The African Resources Development Journal, Vol 6, No. 1, December 2022: 50-76

Investigating Local Community Perception About Climate Change in Gatsibo and Nyagatare Districts, in Rwanda

Théogène Habakubaho[8], Emmanuel Patroba Mhache[9] and Josephat Saria[10]

Abstract
The main objective of this paper was to investigate the perception of local community about climate change in drought prone areas of Nyagatare and Gatsibo districts in Rwanda. This paper perceived changes of climate and their effects, causes of climate change and perception of adaptation measures. Understanding community perception on climate change issues is critical in designing community-based adaptation actions and programs. Data were collected using questionnaire administered to 480 households selected in six sectors. Data were analysed using SPSS Statistics 28.0.1. to generate descriptive results. 89% of responds perceived a decrease in amount of rainfall while 70% perceive changes in reduction of length of rain season. Reported causes of climate change are dominated by environmental degradation (85.6%), deforestation (57.2%). Perceived effects of climate change on community livelihoods include decline of annual households' income (88.3%), increased incidences of pests and diseases in crops (90.1%). The research results indicate that ongoing adaptation initiatives have failed to meet expected results. This is partly because local perception and knowledge are not considered. It is therefore, recommended to change the approach and adopt more community-based approach and considers local characteristics and local knowledge in designing adaptation actions. This will increase community resilience, ownership and address real community needs.

Keywords: *Climate change, Adaptation, Perception, Community*

1.0 INTRODUCTION

Historical and current projections provide evidences of climate change around the World. Projections under different scenario indicate that intensity and frequency of climate related hazards will increase. According to Intergovernmental Panel on climate change, predicted risks will not only increase, but also changes will bring climate related hazards (IPCC, 2014). In the same time, local communities that are mainly depending on natural resources are the most vulnerable to climate change effects due to their strong attachments to their territory and livelihoods (van Aalst *et al.*, 2008). Fortunately, it has been demonstrated that local communities are not passive and have traditionally adapted to variations in their environment. Different communities deployed a combination of local knowledge, perception and learning processes, their social structures, institutions, and internal communal arrangements to deal with climate

[8] PhD (Geography) Candidate, The Open University of Tanzania. *Email: habathe2008@gmail.com*
[9] The Open University of Tanzania, *e-mail: Emmanuel.mhache@out.ac.tz*
[10] The Open University of Tanzania, *e-mail: josephat.saria@out.ac.tz*

change hardships (Boillat and Berkes, 2013). These communities are key actors in the management of environmental challenges (Armitage, 2005) such as climate change. Previous studies have demonstrated social relations may enhance the ability to cope with weather-related and environmental hazards and to address the impacts of climate change (Lorenzoni *et al.*, 2007; Wolf *et al.*, 2013).

It is, therefore, essential to comprehend the perceptions of people within the communities and to include them from the start when developing and designing climate change adaptation strategies (UNPFII, 2008) in a way that translates their capabilities into effective adaptation practices. Understanding how community members perceive and understand environmental and climate changes, these changes mean for them, and how perceptions on climate change differ in each community, it is important in climate change. It has been documented that adaptation is effective only when local communities have sufficient knowledge about climate change and are empowered to effectively participate in proposed adaptative initiatives and actions (Adger *et al.*, 2014). Perceptions about climate change, its causes, impacts, and the necessary response mechanisms to cope with climate calamities are important for any population in a given community (Hannah *et al.*, 2010).

It is understood, that the level of awareness determines the scope of implementation that needs to be taken to tackle the problem. Community knowledge and perception on social and earth systems interact, is significantly becoming key source for comprehending climate change and creating adaptation strategies (Mafongoya and Ajayi, 2017). Thus, community knowledge is an essential and active resource for the survival of agro-pastoralists and other local people. This knowledge is also a cornerstone of social, cultural, political, economic, scientific, and technical identity (Magni, 2017; Ayal *et al.*, 2015), which can help achieve sustainable development goals (Tengo *et al.*, 2014).

Therefore, the objective of this research is to assess the perception and knowledge of local communities and how local knowledge and perspective can be considered in designing adaptation actions especially at community level. The understanding and consideration of perception would reduce issues encountered in the implementation of proposed actions including lack of ownership and linkage between proposed actions and local characteristics.

2.0 MATERIALS AND METHODS

2.1 Study area description

This study was conducted in Nyagatare and Gatsibo Districts, formerly Umutara Region (between 1°17'04.7"S 30°31'57.6"E and 1°38'20.9"S 30°30'52.8"E). Administratively, the two districts are located in the Eastern Province of Rwanda towards the Tanzania and Uganda borders (Figure 1). A big part of these districts used to be part of Akagera national park and was opened to human settlement in 1996 to accommodate returning refugees from after 1994 genocide. Since then, both districts have experienced a major influx of returning refugees and their livestock from neighbouring countries and migrants from other provinces in Rwanda.

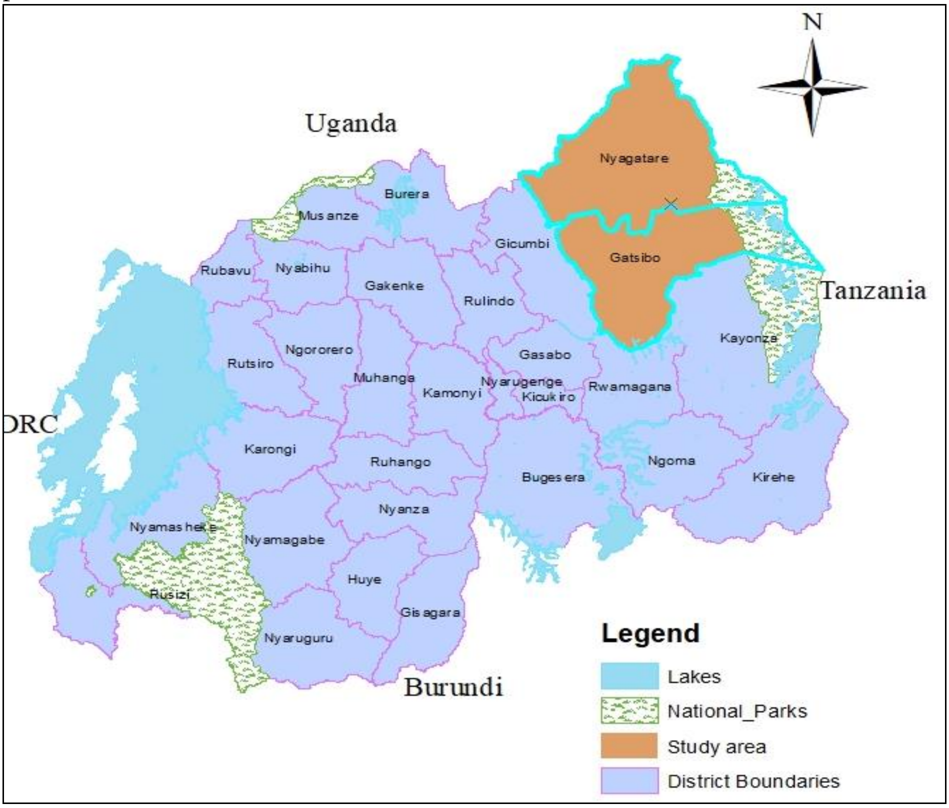

Figure 1: Location of study area on the administrative map of Rwanda
Source: Prepared by author-based National base map, 2022

In terms of climatic conditions, the study area is located in eastern drought-prone region in Rwanda and has been facing rainfall deficits for the past 30 years. According to meteorological services data, the study area receives an annual rainfall of between 700 mm and 1,100 mm, with mean annual temperature oscillating between 20°C and 22°C. Historical observations made between 1961 and 2018, indicate that the years 1991 to 2000 were the driest since 1961. According to these measurements, rainfall was significantly deficient in 1992, 1993, 1996, 1999, and 2000, while there were excesses in 1998 and 2001 (MIDMAR, 2018). The two districts are experiencing very high drought susceptibility (Figure 2), characterized by a substantial number of dry spells, late rainfall onsets, early rainfall cessations, and frequent rainfall deficits (MINAGRI, 2020).

