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Impact of Climate Variability on Community Livelihoods in Rwanda

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Abstract

The variability of climate mainly rainfall and temperature has over last decades contributed to significant losses among community livelihoods and the poorer are the largely affected. This study aimed to analyze the impact of climate variability on community livelihoods in Gicumbi district, Northern Rwanda. The authors employed secondary data on rainfall and temperature and on community livelihoods which ranged from 2013 to 2019. The Geographic Information System (GIS) was used to map factors of climate variability. The Statistical Package for Social Sciences (SPSS) through its Pearson correlation test indicated the extent to which climate variability impacts on community livelihoods. The results indicated that years of 2013 and 2017 recorded high annual mean rainfall (119.345 and 90.05 mm) and years of 2014 and 2015 registered high annual mean temperature of 24.2 and 24.6 degree Celsius, respectively. This led to landslide, flood, rainstorms, windstorms, lightning and hailstorms occurrence which killed/injured people, damaged houses and cropland, led to livestock loss and destruction of infrastructures. The year 2017 registered a high number of community livelihoods losses (885.7 cases). The correlation analysis indicated that both temperature and rainfall variability has negatively impacted on people's livelihoods. This was confirmed by a p-value of 0.015171 and -0.071904 for rainfall and temperature variability with livelihood loss, respectively. These values were smaller than 0.05 and confirmed a statistically significant association between climate variability and loss on community livelihoods. The findings of this study can enable policy makers to better understand how changes on rainfall and temperature impact on livelihoods, and the strategic measures which can be adopted to adapt to climate variability.

Keywords

Climate Variability, Gicumbi District, Livelihoods, Rainfall, Temperature, Rwanda

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1. Introduction

The weather and climate of African continent is 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 [1-3]. Record global greenhouse gas emissions are putting the world on a path toward unacceptable warming, with serious implications for development prospects in Africa. It is reported that limiting warming to 1.5°C is possible by ensuring unprecedented changes. The Inter-Governmental Panel on Climate Change [4] states that this can only be made possible by considering all transitions occurring in land, energy, industry, buildings, transport, and cities [4].

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 [4]. 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

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among the communities, primarily poor people depending on lack of risk awareness, adaptation and financial capabilities [5].

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 [6, 7]. 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 [8, 9]. More losses are mainly registered in the north-western parts of Rwanda including the Gicumbi district [9, 10].

Recent studies have been conducted on climate change and its impact on livelihoods in Rwanda. These reports highlighted that 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 [10 - 12]. Hence, a necessity of conducting an academic research on this matter is important to indicate the impact of climate variability on community livelihoods in Gicumbi district of the northern Rwanda.

2. Methodology

2.1. Description of Study Area

This study considered Gicumbi district located in Norther province of Rwanda. The District of Gicumbi spreads over an area of 829,55km^2 with 418p/sqkm. The district is composed of 21 sectors, 109 cells and 630 villages and its residents are more rural than urban. The district 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 Kigali city. 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 [13].

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 characterized by lateritic soils and granites which results in the soil erosion during the long rain season [13].

The district has 2 rainy seasons and 2 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 [13].

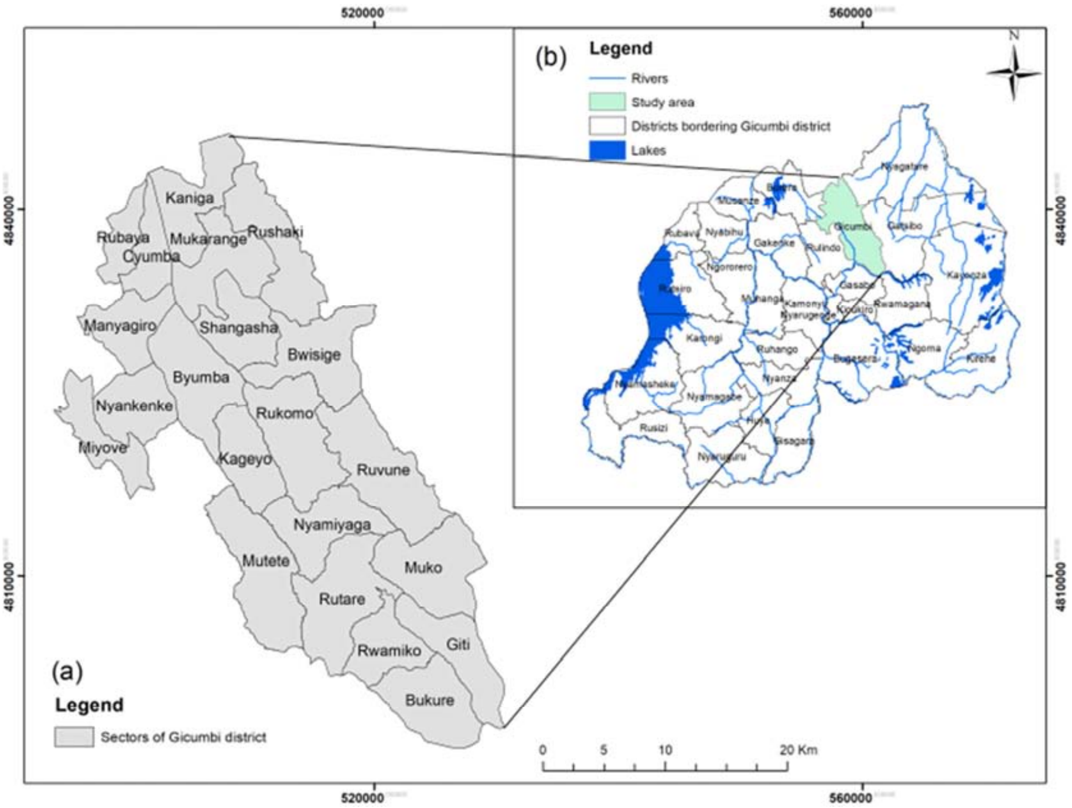

Figure 1. Map indicating the (a) sectors of Gicumbi district and (b) its bordering districts of Rwanda.

