 0.05 revealed no statistically significant association between the variables tested.

The results in Table 5 showed that a p-value of 0.0151 which is smaller than 0.05 and confirmed the fact there is a statistically significant association between rainfall variability and loss on community livelihoods. This was also confirmed by the results of this study where the years during which Gicumbi district recorded high rainfall were the same in which high number of losses on community livelihoods was registered as well (Table 3).

4. DISCUSSION

Several countries including Rwanda, are already adapting to current climatic events at national, provincial, state, district and local levels in short-, medium- and long-term time frames (Nahayo et al. 2016; Mikova et al. 2015). The strategy for adapting to impacts of climate variability and change and

Table 4. Community livelihood losses by risk

Loss types	Risk type						
	Flood	Landslide	Rainstorms	Hailstorms	Windstorms	Lightning	Total
Death and injuries	2	2	6	0	0	28	**38**
House damages	0	59	821	9	11	4	**904**
Cropland damaged	179.8	474.2	198	566	0	0	**1,418**
Lost livestock	0	89	12	0	0	12	**113**
Destroyed infrastructures	0	11	14	0	9	2	**36**
Total	**181.8**	**635.2**	**1,051**	**575**	**20**	**46**	**2,509**

Table 5. Correlation analysis between rainfall variability and livelihood losses

Correlations			
		Rainfall	**No. of livelihood loss cases**
Rainfall	Pearson Correlation	1	0.0151
	Sig. (2-tailed)		0.9742
	N	7	7
No. of livelihood loss cases	Pearson Correlation	0.015171	1
	Sig. (2-tailed)	0.974249	
	N	7	7

rising awareness has been developed and the main strategies include not limited to the (a) recognition of local knowledge and existing adaptation strategies, (b) establishment of an institutional framework through which local adaptation strategies can be reviewed, verified and integrated into the mainstream of resource management (Green 2016; Ndayisaba et al. 2017; Alizadeh-Choobari and Najafi 2018).

These can be useful in Gicumbi district, a district currently facing climate variability (Table) and its associated losses (Tables 2,3 and 4). In addition, as long the losses on community losses are at local scale (recorded by the local community), enhancing its risk awareness would save its lives and belongings as well. This can be achieved through provision of regular climate related information, technical know-how, alternative sources of income and employment, and dissemination of all awareness messages in local language.

In Rwanda, the impact of climate variability and change is mainly manifested through change in rainfall patterns. These cause flooding, land sliding, rainstorm, hailstorms and windstorms in the north-western and southern parts of Rwanda (MIDIMAR 2017; Ntawigenera and Yadufashije 2019). This is similar to the findings of this study where changes on rainfall (Table 1) have been recorded, but also in case that the awareness is improved at local level, the residents of Gicumbi district would better understand the changes on rainfall and associated losses (Table 3) and then develop locally-based adaptation measures.

5. CONCLUSION

This study analyzed the impact of climate variability on community livelihoods in Gicumbi district of the Northern Rwanda. The results indicated that years of 2013 and 2017 recorded high average monthly rainfall of 119.345 and 90.05 mm, respectively. This rainfall variability led to the occurrence of landslide, flood, rainstorms, windstorms, lightning and hailstorms which killed/injured people, damaged houses and cropland, lead to livestock loss and destruction of infrastructures as well. The statistical correlation analysis indicated that rainfall variability have negatively impacted on people's livelihoods. This was confirmed by a p-value of 0.0151 for rainfall variability with livelihood loss. The obtained p-value was smaller than 0.05 and confirmed a statistically significant association between climate variability and loss on community livelihoods in the study area. To minimize the effect of climate variability, it is good to share information on time basis in terms of areas likely exposed to climate variability and the losses that might be recorded. The local people located in high rainfall prone areas can be relocated within areas with moderate rainfall. Further study on settlement location suitability under disasters is suggested.

REFERENCES

Alizadeh-Choobari, O., & Najafi, M. (2018). Climate variability in Iran in response to the diversity of the El Niño-Southern Oscillation. *International Journal of Climatology*, *38*(11), 4239–4250. doi:10.1002/joc.5564

Bang, H. N., & Few, R. (2012). Social risks and challenges in post-disaster resettlement: The case of Lake Nyos, Cameroon. *Journal of Risk Research*, *15*(9), 1141–1157. doi:10.1080/13669877.2012.705315

Bizimana, H., & Sönmez, O. (2015). Landslide occurrences in the hilly areas of Rwanda, their causes and protection measures. *Disaster Science and Engineering*, *1*(1), 1–7.

Bizimana, J.-P., Twarabamenye, E., & Kienberger, S. (2015). Assessing the social vulnerability to malaria in Rwanda. *Malaria Journal*, *14*(1), 2. doi:10.1186/1475-2875-14-2 PMID:25566988

Bosco, N. J., Ildephonse, M., & Alexandre, N. (2018). Agriculture and Food Security in Gicumbi District, Northern Province of Rwanda. *International Academic Journal of Social Sciences*, *5*(1), 154–168. doi:10.9756/IAJSS/V5I1/1810014

Chaudhury, M., Vervoort, J., Kristjanson, P., Ericksen, P., & Ainslie, A. (2013). Participatory scenarios as a tool to link science and policy on food security under climate change in East Africa. *Regional Environmental Change*, *13*(2), 389–398. doi:10.1007/s10113-012-0350-1

Dami, A., Inuwa Kuchali, B., & Ayuba, H. (2017). The Influence of Climate Variability on Hadejia-Nguru Wetlands, Yobe State, Nigeria. *International Journal of Geography and Geology*, *6*(5), 105–112. doi:10.18488/journal.10.2017.65.105.112

DDP. (2013). *District Development Plan (DDP: 2013-2018) of Gicumbi ditsrict, Northern Rwanda*. DDP.