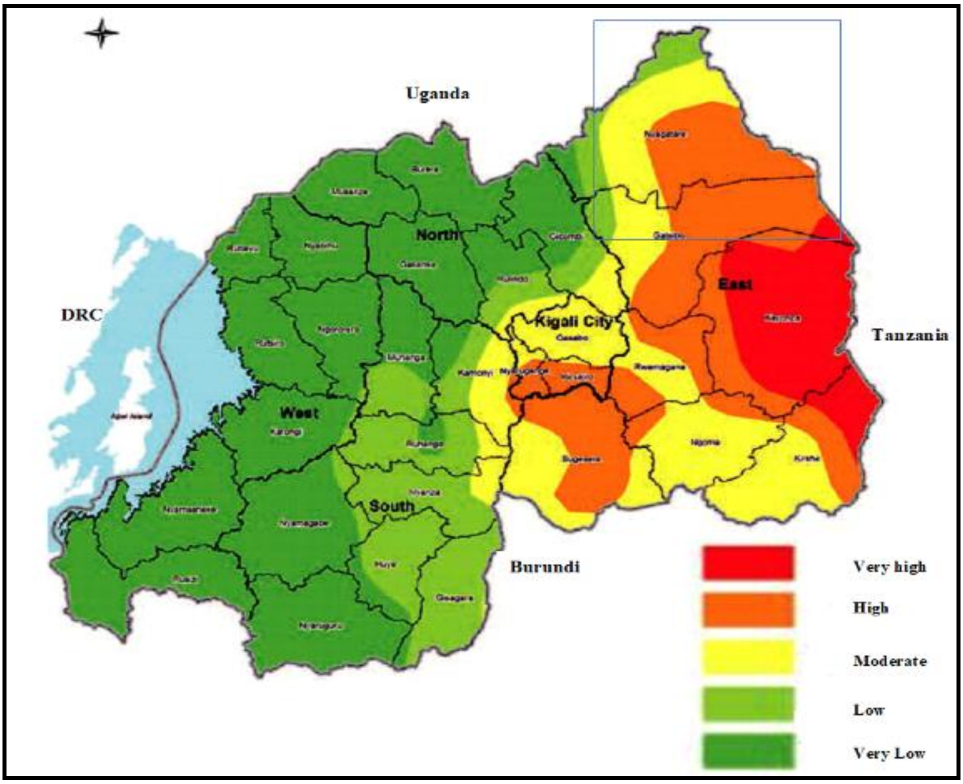

Figure 2: Location of the study area in drought susceptibility in Rwanda
Source: National disaster atlas, MIDMAR, 2018

From figure 2 it can be observed that the eastern part of Rwanda is located in very high drought susceptibility compared to central and western region. Prolonged drought and deficit in rain, has caused famine, food shortages, a decline in plant and animal species. Frequenty migration of people in search of food and pasture are results of these prolonged droughts. This has also impacted natural resources whereby drought has forced herders to move their herds from their pastures closer to or into the Akagera National Park during the dry season (MIDMAR, 2018).

2.2 Research Design and research approaches

2.2.1 Research design

The researcher opted for a descriptive research design for the current investigation. This design was chosen because of its high representative and made it simple for the researcher to get the participants' thoughts (Polit and Beck, 2004). Additionally, descriptive research is used to characterize what is there in terms of variables or conditions in a situation and to learn more about the status of the phenomenon (Ticharwa, 2014).

This study used both qualitative and quantitative research approaches. Interviews with professionals, community leaders, chosen elders, and well-known members of the neighbourhood were performed under the auspices of the qualitative approach. Quantitative data were gathered via household questionnaires given to agro-pastoralists in the study area as part of the quantitative research approach.

2.2.2 Source of data and data collection methods

Data used in this research were drawn from primary and secondary sources. First, the researcher collected primary data from households in Nyagatare and Gatsibo districts. These data were collected using a questionnaire distributed to 480 heads of sampled households. Additional primary data were obtained from interviews conducted with key informants selected in various ministries, agencies, and research institutions at the central government level.

Secondary data were obtained from documents and reports held by various institutions such as the Rwanda Meteorological Agency, the National Institute of Statistics of Rwanda, the Ministry of Environment, the Rwanda Environment Management Authority, the Ministry of Agriculture and the Ministry of Disaster and Risk Management.

2.2.3 Targeted Population

This research targeted agro-pastoralists in Nyagatare and Gatsibo District (Table1). Agro-pastoralists in the area were obtained from National Institute of Statists in Rwanda. According to available data, the target population was 65,402 households, including 33,717 households in Nyagatare District and 30,822 households in Gatsibo District (NISR,2012). The population appears to be large, so the researcher has used sampling methods and techniques to get a small population size (Table 1).

Table 1: Target Population

Category of targeted Population	**Size of the Population**		**National Level**	**Total**
	Nyagatare	**Gatsibo**		
Total Households	33,717	30,822	n/a	64,539
Grand Total	**33,832**	**30,933**	**653**	**65,402**

Source: NISR, 2022

2.2.4 Sampling Procedures

A sample is a group of comparatively fewer persons picked from a population for the purposes of research (Alvi, 2016). It is also the choosing of a portion of an aggregate or total based on a conclusion or inference (Bernard, 2006). In other words, it is the process of acquiring knowledge about an entire population by analysing a small sample. This study included two sampling methods: systematic random sampling and purposive sampling.

Systematic random sampling was used to sample villages where households were sampled from Nyagatare and Gatsibo District. In total, 40 villages were sampled from 1,230 villages by using an interval of

31((N/n=1,230/40=30.75≈31). Thus, on a list sorted A-Z district by district, 40 villages were selected, starting from randomly selected villages and skipping 31 to choose the next village and so on, up to a total of 40 villages. Each village was represented by total sampled households divided by 40 villages (480/40) to get 12 households per sampled village. Once villages were known, households were selected with simple random selection whereby all households in the village were listed, and 12 households were selected randomly applying the same interval.

Purposive sampling aimed at selecting population of interest able to answer research questions. Given that this research aimed to collect information related to climate change in agro-pastoralism area, only agro-pastoralists were purposively targeted. To determine the sample size for all levels, the researcher relay on the Slovin formula of sample calculation taken from the study of Williams (2013) where: n=N/(1+(N*(e)^2). Where "n" is the sample size, "N" is the total population, and "e" is the level of significance or margin error. The Slovin's sample calculation formula is flexible, so the researcher diversified the margin error from one given population category to another. This was made with a focus on the weight a certain population category has in the entire study. The main target population for the study is the agro-pastoral households in six sectors of Gatsibo and Nyagatare Districts.