2.2. Data Collection and Analysis

This study adopted the quantitative research design by merely using secondary data on climate variability, its related risks and the resulting impact on community livelihoods. These ranged from 2013 to 2019.

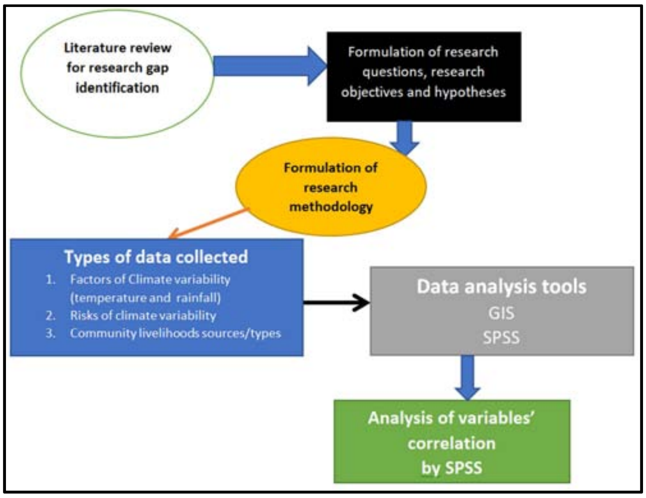

Figure 2. Research methodological flowchart.

2.2.1. Climate Variability Factors

The data on rainfall and temperature were collected from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) for Biogeochemical Dynamics which is a NASA Earth Observing System Data and Information System (EOSDIS) data center managed by the Earth Science Data and Information System (ESDIS) Project. The climate related data were mainly collected from the Spatial Data Access Tool (SDAT) of the ORNL DAAC's available at: https://webmap.ornl.gov/wcsdown/dataset.jsp?ds_id=550&startPos=0&maxRecords=10&orderBy=category_name&bAscend=true.

In addition, the statistical data on rainfall and temperature recorded by six meteorological stations located in the study area (Mirindi, Nyabishambi, Rwesero, Karambo, Byumba and Cyohoha) were utilized in conjunction with the above data collected from the ORNLDAAC of NASA. The authors utilized both the above data sources in order to reach the study period from 2013 to 2019.

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).

This exercise showed that malaria and disasters like flood, landslide, hailstorms, rainstorms, and windstorms were the key risks which resulted from climate variability in Gicumbi district. 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 [11, 12, 13].

However, due to data availability, the authors chose only to employ the disasters losses as risks of climate variability on community livelihoods in Gicumbi district. Thereafter, the losses on community livelihoods specifically, the number of death and injuries, houses damaged, hectares of cropland damaged, lost livestock, and destroyed infrastructures mainly classrooms, roads, bridges, markets, health centers, administrative offices, water supply and electricity lines were employed.

2.3. Data Analysis

The average annual rainfall and temperature data were processed in GIS, Spatial Analysis Tool, by using the IDW (interpolation) and the extraction by mask techniques to clip the study area.

The Statistical Package for Social Sciences (SPSS) presented the recorded infrastructure losses and then its Pearson Correlation was employed to indicate the extent to which climate variability impacts on community livelihoods. This analysis indicated whether there is a statistically significant correlation between climate variability and community livelihoods or not in Gicumbi district.

3. Results

3.1. Climate Variability in Gicumbi District

3.1.1. Recorded Rainfall Variability

The results in Figure 3 (a) demonstrated that the average annual rainfall recorded over Gicumbi district was differently distributed across its sectors. The results indicated that in 2013, Miyove, Nyankenke, Manyagiro, Cyumba and Rubaya sectors recorded high rainfall of 139.6 mm while low rainfall of 99.09 mm was registered by Bukure, Rwamiko, Muko and Giti sectors (Figure 3 (a)).

The same Figure 3 (b) demonstrated that in 2014, the rainfall reduced compared to that of 2013. The highest record was 68.3 mm within Rutare and Nyamiyaga sectors while the lowest rainfall was 58.8 mm mainly within the Bwisige, Shangasha and Byumba sectors (Figure 3 (b)).