Fosu-Mensah, B. Y., Vlek, P. L., & MacCarthy, D. S. (2012). Farmers' perception and adaptation to climate change: A case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*, *14*(4), 495–505. doi:10.1007/s10668-012-9339-7

Gonzalez, F. R., Raval, S., Taplin, R., Timms, W., & Hitch, M. (2018). Evaluation of Impact of Potential Extreme Rainfall Events on Mining in Peru. *Natural Resources Research*, 1–16.

Green, F. (2016). *Mobilizing private finance: Unlocking the potential of Rwanda's businesses to drive climate change adaptation*. Academic Press.

Habimana, A., Harerimana, A., Asingizwe, D., Nyandwi, T., & Njunwa, K. J. (2016). Community Health Workers' knowledge, attitudes and practices about malaria prevention in Gicumbi District, Rwanda. *Rwanda Journal*, *3*(1), 27–35. doi:10.4314/rj.v3i1.5F

Huong, N. T. L., Yao, S., & Fahad, S. (2018). Assessing household livelihood vulnerability to climate change: The case of Northwest Vietnam. *Human and Ecological Risk Assessment*, 1–19.

IPCC. (2014). *Mitigation of climate change.* Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

MIDIMAR. (2014). *National Contingency for Flood and Landslides, Ministry of Disaster Management and Refugees*. MIDIMAR.

MIDIMAR. (2017). *The Monthly and Annual Data on Disasters Countrywide*. The Ministry of Disaster Management and Refugee Affairs (MIDIMAR). Available at:http://midimar.gov.rw/index.php?id=65

Mikova, K., Makupa, E., & Kayumba, J. (2015). Effect of climate change on crop production in Rwanda. *Earth Sciences (Paris)*, *4*(3), 120–128. doi:10.11648/j.earth.20150403.15

MINEMA. (2020). *Ministry in Charge of Emergency Management*. Disaster Management Information System.

Mızrak, S., & Aslan, R. (2020). Disaster Risk Perception of University Students. *Risk, Hazards & Crisis in Public Policy*, *11*(4), 411–433. doi:10.1002/rhc3.12202

Nahayo, L., Li, L., Kayiranga, A., Karamage, F., Mupenzi, C., Ndayisaba, F., & Nyesheja, E. M. (2016). Agricultural impact on environment and counter measures in Rwanda. *African Journal of Agricultural Research*, *11*(25), 2205–2212. doi:10.5897/AJAR2016.10899

Ndayisaba, F., Guo, H., Isabwe, A., Bao, A., Nahayo, L., Khan, G., Kayiranga, A., Karamage, F., & Muhire, E. N. (2017). Inter-Annual Vegetation Changes in Response to Climate Variability in Rwanda. *Journal of Environmental Protection*, *8*(4), 464–481. doi:10.4236/jep.2017.84033

Norbu, Downs, Yeboah, Scholtens, Bapat, Oelbermann, Kowsar, Webbe, Govaerts, & Verhulst. (2008). *Experts address the question:"How can sustainable land management contribute to mitigating climate change?* Paper read at Natural Resources Forum.

Ntawigenera, N., & Yadufashije, C. (2019). Environmental Protection as Disasters' Risk Reduction Strategy in Rwanda: Knowledge, Attitudes and Practices of Community Members in Kamonyi District. *International Journal of Research in Environmental Science*, *5*(3), 1–9.

Orencio, P. M., & Fujii, M. (2014). A spatiotemporal approach for determining disaster-risk potential based on damage consequences of multiple hazard events. *Journal of Risk Research*, *17*(7), 815–836. doi:10.1080/13669877.2013.816334

Osabuohien, E. S., Oduntan, E. A., Gershon, O., Onanuga, O., & Ola-David, O. (2020). *Handbook of Research on Institution Development for Sustainable and Inclusive Economic Growth in Africa*. Business Science Reference.

Rugigana, E., Nyirazinyoye, L., Umubyeyi, A., Nsengiyumva, J., Kanyandekwe, C., & Ntahobakulira, I. (2013). Prioritization of disasters and their management in Rwanda. *East African Journal of Public Health*, *10*(2), 429–439. PMID:25130023

Sowers, J., Vengosh, A., & Weinthal, E. (2011). Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Climatic Change*, *104*(3-4), 599–627. doi:10.1007/s10584-010-9835-4

Wagesho, N., & Claire, M. (2016). Analysis of Rainfall Intensity-Duration-Frequency Relationship for Rwanda. *Journal of Water Resource and Protection*, *8*(07), 706–723. doi:10.4236/jwarp.2016.87058

Lamek Nahayo received his MS in Physical Geography from the University of Chinese Academy of Sciences, China in 29016. In 2019 he received his doctoral degree in Physical Geography from the same university (University of Chinese Academy of Sciences), China. Since 2016 to date, he is serving as Lecturer at the University of Lay Adventists of Kigali (UNILAK) in Rwanda. His research concentrates on disaster risk management, natural resources, and environmental management.

Lanhai Li is a Professor and Director at the Xinjiang Key Lab of Water Cycle and Utilization in Arid Zone. He is also the Head of Tianshan Station for Snow and Avalanche Research. He serves the above at the Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences. His research concentrates on hydrology and modeling, and physical geography.

Christophe Mupenzi received his doctoral degree in Physical Geography from the same university (University of Chinese Academy of Sciences), China in 2018. Since 2015 to date, he is serving as Lecturer at the University of Lay Adventists of Kigali (UNILAK) in Rwanda.