Table 2: Sample distribution and selection for sectors in Gatsibo and Nyagatare districts

Sectors	Total targeted population	Sample Size
Sectors	**28**	$n=28/(1+(28*(0.3618730)^2)=6$
Rwimiyaga	3,499	$n=3,499/ (1+(3,499*(0. 106499)^2)=86$
Nyagatare	3,396	$n=3,396/(1+(3,396*(0.0.109090)^2)=82$
Karangazi	3,390	$n=3,390/(1+(3,390*(0.111917579)^2)=78$
Kabarore	3,046	$n=3,046/(1+(3,046*(0.11047641323)^2)=80$
Matimba	2,317	$n=2,317/(1+(2,317*(0.1182820840)^2)=70$
Rwimbogo	2,247	$n=2,247/(1+(2,247*(0.10774874680)^2)=84$
Total	**17,895**	**480**

Source: NISR and researcher calculations, 2012

Reference made to Table 2, the sample calculation was made from 28 sectors of the former Umutara region (14 sectors from Gatsibo District and 14 sectors in Nyagatare District). Thus, the researcher got 6 sectors to be evaluated as a sample size from 28 sectors. Using systematic sampling, the sample was taken from total agro-pastoralists in selected sectors using data available at the sector level. To select sectors 6 sectors from 28 sectors in the two districts, systematic sampling was also used. Thus, six sectors were selected, including Rwimiyaga, Nyagatare, Karangazi, Kabarore, Matimba and Rwimbogo. For each sampled sector, a sample size was calculated based on a total sample of 480 households for two districts. Thus, from Rwimbogo, only 86 households were assessed, 82 from the Nyagatare sector, 78 from the Karangazi sector, 80 from Kabarore sector, 70 from Matimba sector and 84 from Rwimbogo sector.

2.2.5 Data analysis and data presentation

Analysis, interpretation, and presentation of data are crucial research tasks. The objective of data analysis is to obtain information that is usable and valuable. Whether the data is qualitative or quantitative, the analysis describes and summarizes the data, identifies links between variables, compares variables, and distinguishes between variables and predicted outcomes (Bruscia, 2005). Qualitative and quantitative data were analysed, interpreted, and presented in this research. Typically, qualitative data consists of words, audio or visual recordings, and observations, rather than statistics (Fisher, 2010). All recorded interviews were transcribed, translated, and entered into Microsoft Word documents. Responses from local communities were confirmed or complemented by results of interviews held government officials.

In this study, questionnaire-derived quantitative data were analysed using the Statistical Package for Social Science database (SPSS Statistics 28.0.1.). This software was useful for generating straightforward descriptive statistics, such as frequencies, percentages, and cross-tabulations. The results were then displayed using tables, bar charts, and pie charts, with interpretations based on frequencies and percentages. Results were discussed and compared to other research conducted in other regions.

3.0 RESULTS AND DISCUSSION

This section presents and discusses findings of research including socio-economic characteristics of respondents, key effects of climate change in the area, perceived causes of climate and perception of local community on proposed adaptation actions.

3.1 Socio-Demographic Characteristics of the Respondents

3.1.1 Age of the respondents

Table 3 indicates that most respondents, 62.9%, were between 36-65 years of age, followed by 65 years and above with 22.3%. The 18-35 represents only 14.8% of the respondents. Two factors can explain the presence of a small percentage of young people. One is that the selection criteria considered people above 18 years. The second reason is reported migration of young people to urban areas, especially in Kigali leaving agro-pastoralism managed by older adults.

Table 3: Age of respondents in the six sectors covered under this research

Age of respondent	**Kabarore (n=80)**		**Karangazi (n=78)**		**Matimba (n=70)**		**Nyagatare (n=82)**		**Rwimbogo (n=84)**		**Rwimiyaga (n=86)**		**Grand Total (n=480)**	
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
18-35	12	15.0	13	16.7	11	15.7	15	18.3	6	7.1	14	16.3	71	14.8
36-65	51	63.8	40	51.3	48	68.6	55	67.1	59	70.2	49	57.0	302	62.9
65+	17	21.3	25	32.1	11	15.7	12	14.6	19	22.6	23	26.7	107	22.3
Grand Total	**80**	**100**	**78**	**100**	**70**		**82**	**100**	**84**	**100**	**86**	**100**	**480**	**100**

Source: Questionnaire results, 2022

3.1.2 Sex of respondents

As presented in Figure 3, males were the majority, 59.2% of all respondents, while women represented 40.8%. This is opposite to the general distribution of the population in Rwanda where females slightly outnumber males, with 111 females per 100 males (NISR, 2012). This higher proportion of males can be justified by the survey methodology that targeted agro-pastoralism mainly done by Rwanda males.

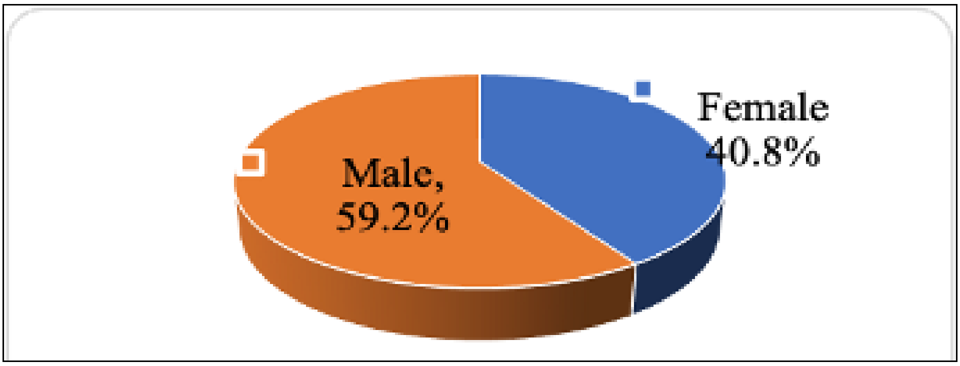

Figure 3:Distribution of respondents by sex
Source: Questionnaire results, 2022

3.1.3 The main source of income of respondents

As presented in Table 4, cattle rearing largely outnumbers other activities, with 59.4% of all respondents. The situation is similar across all six sectors because of the location of the study area in the agro-pastoralism region, where livestock is the main activity. Growing crops and small businesses come second, with 14.8% of the respondents.

Table 4: Main source of income among respondents per sector

Main Income Sources	Kabarore		Karangazi		Matimba		Nyagatare		Rwimbogo		Rwimiyaga		Total	
	n=80	%	n=78	%	n=70	%	n=82	%	n=84	%	n=86	%	n=480	%
Full-time job	11	13.8	5	6.4	6	8.6	7	8.5	17	20.2	7	8.1	53	11.0
Growing Crops	11	13.8	17	21.8	10	14.3	11	13.4	8	9.5	14	16.3	71	14.8
Small Business	13	16.3	12	15.4	11	15.7	10	12.2	15	17.9	10	11.6	71	14.8
Sub-Total	**35**	**43.8**	**34**	**43.6**	**27**	**38.6**	**28**	**34.1**	**40**	**47.6**	**31**	**36.0**	**195**	**40.6**
Cattle keeping	45	56.3	44	56.4	43	61.4	54	65.9	44	52.4	55	64.0	285	59.4
Grand Total	**80**	**100**	**78**	**100**	**70**	**100**	**82**	**100**	**84**	**100**	**86**	**100**	**480**	**100**

Source: Questionnaire results, 2022

This was also observed earlier by Delgado (2005) that livestock rearing or animal husbandry is one of the fastest-growing agricultural subsectors in Rwanda. Animal husbandry in Rwanda has a big share in agricultural Gross Domestic Product (GDP), about 33%, and is rapidly increasing (Delgado, 2005). According to Rosegrant *et al., (*2009), this growth of animal husbandry in Rwanda is driven by the rapidly demand for livestock products, which is driven by population growth, urbanization and rising incomes but also government policy such as "Girinka program"[11]. program.

3.1.4 Highest level of education attainment

Survey results (Table 5) indicate that most respondents in the study area (40.8%) have completed only primary schools, followed by secondary school and vocational training schools with 11% and 3.8%, respectively. The proportion of women who attained primary school is slightly lower than that of men in the area, with 48% and 52%, respectively. At the secondary education level, the percentages are 37% for women and 63%. Those with no formal education represent 18.5 %, while those who have completed university represent 7.3%.