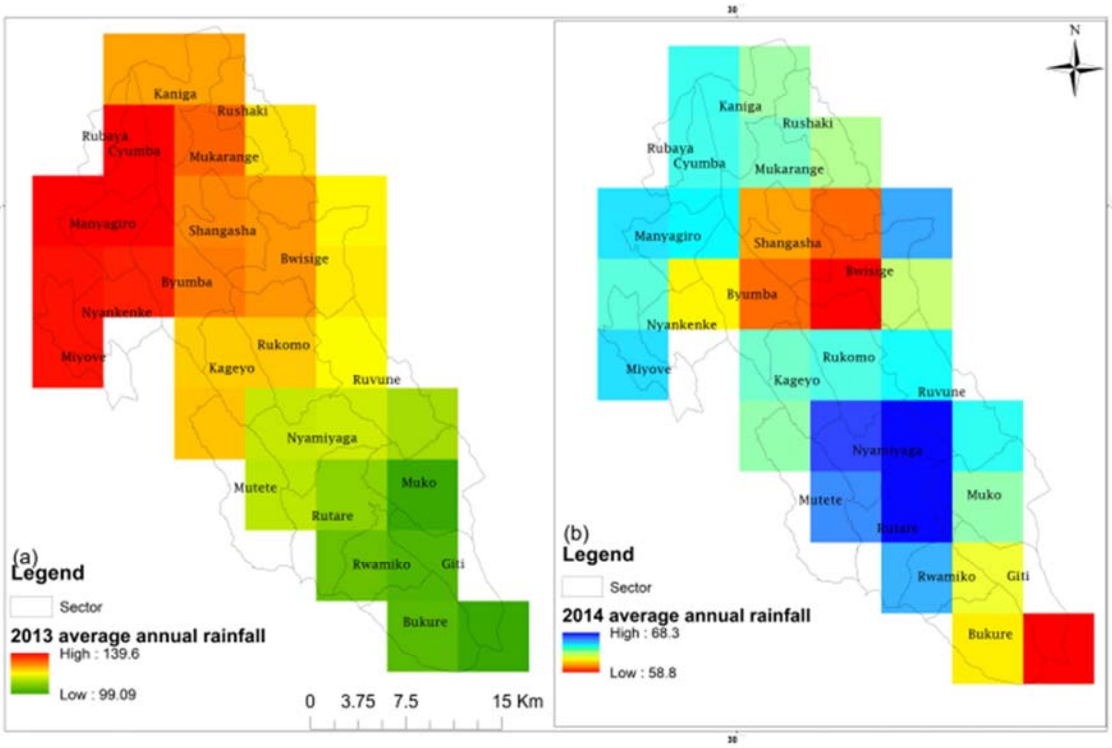

Figure 3. Average annual rainfall of (a) 2013 and (b) 2014 in Gicumbi district.

Nevertheless, rainfall in 2015 revealed an increasing trend compared to 2014. The results as shown in Figure 4 (a) showed that the highest rainfall was 74.2 mm and was mainly registered by the sectors of Kageyo and Manyagiro. The lowest record was 62.7 mm and was mainly distributed within Muko, Rwamiko, Giti, Bukure, Bwisige and Rushaki sectors.

In 2016, as depicted in Figure 4 (b), rainfall considerably reduced where the highest rainfall was 67.7mm across Miyove, Manyuagiro and Cyumba sectors and the lowest record was 48.6 mm in Bukure, Giti and Muko sectors.

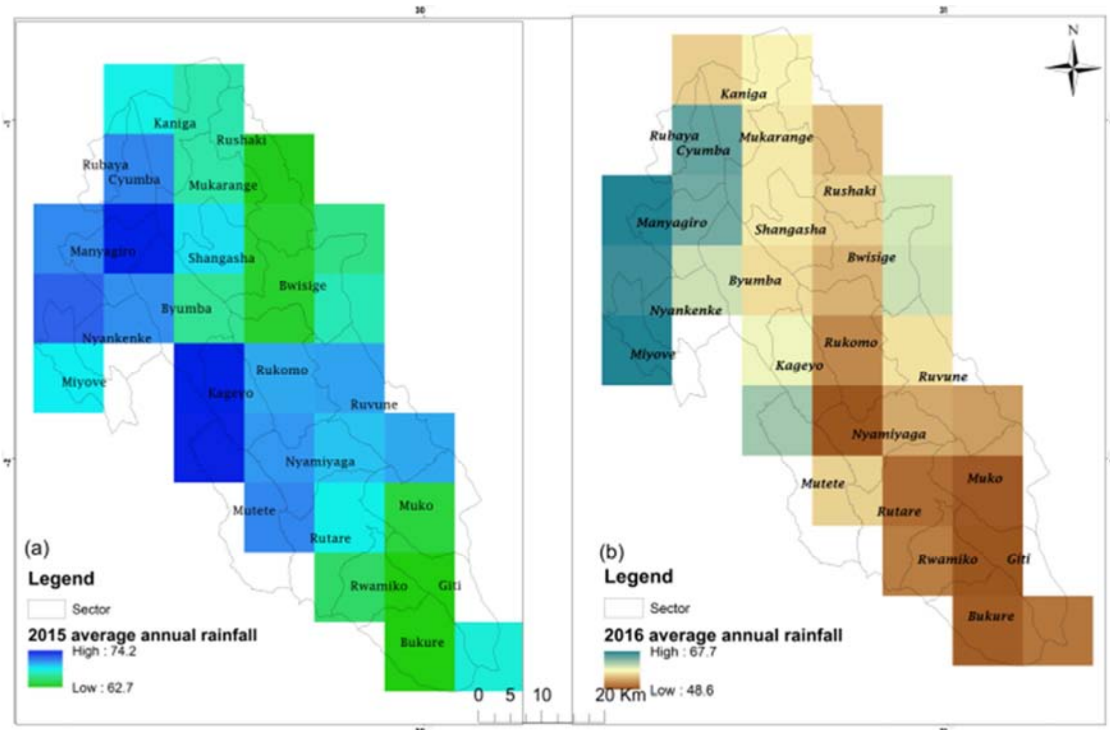

Figure 4. Average annual rainfall of (a) 2015 and (b) 2016 in Gicumbi district.

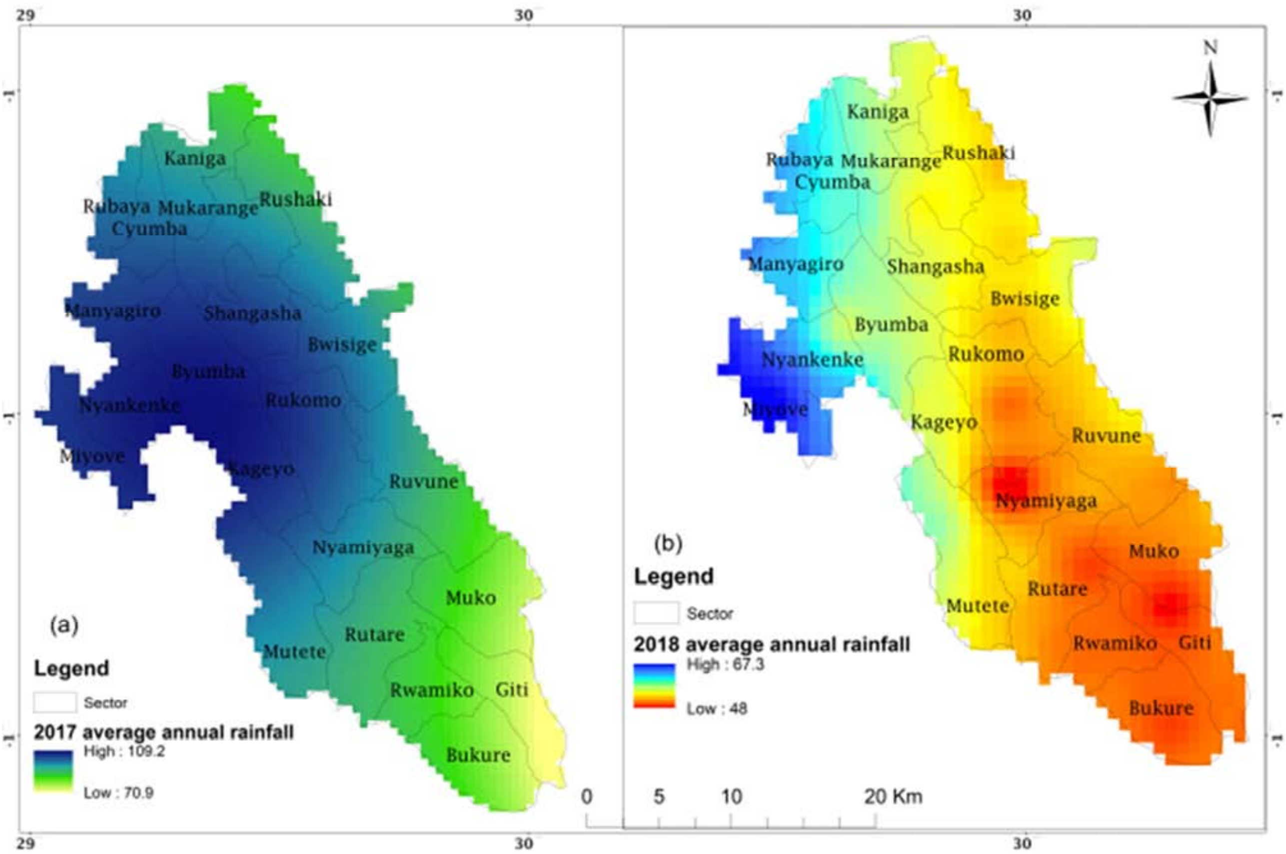

Figure 5. Average annual rainfall of (a) 2017 and (b) 2018 within Gicumbi district.