Table 5: The highest level of education attained

Level of education	**Kabarore (n=80)**		**Karangazi (n=78)**		**Matimba (n=70)**		**Nyagatare (n=82)**		**Rwimbogo (nN=84)**		**Rwimiyaga (n=86)**		**Total (n=480)**	
	f	%	f	%	F	%	f	%	f	%	f	%	f	**%**
Complete University	7	8.8	6	7.7	4	5.7	1	1.2	13	15.5	4	4.7	**35**	**7.3**
Incomplete Primary	14	17.5	17	21.8	13	18.6	17	20.7	12	14.3	16	18.6	**89**	**18.5**
No formal school	14	17.5	14	17.9	13	18.6	17	20.7	14	16.7	17	19.8	**89**	**18.5**
Primary	31	38.8	36	46.2	26	37.1	34	41.5	29	34.5	40	46.5	**196**	**40.8**
Secondary	10	12.5	3	3.8	11	15.7	12	14.6	10	11.9	7	8.1	**53**	**11.0**
Vocational	4	5.0	2	2.6	3	4.3	1	1.2	6	7.1	2	2.3	**18**	**3.8**
Grand Total	**80**	**100**	**78**	**100**	**70**	**100**	**82**	**100**	**84**	**100**	**86**	**100**	**480**	**100**

Source: Questionnaire results, 2022

In terms of education, Rwanda has achieved a lot in gender parity in access to primary school education since 2001 (in 2001, net enrolment for girls was 76.1% and for boys it was 74.4%). This is partly due to the effective Rwanda's Education Sector Strategic Plan (ESSP), 2018/2019 – 2023/2024 (Karareba *et al.*, 2019), which recognizes pre-primary education as foundation for future learning. The Government of Rwanda commits to expanding access to three years of early learning for children aged 3 to 6, with the national goal to increase access to 45% of children by 2023/2024 (Paxton, 2012). Hence, more graduates in primary education compared to other levels.

3.2 Community perception about climate change and its effects

3.2.1 Level of knowledge of local community about climate change and variability

Before understanding the perceived effects of climate change, it was important to understand the level of community knowledge on climate change (Figure 4).

[11] Girinka program was established the president to facilitate poor family to own at least one cow. Each poor family is given a cow with initial feeds and medicines.

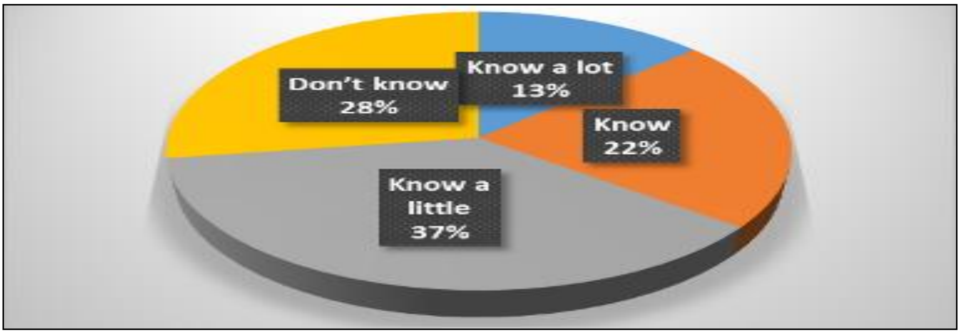

Figure 4: Knowledge of the local community about climate change and variability
Source: Questionnaire results, 2022

Figure 4 indicates that 37% of all respondents have little knowledge about climate change. The fraction of people who reported having sufficient knowledge about climate change and climate variability is equal to 22% while 13 % reported having a lot of information about climate change. Hamilton and Keim (2009) indicated earlier that in Africa and many parts of the World, anthropologic climate science denial persists among the public because individuals lack sufficient information, have a poor understanding of the matter, or associate climate science with conspiracy theories and the like. A recent survey from Africa suggests that only 56% of the continent's population has heard about climate change and about 20% believe that ordinary citizens can do nothing to stop climate change (Afro-barometer, 2019).

In an interview with an environmental specialist at Rwanda Management Authority, it was stated that

> "…. there *is ongoing training and awareness programme to educate people about climate change. However, due to lack of funds, these training are only provided to few people where climate change projects are being implemented".*

This was confirmed by agronomists at district and sector levels, who reported that

> "*...most people are aware of climate change because they are experiencing its effects. They provided different* examples, *including the length of the dry season, changes in planting time, and the amount of rain received during rainy seasons".*

3.2.2 Perceived changes in climate patterns

Understanding public perception of climate change risk and the factors that influence it has been established to be crucial in generating support for climate change response (Thomas, 2019). Several factors including the experience of extreme weather events have been identified in previous studies for having an influence on public opinions and concerns of climate change. To understand how local community perceived changes in climate patterns, the researcher asked respondents to list any change observed over the last 30 years. Table 6 portrays findings from this research is the six sectors covered by research.

Table 6: Local community's perception of climate change at the sector level

Local community's perception	Kabarore (n=80)		Karangazi (n=78)		Matimba (n=70)		Nyagatare (n=82)		Rwimbogo (n=84)		Rwimiyaga (n=86)		Total (n=480)	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Decreased amount of rainfall during the rainy season	71	88.8	69	88.5	62	88.6	73	89.0	75	89.3	77	89.5	427	89.0
Increased length of the dry season	74	92.5	72	92.3	65	92.9	76	92.7	78	92.9	80	93.0	444	92.5
Decreased length of the rain season	57	71.3	55	70.5	49	70.0	58	70.7	59	70.2	61	70.9	339	70.6
Late onset of rain days	48	60.0	46	59.0	42	60.0	49	59.8	50	59.5	51	59.3	286	59.6
Increase of strong winds events	68	85.0	66	84.6	60	85.7	70	85.4	71	84.5	73	84.9	408	85.0
Increasing temperature of the area	51	63.8	49	62.8	44	62.9	52	63.4	53	63.1	54	62.8	304	63.3
The decreasing temperature of the area	56	70.2	55	70.1	49	70.9	57	70.3	58	70.6	60	70.8	337	70.2
Total	**80**	**100**	**78**	**100**	**70**	**100**	**82**	**100**	**84**	**100**	**86**	**100**	**480**	**100**

Source: Questionnaire results, 2022

From Table 6, most respondents in all 6 sectors; 88.8% for Kabarore, 89.0% for Nyagatare, 88.5% for Karangazi, 88.6% for Matimba, 89.5% for Rwimiyaga and 89.3% for Rwimbogo reported that rainfall amount was decreasing. At the same time, survey data indicates that more than 70% of agro-pastoralists from six sectors, including 71.3% from Kabarore, 70.7 % from Nyagatare, 70.5% from Karangazi, 70.0%, from Matima,70.9% from Rwimiyaga and 70.2%) from Rwimbogo perceived that the rainy seasons are shorter compared to some years back.

In an interview with agro-meteorology specialists, these changes were confirmed. It was reported that available historical show a decrease in rainfall in the Eastern province over the last 30 years. Furthermore, the agro-meteorologist indicated that the rainy season has decreased while the dry seasons are becoming longer. This was also observed earlier (Lyon and DeWitt, 2012), who indicated that the rains have declined since 1985 in the African continent, with major consequences for livelihoods.

Historical and projected temperature and rainfall data presented in Figure 5 and Figure 6 indicates higher temperature where the extreme can go beyond 30°C in February and July-August. On the other hand, available data indicated that the study area has been experiencing rainfall deficits over the last 20 years.

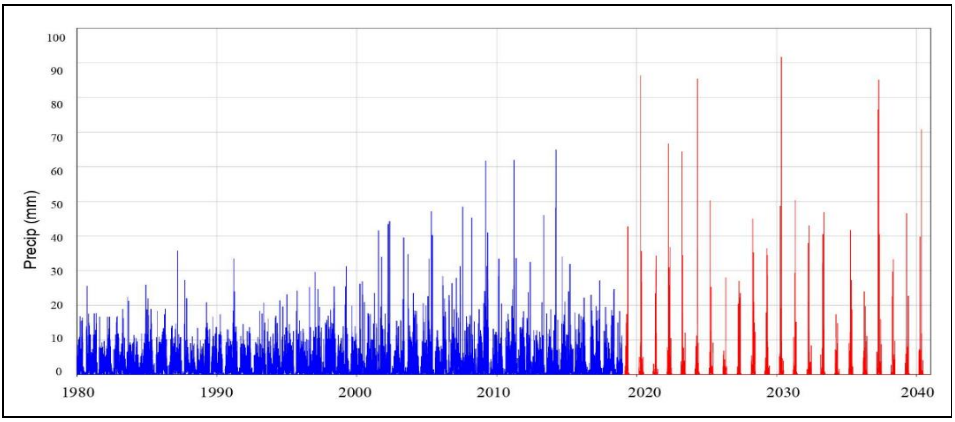

Figure 5: Historical and projected temperature in the study area
Source: Data from meteorological service,2022

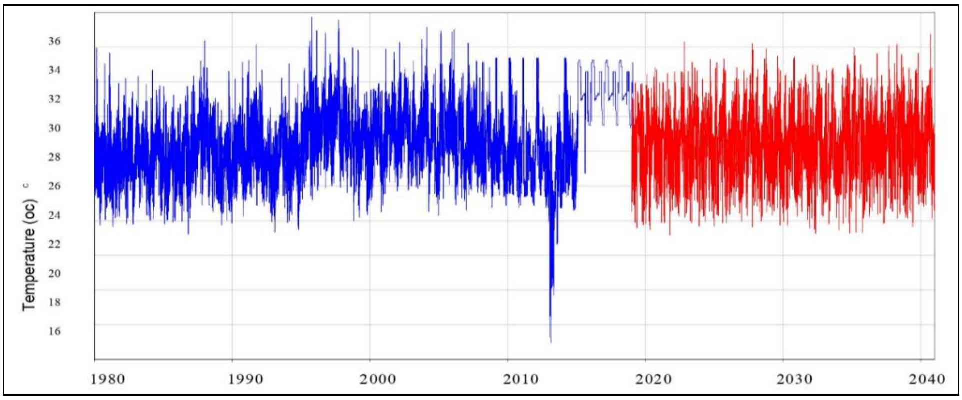

Figure 6: Historical and projected temperature in the study area
Source: Data from meteorological service, 2022

Some climate change literature was collected and analysed. Although the future scenarios are very variable, some findings are common to different studies. Awange *et al.* (2013, 2014, and 2016) points out that future climate change may lead to increases in average mean temperature, and changes in annual and seasonal rainfall. Henniger (2009) analysed air temperature at Kigali using 3 meteorological stations maintained by "Service Meteo du Rwanda" in the period from 1971 to 2008. Data indicated an increasing mean annual temperature of 2.60 C for a period of nearly 40 years. Haggag *et. al*. (2016) investigated past/present climate conditions and future climate projections in some potential hillside irrigation sites in Rwanda and stated that increases in mean air temperature, precipitation and potential evapotranspiration are projected under all models and all emissions scenarios. The increases in rainfalls are generally small relative to the inter-annual variability currently experienced in Rwanda. There is also a trend of precipitation increase of 1 to 29% corresponding to 2010-2019 and 2070-2099 duration and the range of warming varies from 0.75 to 4.50C.

3.2.3 Local perception about weather and meteorological information

Despite efforts made by national meteorological services to disseminate scientific weather and meteorological information, local communities are still relying on their own weather forecasting. This research attempted to understand traditional indicators used by community to understand weather behaviour in planning their agriculture activities. Table 7 presents traditional indicators reported by local communities in terms weather forecast.

Table 7: Reported traditional weather forecast indicators in community

Indicators	Kabarore (N=80)		Karangazi (N=78)		Matimba (N=70)		Nyagatare (N=82)		Rwimbogo (N=84)		Rwimiyaga (N=86)		Total (N=480)	
	fi	%	Fi	%	fi	%	fi	%	fi	%	fi	%	fi	%
Observation of clouds/sky colour and formation	66	82.5	59	75.6	58	82.9	66	80.5	69	82.1	69	80.2	**387**	**80.6**
Unexpected changes of temperature during the day	52	65.0	53	67.9	42	60.0	58	70.7	58	69.0	56	65.1	**319**	**66.5**
Direction and strength of winds,	47	58.8	42	53.8	44	62.9	49	59.8	51	60.7	49	57.0	**282**	**58.8**
Lightning and thunder,	35	43.8	38	48.7	33	47.1	37	45.1	37	44.0	42	48.8	**222**	**46.3**

Source: Primary data, 2022

Depicted from Table 7, the most reported local knowledge in terms of weather forecasting are the observation of cloud/sky colour (80.6%), change of temperature during the day (66.5%) direction and strength of winds (58.8%), followed by lightning and thunder with 46.3%. These results show that local community has developed their own knowledge and they can predict weather behaviour. For instance, unusual changes in temperature, the presence of heavy black clouds announces heavy rain while clear cloud and or presence of rainbow indicates that there is no rain. Though these indicators are not well documents and streamlined as scientific weather forecasting, they are almost the same as indicators used by meteorological services or scientist and weather forecasting.

The key difference is that traditional knowledge uses only observation and feelings while scientific weather forecasting uses sophisticated instruments to predicts and interpret climate data. Under scientific weather forecasting data collection are divided into two categories namely surface weather observations and upper-air weather observations. Weather observations can be taken manually by a weather observer or computer through automated weather station (Iseh and Woma, 2013). All in all, both knowledge has in common the observations atmospheric behaviour such as temperature, wind speed and direction, humidity, precipitations. Therefore, the two knowledge can complement each other especially when it comes to explain methodology used in weather forecast to ordinary farmers. Further, local communities can provide data and historical information when it comes to futures predications which rely heavily on past events (Iseh and Woma, 2013).

3.2.4 Perceived causes of climate change

Local communities have their own perception of causes of climate change which are at some extent linked with real causes of climate change. Table 8 summarizes causes of climate change as reported by local communities in the six sectors.

Table 8: Reported causes of climate change by sector

Perceived causes of climate change	Kabarore (N=80)		Karangazi (N=78)		Matimba (N=70)		Nyagatare (N=82)		Rwimbogo (N=84)		Rwimiyaga (N=86)		Grand Total (N=480)	
	fi	%	fi	%	fi	%	fi	%	fi	%	fi	%	fi	%
Environmental degradation	69	85.7	67	85.9	60	85.7	70	85.4	72	85.7	74	86.0	411	85.6
Air Pollution	43	53.75	42	53.8	37	52.9	44	53.7	45	53.6	46	53.5	257	53.5
Deforestation	46	57.5	48	61.5	41	58.6	47	57.3	48	57.1	49	57.0	274	57.1
Poor agriculture practices	28	35.2	27	34.6	24	34.3	28	34.1	29	34.5	30	34.9	165	34.4
Economic Development	11	13.75	10	12.8	9	12.9	11	13.4	11	13.1	11	12.8	63	13.1
Disrespecting ancestral	7	8.75	7	9.0	6	8.6	7	8.5	7	8.3	8	9.3	42	8.8

Source: Fieldwork, 2022

As presented in Table 8,85.7% of the respondents for Kabarore, 85.4% for Nyagatare, 85.9% for Karangazi, 85.7% for Matimba, 86.0%for Rwimiyaga and 85.4% for Rwimbogo perceived that environmental degradation was causing climate change risks. Another factor reported by most of respondents is deforestation reported by 57.5% for Kabarore, 61.5% for Karangazi, 58.6% for Matimba, 57.0% for Rwimiyaga and 57.1 for Rwimbogo. Other respondents attributed climate change to some government policies such as land consolidation, monoculture, fertilizer application and improved seeds. Some of the actions that contribute to environmental degradation were confirmed during site visits and are presented in Plate 1.