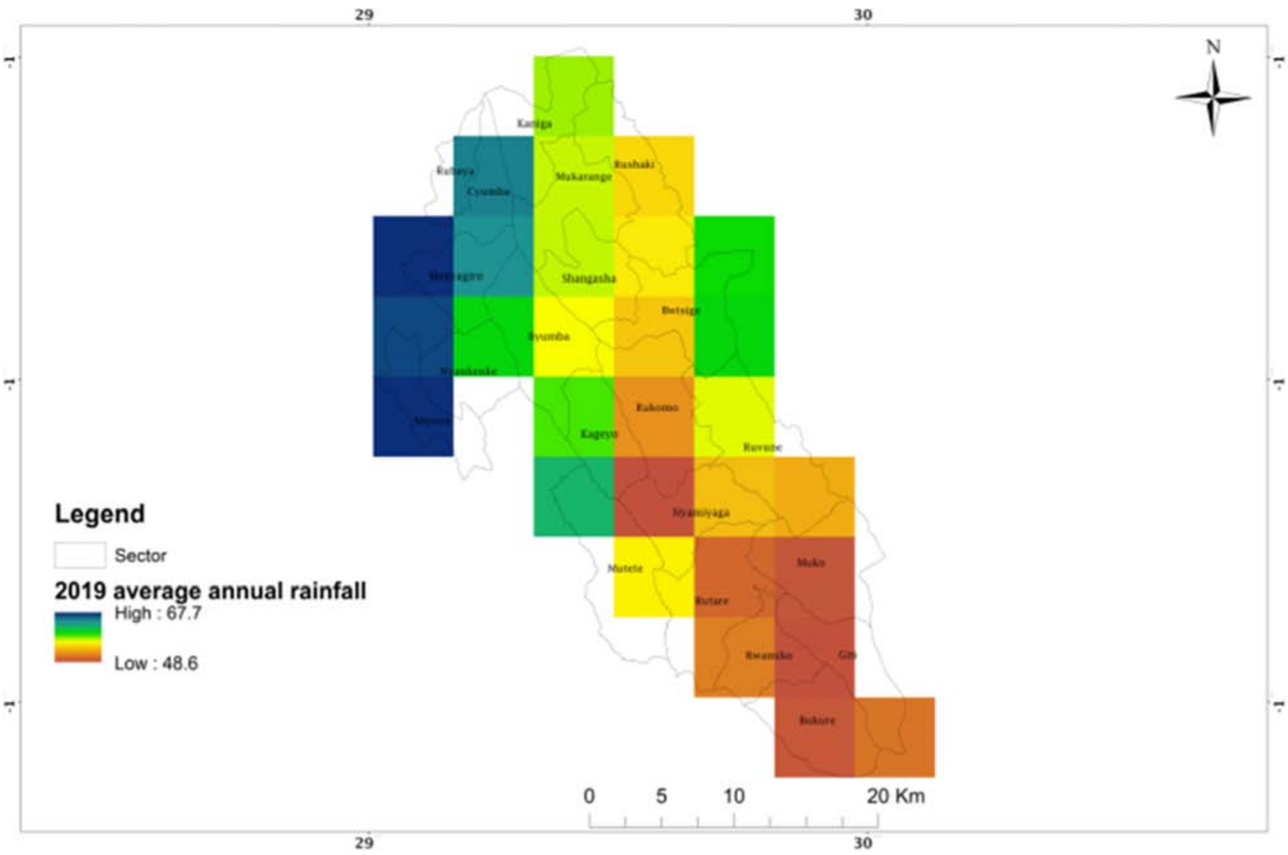

Figure 6. Average annual rainfall registered in 2019 across Gicumbi district.

Regarding the year 2017, the analysis in Figure 5 (a) showed that it was the period in which high rainfall was recorded across sectors of Gicumbi district. The highest record reached 109.2 mm and was recorded by Miyove, Kageyo, Byumba, Manyagiro and Nyankenke sectors. The lowest rainfall was 70.9 mm within Rushashi, Giti, Bukure, Rwamiko and Muko 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 rainfall which was 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 annual rainfall registered in 2019 across Gicumbi district, the results in Figure 5 showed that Miyove, Manyagiro, Nyankenke, Cyumba and Rubaya sectors, at large extent, recorded high rainfall which ranged from 67.7mm.

The lowest rainfall of 48.6 mm was mainly noticed across Muko, Bukure, Rwamiko and Giti sectors of Gicumbi (Figure 5). The mean annual rainfall summarized for every year considered by the current research (2013-2019) indicated that 2013 recorded high rainfall (119.345 mm) followed by the year 2017 which registered a mean rainfall of 90.05 mm (Table 1).

Table 1. Mean annual rainfall 2013-2019.

Year	2013	2014	2015	2016	2017	2018	2019
Mean rainfall (mm)	119.345	63.55	68.45	58.15	90.05	57.65	58.15

3.1.2. Recorded Temperature Variability

The results in Figure 7 (a) showed that Kaniga, Shangasha, Byumba and Nyankenke recorded low temperature of 21.7 degree Celsius. High temperature of 25.2 degree Celsius was mainly noticed within Bukure, Giti, Rwamiko and Muko sectors.

Nevertheless, in 2014, as depicted in Figure 7 (b), Bukure, Giti, Rwamiko and Muko sectors recorded low temperature in 2013.