Plate 1: Mining activities on Muvumba River
Source: Fieldwork, 2022

Reported causes at some extent concur with causes documented in literature. Scientists have tried to divide the causes climate into two broad categories, natural and human causes. The natural causes are many including earth's orbital changes, solar variations, volcanic eruptions and ocean currents. The human causes include burning of fossil fuels, land-use and deforestation (Poehler, 2007).

For instance, Urbanization is believed to be a driving force of an economy which facilitates the transfer of surplus labour from the rural agricultural sector to the urban industrial sector and contributes to economic development (Muntasir and Syed, 2018). Urban expansion can enhance warming in cities and their surroundings especially during heat related events. Increased urbanization can also intensify extreme rainfall that may result in additional risks to the flood system (IPCC, 2020). On the other hand, when forests are burned or cleared for other uses such as cropland, pasture, infrastructure or urbanization, the net flow of carbon from the atmosphere into the forest ends (FAO, 2010). Deforestation also causes the release of the stock of carbon that has accumulated, both in the trees themselves and in the forest soil (David, 2018).

3.2.5 Source of climate change information

Climate change information is received from different sources including government officials, personnel experience, schools and training or neighbours or colleagues in working areas. The Figure 7 presents source of information in the study area.

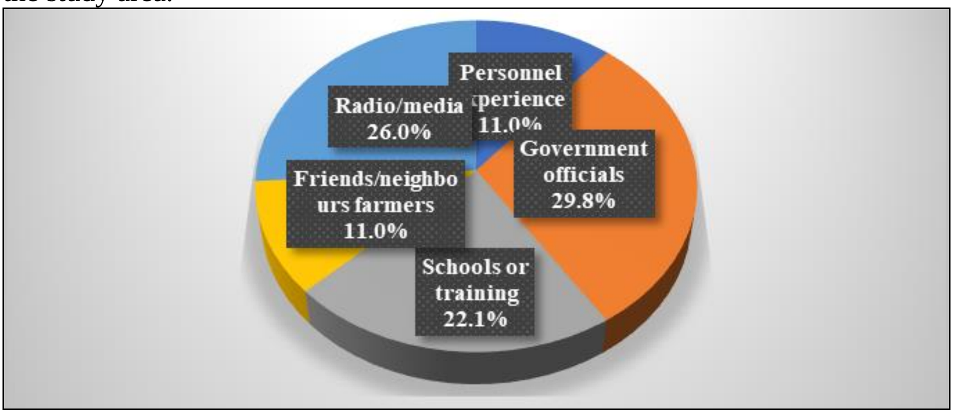

Figure 7: Source of climate change information
Source: Field work, 2021

The Figure7indicates that local community receive information from different sources. Most respondents, 29.8% have received information about climate change from government officials during meetings or when launching climate related projects. Another source of climate change related information is radio/media reported by 26.0%) of all respondents. Other respondents reported school training, personnel experience, or neighbours as the source of information about climate change.

These sources of information were reported by Naswem (2016) who indicated that personal observation/experience, Radio/television, and fellow farmers were the major sources of information. These findings also concur with Isife and Ofuoku (2008), who documented that radio, has the highest audience and has the strength of reaching a large population of farmers and other rural dwellers faster than other means of communication.

3.2.6 Perceived climate change effects on environmental and socio-economic systems

Findings from this research show that reported changes has affected communities' livelihoods but also local ecosystems a presented in Figure 8.

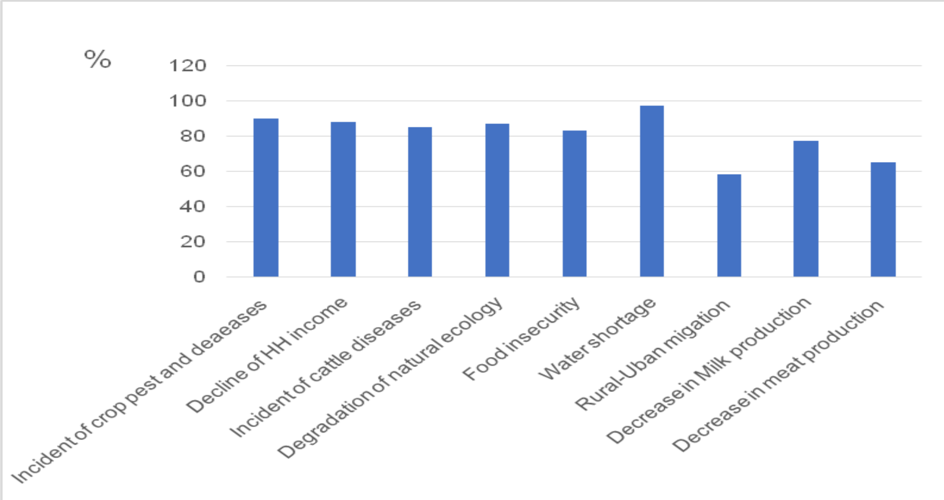

Figure 8: Perceived climate change effects on Socio-economic and environmental system
Source: Fieldwork, 2022

As portrayed in Figure 8, reported climate change effects on community livelihoods are decline of annual households' income (88.3%), increased incidences of pests and diseases in crops (90.1%) food insecurity (83.3%) and rural urban migration (with 58%of all respondents. Decreases in milk and meat production were reported by 77% and 55%of the respondents, respectively.

In terms of climate change effects on environmental and natural resources, respondents mentioned water shortages reported by 97% and degradation of natural ecology with 87.3% of all respondents. Discussion with agronomist at both Nyagatare and Gatsibo district revealed that reported that, in recent years the incidences of new diseases and pests have been a problem for crops and livestock production. Reported diseases the ones that affected Cassava and banana such as severe cassava mosaic (Kirabiranya) and banana bacterial wilt (Known as Kabore in Local language).

The most banana production losses were much observed since the occurrence of banana bacteria wilt which was first reported in 2005 and in 2012 has spread to two third of Rwanda's territory. The study on adverse impacts of banana bacterial wilt on farmers' livelihoods has estimated the banana production loss in Rwanda to be 433ha in 2007 with an economic loss of USD 638,675(Benjamin, 2016). Although the analysis of crop production loss in relation to weather variability is limited by insufficient climate data of the years where declines were observed, the World Bank report (World Bank, 2015) states that weather related risks including drought, erratic temperatures, floods, hailstorms, and landslides have posed major damages on agricultural production in 1995- 2012. Further, The IPCC (2007) report has succinctly identified the most relevant impacts of climate change on human health as "changes in conditions, temperature, rainfall, humidity, and wind likely to alter the intensity and geographical distribution of extreme weather events, raise water levels in coastal regions, alter the distribution of vector insects and mammals, exacerbate health relevant air pollution, intensify the existing burden of malnutrition, and increase human exposure to toxic substances due to the deterioration of natural and man-made environment" (Graciano, 2010)

3.2.7 Perceived effects on livestock production and productivity

The Figure 8 presents perceived effects of climate change on livestock system in the community as reported by local community.

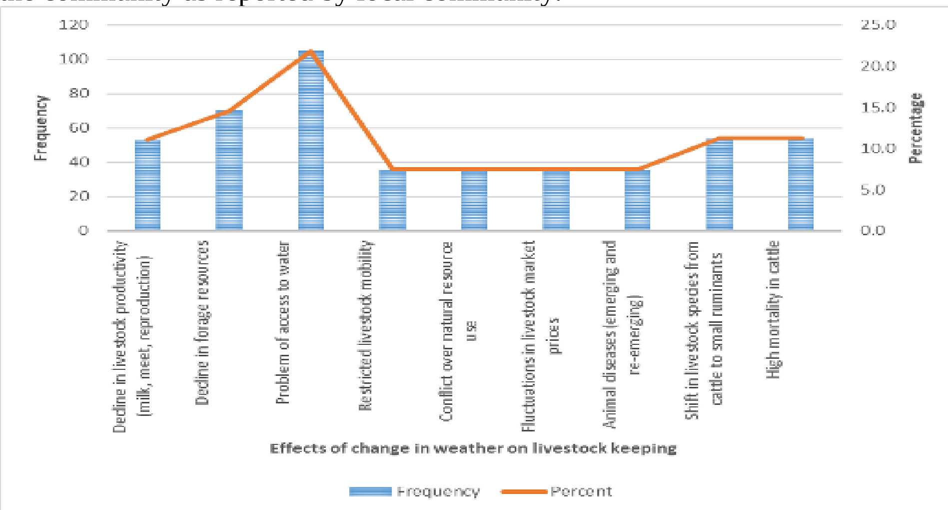

Figure 9: Perceived effects of climate change on livestock systems
Source: Field work, 2022

As illustrated in Figure 8, problem of access to water occupies the first place with 100% respondents mentioning it as measure effects of climate change on livestock systems. Other effects reported as consequence of climate change on livestock include decline in forage resources reported by 72.5% respondents, decline in livestock productivity (milk, meet, reproduction) reported by 56.6%, high mortality in cattle reported by 52.8% and shifts in livestock species (from cattle to small Ruminants) by 51.6% respondents.

It has been reported that climate change is expected to severely affect survival and production of livestock, and cattle in particular are reported to be more impacted than other livestock species due to their feeding behaviour and potential for heat stress (Nardone et al., 2010). Due to scarcity of pasture and water following recurrent drought periods in different countries, livestock have already succumbed to several climate-driven impacts including massive deaths of livestock, loss of body condition and reduced productivity (Maleko and Koipapi,2015; Magita and Sangeda,2017).

3.2.8 Perception on proposed adaptation practices and actions

This section presents adaptation actions implemented in the study area. In addition to traditional adjustments developed by local communities, new practices observed or reported in the study area are funded by international funding agencies such as World Bank Group or the International Fund for Agriculture Development (IFADA). Figure 10, summarizes traditional knowledge applied by local communities do address climate change effects. Traditional knowledge is applied as part of agriculture practices used by local communities to enhance productivity and production (Benjamin, 2016). Western knowledge is either used as part of adaptation measures or as agriculture practices.

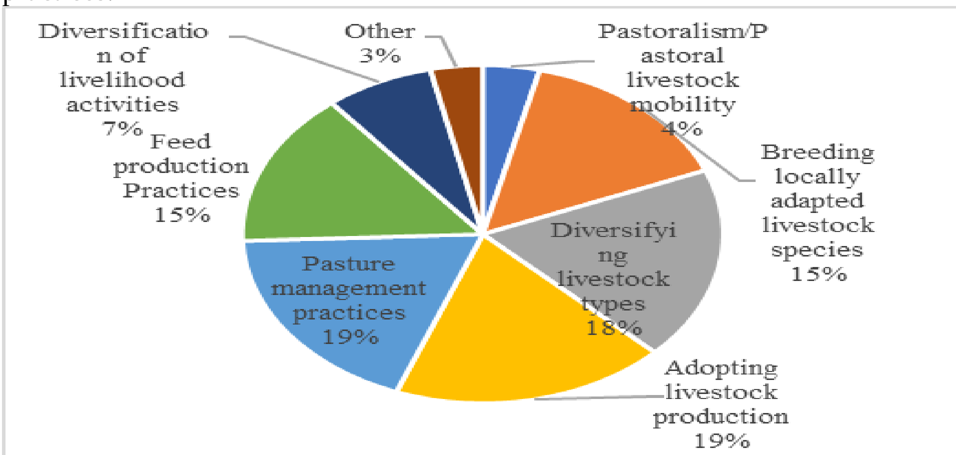

Figure 10: Traditional adjustments to address long-term shifts in livestock keeping
Source: Primary Data, 2022

As seen from Figure 10, the 3.8% reported livestock mobility as adjustment measures during prolonged drought. During this period cattle keepers moves to other areas with rainfall or keep their cattle along Akagera River. 15% of respondents has changed cattle species and opted for locally adapted livestock species, 18.5% diversifying livestock production by introducing small ruminants which does not consume a lot of fodders. These practices address not only the tolerance of livestock to heat, but also their ability to survive, grow and reproduce in conditions of poor nutrition, parasites and diseases (Hoffmann, 2008). If climate change is faster than natural selection, the risk to the survival and adaptation of the new breed is greater (Hoffmann, 2008). In Sahel region to cope with climate change effects on livestock, pastoralists use emergency fodder in times of droughts, multi-species composition of herds to survive climate extremes, and culling of weak livestock for food during periods of drought (Oba, 1997). Further, reduction of livestock numbers – a lower number of more productive animals leads to more efficient production and lower GHG emissions from livestock production (Batima, 2006).

These traditional adjustments are complemented with western technologies implemented under government funded projects. Key adjustment practices reported by local communities are presented in Figure 11.

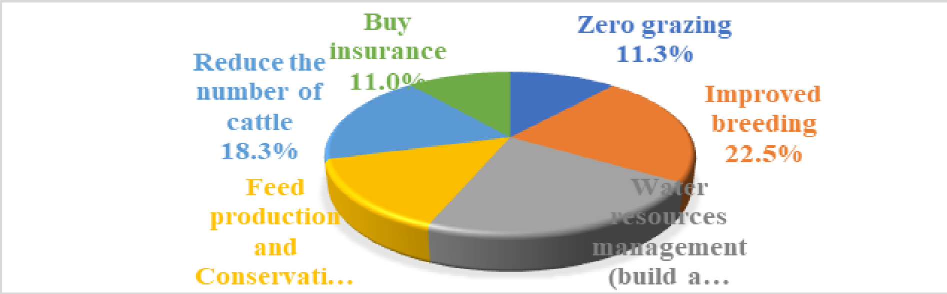

Figure 11: Western knowledge for climate change adaptation
Source: Primary Data, 2022

As seen from the above figure, people in study area have adopted or are implementing different activities against long-term shifts rainfall including improved breed with artificial insemination reported by 22% of all respondents. With these improved breeds, agro pastoralists can reduce the number of cattle and practice zero grazing. Other copying practices reported by local community include feed production and conservation technologies (14.6%) and cattle insurance (11%).

Plate 2: Feeds conservation and zero-grazing practice in the study area
Source: Primary Data, 2021

The left plate shows the fodder conservation piloted in the area while the right plate shows zero grazing practice where animals are kept in cowsheds. This practice is being promoted in entire country and even a law prohibiting extensive cattle keeping has been approved. Cattle keepers have either to keep cattle inside a fenced rangeland or construct sheds for cattle.

The Government of Rwanda (GoR) is promoting zero-grazing because it reduces over-grazing and environmental degradation. The main feed available for dairy cattle under this system is Napier grass (Mutimura *et al., 2013*). Provision of concentrate feed and conservation of fodder for supplementary feeding in dry seasons remain exceptional in both systems. Insufficient quantities of feed especially during dry spells, and low-quality diets can only support low levels of milk production, and lead to low productivity and high seasonality of production (Lukuyu *et al.* 2013; Maina *et al.* 2020)**.**

In terms water management government is investing in small scale irrigation projects where farmers are supported up to 75% of irrigation facilities including dam sheets and irrigation technologies. Most of the technologies are implemented under on-going projects such as Sustainable Agriculture Intensification Project (SAIP), Land husbandry Water harvesting, and Hillside irrigation projects funded by World Bank and Kayonza Irrigation and integrated Watershed Management projects supported by International Fund for Agriculture (IFAD). This approach will not help reducing the cost involved but also will be used to increase awareness among local community. Some of these practices are presented in figure 12 and Plate 3.