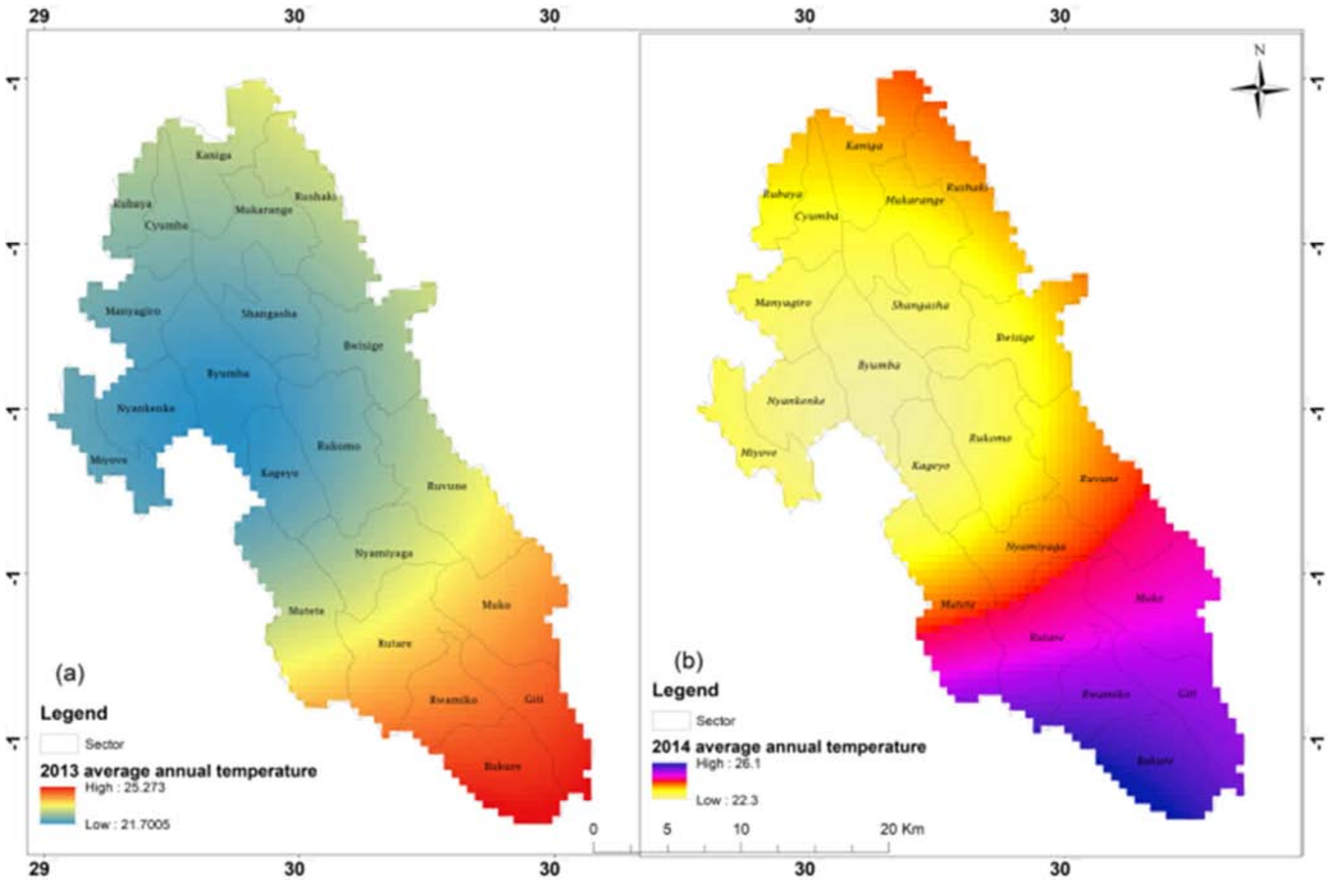

Figure 7. Average annual temperature of (a) 2013 and (b) 2014 within Gicumbi district.

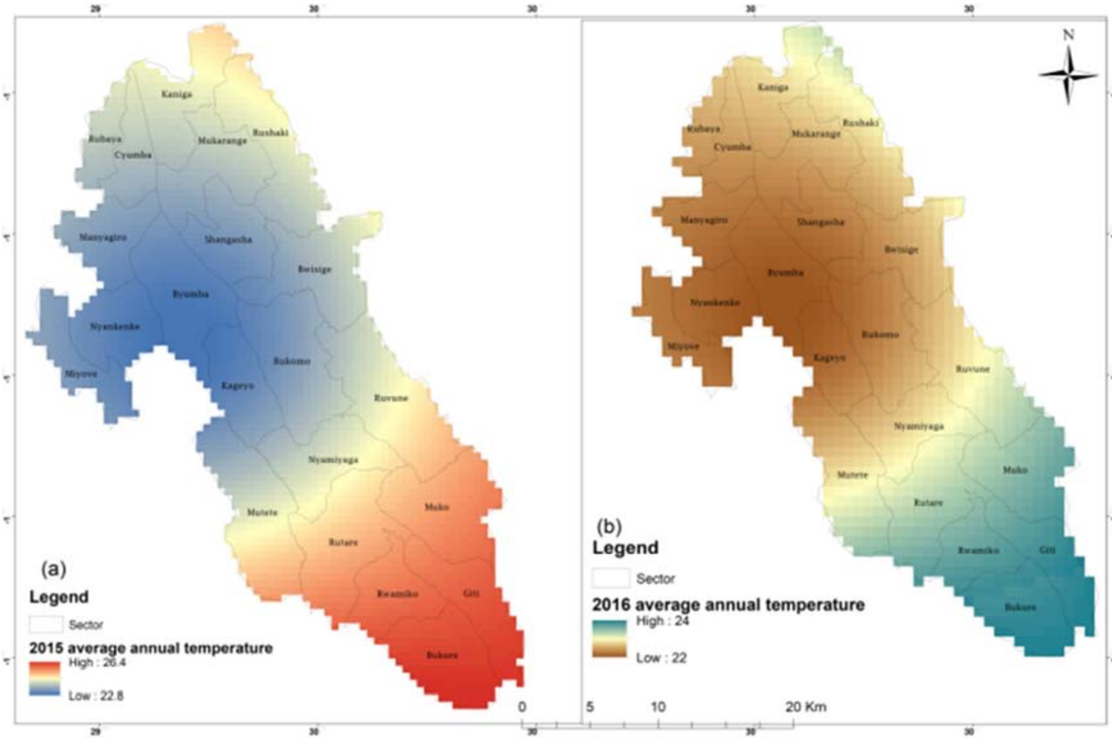

Figure 8. Average annual temperature of (a) 2015 and (b) 2016 across Gicumbi district.

Regarding the temperature record of 2015, the analysis in Figure 8 (a) revealed that the highest record was 26.4 degree Celsius in Giti, Bukure, Rwamiko and Muko sectors while the lowest record of 22.8 degree Celsius was mainly noticed across the sectors of Nyankenke, Shangasha, Miyove and Kageyo (Figure 8 (a)).