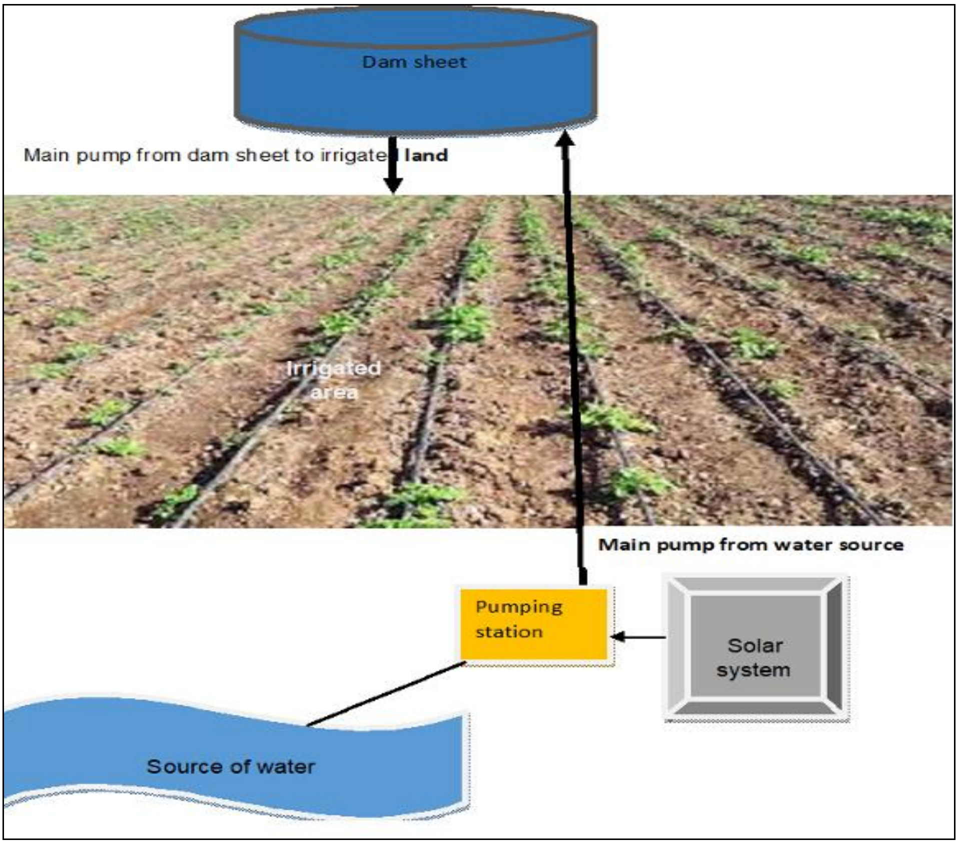

Figure 12: Small scale irrigation schemes
Source: MINAGRI. 2022

Plate 3: Small scale irrigation technology in study area and water harvesting dam sheet
Source: Field data, 2022.

It has been documented that effective adaptation to climate change adaptation in drought prone areas depends on water availability (Lukuyu *et al.* 2013; Maina *et al.* 2020). Under these conditions, improved and accessible irrigation technologies will become an important adaptation tool, especially in dry season, because irrigation practices the for dry area are water intensive. It is reported that climate change is expected to result in decreased fresh water availability (surface and groundwater) and reduced soil moisture during the dry season, while the crop water demand is expected to increase because of increased evapo-transpiration caused by climate change and the continuous introduction of high-yielding varieties and intensive agriculture (Selvaraju *et al.*, 2006).

Unfortunately, it was observed that local communities are not up taking some of the modern technologies and recommendations given by extensionist. For instance, 27.6% of respondents are using irrigation technologies while 43.3%farmers are not enthusiastic about using chemical fertilizer and herbicides or improved seeds. This is mainly due to the high cost but also their potential impacts on environment. In addition to that, communities are not well trained or sensitized on these imported technologies.

Local communities and scientists interviewed believe that the level of uptake and use of proposed adaptation measures would increase if its design considers what local community are already doing. This approach has been confirmed by other authors. For example, Chifamba (2013), reported that different projects failed because beneficiaries are not involved in the design which ultimately affects their level of ownership. It is therefore essential that state agencies and other stakeholders change that approach and establish clear, meaningful partnerships with local communities. This will help identify and address community needs and build on what is already undertaken by local communities. The local community stressed that consultation should be two ways of communication where their views are heard and considered rather than receiving instructions from authorities (Hyland-Wood, 2021). Further, Community engagement and consultation will lead to successful integration processes and could create an equitable, participatory approach, knowledge exchanges, and collaborative processes. It would also enhance the capacity building of all stakeholders, public awareness, and a culture of continuity and sustainability (Karki *et al.*, 2013).

Recent studies and research on building community resilience, especially in rural sets up, highlighted the importance of transferring and integrating a range of information using a shared learning dialogue and including indigenous and modern scientific techniques into the local social, political, and cultural context (Dixit *et al.*, 2014).This learning puts actors with different views, information, knowledge, and experience on the same ground for conversation using a participatory and problem-solving approach. Such an approach can reinforce reciprocal learning between local communities and scientists. Furthermore, using different channels and platforms can simulate continual reflection that enhances the culture of exchanging specific knowledge and perspectives between custodians of local knowledge and external experts. In addition to that, a such approach may improve effectiveness in terms of decision-making in adaptation to climate and climate risk assessment (Benjamin, 2016).

4.0 CONCLSION AND RECOMMENDATION

The objective of this research was to assess community members' perceptions and understanding of the climate change. Results of this research indicate that local communities in study area have advanced knowledge about climate change and climate variability. Reported changes include the decreased amount of rainfall during rainy season, decreased length of rain season, late onset of rain days, increase of strong winds events and increased temperature. These perception and knowledge concur with data available in meteorological services. Further, the local community are aware of climate change induced effects including shortage of water and fodder and outbreak of climate related pest and diseases.

The research noted that, over time, agro-pastoralists have developed local practices to cope with ongoing climate and non-climate changes. Some of this knowledge are still applied by local communities, while others are disappearing. Despite huge knowledge held by local communities, research results indicate that these knowledges are not considered when designing adaptation strategy at local level. Most of applied practices are brought western adaptation practices. This has cause failure of introduced adaptation measures, low level of uptake or ownership. This situation calls for changes in approaches when addressing local community challenges in terms climate change adaptation but also in other development programs.

It is important to focus on how local community perceive local challenges and what they are already coping with these challenges. This approach will help to understand how existing local knowledge and context can be incorporated into modern knowledge to design adaptation programs. With this approach, designed actions will reduce community vulnerability and enhance adaptive capacity and community resilience. It is the view of the author, that successfully adaptation to climate change will depend on a close relationship between scientific knowledge and indigenous knowledge. This should be emphasized, especially in developing local action plans where the level of education and technical knowledge remain low. This will increase the level of uptake but also ownership of local communities. Further, introduced adaptation programs should consider local characteristics but also be affordable to local communities.

Therefore, the researcher recommends that:

i) Local community knowledge and perception should be assessed and incorporated in designing adaptation actions especially at community and local level.
ii) Local communities should be empowered and trained to facilitate the adoption and integration of local knowledge into modern adaptation practices through simplified training and awareness, such as the Farmers Field School approach and formal training.
iii) The consideration of indigenous knowledge should be on how the local community can be involved in the adaptation process and how existing local knowledge and context can be incorporated into modern knowledge to design programs and actions to reduce community vulnerability, enhance adaptive capacity and community resilience.

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