Similarly, the results in Figure 8 (b) showed that the same sectors (Nyankenke, Shangasha, Miyove and Kageyo) recording low temperature which was 22 degree Celsius and those (Giti, Bukure, Rwamiko and Muko) registering high temperature (24 degree Celsius) remained the same in 2015 as that in 2016.

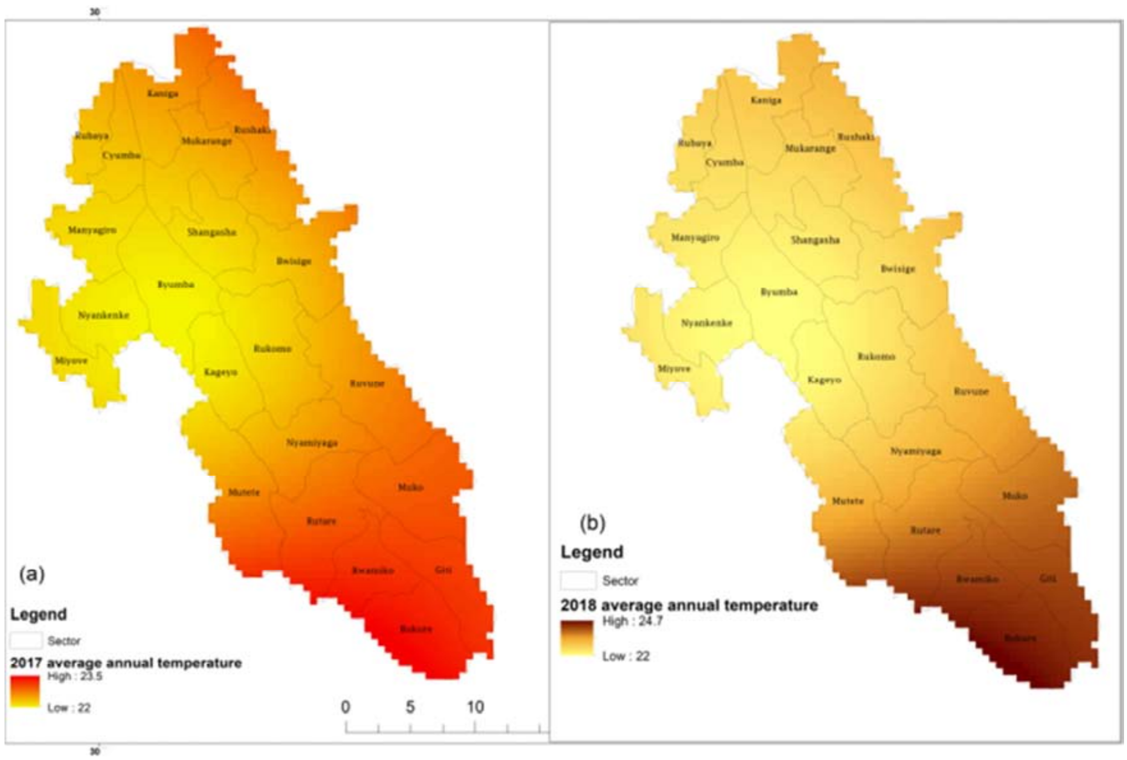

Figure 9. Average annual temperature of (a) 2017 and (b) 2018 across Gicumbi district.

The results in Figure 9 (a) demonstrated that in 2017, Giti, Rutare, Muko, Bukure and Rwamiko sectors were under high temperature of 23.5 degree Celsius. The same Figure 9 (b) showed that the temperature of 2018 increased little bit where the highest record was 24.7 degree Celsius and sectors of Giti, Rutare, Muko, Bukure and Rwamiko remained under higher temperature as in 2017 (Figure 9 (a)).

Finally, as indicated in Figure 10, the highest average annual temperature in Gicumbi district was 23.5 degree Celsius and was registered particularly in Giti, Rutare, Muko, Bukure and Rwamiko sectors. The lowest record was distributed within Byumba, Nyankenke, Miyove, Shangasha, Manyagiro, and Kageyo Rukoma sectors at 22 degree Celsius (Figure 10).

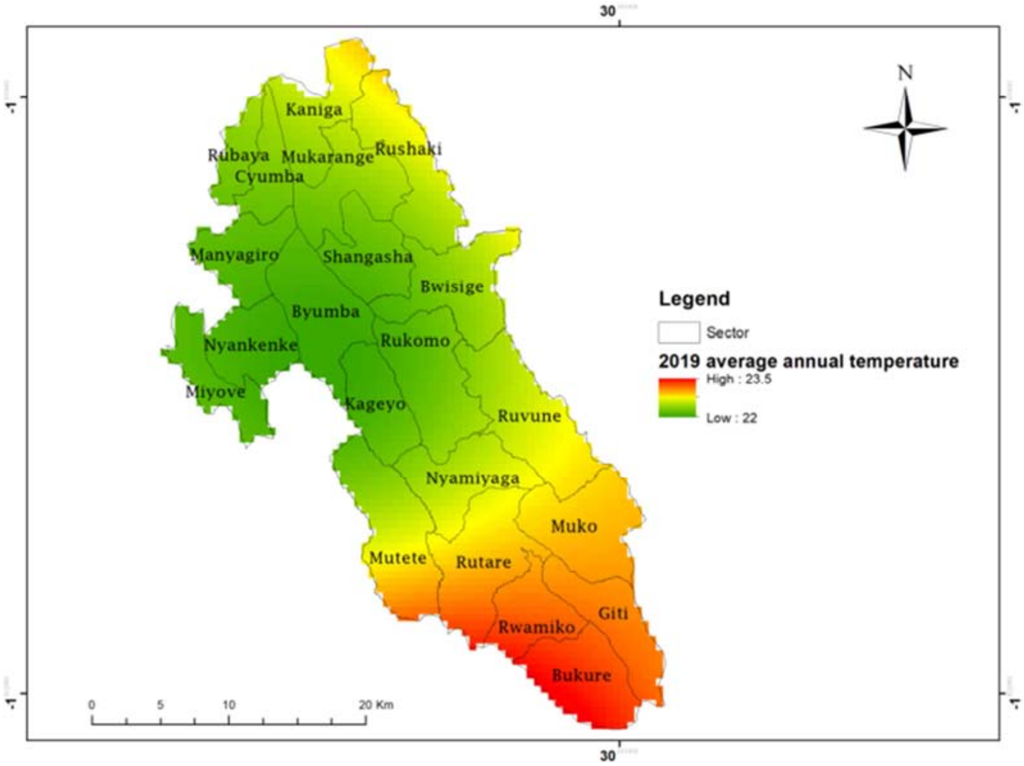

Figure 10. Average annual temperature of 2019 in Gicumbi district.

Regarding the mean annual temperature recorded per year, the results in Table 2 showed that the years 2014 and 2015 registered high mean temperature of 24.2 and 24.6 degree Celsius, respectively. The lowest mean temperature was registered by both years of 2017 and 2019 at 22.75 degree Celsius, respectively.

Table 2. Mean annual temperature between 2013 and 2019.

Year	2013	2014	2015	2016	2017	2018	2019
Mean temperature (°C)	23.45	24.2	24.6	23	22.75	23.35	22.75

3.1.3. Risks of Climate Variability in Gicumbi District

The results in Table 3 indicated that landslide, windstorms, flood, lightning, rainstorm and hailstorms resulted from climate variability in Gicumbi district. The same Table 3 revealed that the years 2014, 2015, 2017 and 2019 recorded high number of these cases of climate variability risks.

Table 3. 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

3.2. Losses on Community Livelihoods

The results in Table 4 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.

Table 4. 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

The results in Table 5 indicated that among climate variability losses considered, major losses resulted from the cropland and house damages which ranked 1,418 and 904 cases respectively.

However, regarding the risks which caused the community livelihood losses, the results in Table 5 revealed that 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 5. 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

3.3. Extent to Which Climate Variability Impacts on Livelihoods

The authors applied the Statistical Package for Social Science to analyze the relationship between rainfall, temperature and loss on community livelihoods by applying the Pearson correlation analysis. The authors 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 6 showed a p-value of 0.015171 which is smaller than 0.05 and confirmed the fact that 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 4).

Table 6. Correlation analysis between rainfall variability and livelihood losses.

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

In addition, the Pearson correlation analysis between temperature variability and loss on community livelihood (Table 7) generated a p-value of -0.071904 which also was smaller than 0.05 and meant that temperature variability also contributes to impacting on people's livelihoods in Gicumbi district.

Table 7. Correlation analysis between temperature variability and livelihood losses.

Correlations			
		Temperature	**No. of livelihood loss cases**
Temperature	Pearson Correlation	1	-0.071904
	Sig. (2-tailed)		0.878247
	N	7	7
No. of livelihood loss cases	Pearson Correlation	-0.071904	1
	Sig. (2-tailed)	0.878247	
	N	7	7

4. Discussion

The impact of climate variability and change is a global concern. Adaptation to climate change is one of the approaches considered likely to reduce the impacts of long-term changes in climate variables [13]. Adaptation is a process by which strategies to moderate and cope with the consequences of climate change, including climate variability, can be enhanced, developed and implemented [14].

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 [15-17]. The strategy for adapting to climate variability and change impacts and awareness rising 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.

There is also (c) creation of mass awareness of climate variability at grassroots level, through government and non-governmental intervention and provision of essential support such as information, technology, technical know-how, alternative sources of income and employment, credit facilities, health facilities and markets information along with the (d) dissemination of all awareness messages in local language [15-17].

In Rwanda, the impact of climate variability and change is mainly manifested through change in rainfall and temperature patterns. These cause flooding, land sliding, rainstorm, hailstorms and windstorms in the north-western and southern parts of Rwanda. The windstorms, droughts are largely recorded win the south and eastern regions of the country [18].

This agrees with the findings of this study (Tables 6 and 7) that climate variability is impacting on people's livelihoods that relevant measures should be undertaken in Gicumbi district.

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 rainfall (119.345 and 90.05 mm) and both 2014 and 2015 years registered high mean annual temperature of 24.2 and 24.6 degree Celsius, respectively. The rainfall and temperature variability caused landslide, flood, rainstorms, windstorms, lightning and hailstorms occurrence. The above risks affected livelihoods by killing/injuring people, damaging their houses and cropland, leading to livestock loss, and destruction of infrastructures as well. The year 2017 registered a high number of community livelihoods losses (885.7). The correlation analysis indicated a p-value of 0.015171 and -0.071904 for rainfall and temperature variability with livelihood loss, respectively. These values were smaller than 0.05 and confirmed a statistically significant association between climate variability and loss on community livelihoods. 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 areas can be relocated within areas with moderate rainfall. Further study on settlement location suitability under disasters is suggested.

Acknowledgements

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