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Empowering Vulnerable Livelihoods' Climate Resilience Capacities with Climate Information Services for Sustainable Future

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Abstract: *Climate change remains a critical global challenge, disproportionately affecting livelihoods in less developed countries that rely heavily on rain-fed agriculture. Climate Information Services (CIS) have been identified as an important mechanism for enhancing community resilience to climate-related shocks. This study examined farmers' understanding of climate change and environmental policies, their knowledge, attitudes, and practices regarding CIS, and the capacities required to strengthen resilience in Rwanda's Eastern Province. A mixed-methods approach was applied, involving 377 participants selected from Rwimiyaga and Rwempasha Sectors of Nyagatare District. Data were collected using structured questionnaires and interviews and analyzed through descriptive and thematic techniques. Findings revealed that farmers were generally knowledgeable about climate change and related policies. Major reported effects included droughts, prolonged dry spells, hailstorms, and windstorms. Access to CIS was reported by 87.5% of respondents, mainly through radio (52%) and television (14%), with 97% rating the information as relevant. CIS was primarily used to predict the onset of farming seasons, although only 10% expressed full trust in the information. Key capacities identified for improving resilience included improved access to CIS, training in CIS interpretation and application, provision of irrigation water and infrastructure, access to drought-resistant seeds, pest control measures, and tree planting materials. The study concludes that strengthening CIS delivery and farmer capacity is critical to enhancing resilience. It recommends the design and implementation of comprehensive CIS capacity-building programs, coupled with improved access to irrigation resources, as pathways to adaptive and sustainable livelihoods.*

Keywords*: Climate change, Resilience, Farmers, capacity building, irrigation, Climate Information Services, Eastern Province*

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1. Introduction

Climate change and variability is one of the most global challenges affecting both rural and urban livelihoods because it is increasing its intensity, spatial coverage, frequency, time and duration (Zougmoré et al., 2021). Its hazards include heat waves, rising sea levels, cyclones, storms precipitation and droughts (FAO, 2021; Gatsinzi & Byandaga, 2020). Related impacts are the global increasing hunger, poverty, loss of property, infrastructure, environment resources, humans, animals and service provision (UNEP, 2021).

Statistics show that in 2019, about 91 million people globally were affected; 361 disasters had occurred annually between the years 2000 to 2019; 90% of deaths from storms were experienced in low income countries in the last two decades (UNEP, 2021, UNISDR, 2015). In Southern Africa, the tropical cyclones Idai and Kenneth that occurred in 2019 disastrously affected Mozambique's infrastructure, schools, settlements, work places, etc. (UNEP, 2021).

To exacerbate the situation, global forecasting indicates that by 2050, 1.6 billion people living in urban centres will experience extreme high temperatures, while over 8 million living on over 570 urban centres are liable to flooding and rising sea levels. Climate hazards are further forecasted to severely affect low income and developing countries of Africa and South East Asia because these regions lack the capacity to build resilience and cope with the climate impacts (UNEP, 2021; Cuaresma et al., 2018). Studies further reveal that by 2030, around 700 million small holder farmers will be highly vulnerable, while 71 million will be food insecure (Zougmoré et al., 2021).

There is a strong link between climate change and food insecurity in East African countries, owing to shifts in growing seasons, combined with increased droughts and floods that destroy food crops, which are considered as one of the most widespread and devastating effects of climate change, potentially leading to famine in the region (Apollo & Mbah, 2021).

Rwanda is not exempted from those climate change and variability impacts. It is a landlocked country located in equatorial East Africa covering 26,338 km^2, bordering the Democratic Republic of Congo, Burundi, Uganda and Tanzania (Byamukama et al., 2011). It has steep, hilly terrain in the Western, Northern and Central regions, and low- lying terrain with rolling sandstone hills in the Eastern Region. Besides, it is a low -income country with a population of 11,809,295, of which 80% live in rural areas and are primarily depending on subsistence rain-fed agriculture (NISR, 2015). With that population, Rwanda is one of the most densely populated countries (448 habitants/km^2) in the world (NISR, 2017).

The agriculture sector is one of the pillars of Rwandan economy as it contributes to 31% of GDP, generates 60 % of the foreign exchange, provides 75 % of raw materials supplied to industries, and provides about 45 % of total Government revenues (MINAGRI, 2017; Mikova et al., 2017). Despite its great importance, the agricultural sector is challenged by climate change and climate variability consequences like drought, rainstorms and winds (Gatsinzi & Byandaga, 2020; Gasheja and Gatemberezi, 2017; Mikova et al., 2017). The current evolutions of both temperature and rainfall are predicted to continue in future where temperature is expected to increase about 1-2^{O}C (REMA, 2011), while the annual average rainfall is predicted to be irregular and unpredictable varying between negative (-) 100 mm and positive (+) 400 mm in the periods of 2000 to 2050 (NCEA, 2015).

Among the key agroclimatic challenges Rwanda faces are droughts and floods. Drought commonly happens when rains start late or stop abruptly, particularly affecting the Eastern Province (USAID, 2016). Over the last decade, the frequency and severity of natural disasters, particularly floods, droughts and landslides have significantly increased, resulting in loss of lives, crop and livestock losses, health risks, and damage to infrastructure and reduced land availability. In addition, over the past two decades, floods and droughts have affected over two million people (MINEMA, 2015).

Climate change affects mostly smallholder famers who do not have enough capacity to utilize existing adaptation practices (NBDF, 2014). Despite the increased government expenditure on environment and climate change (Tusiime & Imaniraho, 2020), the effects of climate risk disasters have significantly increased. For example, in 2020 Rwanda experienced 2,522 disaster incidents that resulted in the 298 deaths, destruction of 5,968.653 hectares of crops, 458 hectares of forests, 8,013 houses, 95 classrooms, 4 health centres, 151 roads, 102 bridges, 22 churches, 26 water supply systems and 96 electricity transmission lines (MINEMA, 2020). Other statistics indicate that from January to February 2021, disasters increased by 50% compared to previous years (MINEMA 2021).

With such climate change and variability effects, Rwanda's population become food insecure, especially the vulnerable livelihoods (Zougmoré et al., 2021). Various global and government efforts and initiatives (SDG 1=no poverty, SDG2=zero hunger, SDG3= good health and well-being, SGD 4= quality education, SDG11=sustainable cities and communities, and SDG 13= climate action; Paris agreement 2015; Rome declaration, Montreal protocol,

Kigali amendment, COP26, COP27, etc.) aim at building climate resilience, mitigation, adaptation and financing but the results are yet to be seen. (UNFCC, 2022; NEP, 2021). To address this, building farmers 'climate resilience and increasing food productivity through capacity building is essential (Hunter, 2017). Capacity building in this case is required to help vulnerable livelihoods on how to access and translate the climate information services into their farming and living livelihoods.

This study therefore aimed at assessing how climate change education at policy level is articulated at community level for uptake, the knowledge, attitude and practices of vulnerable people on climate hazards resilience, and which capacities are needed for building climate resilience, adaptation, and mitigation in Rwanda's Eastern Province.

2. Literature Review

This study was premised on the participatory approaches to building climate resilience capacities. Mugambiwa (2021) identifies 4 multi-level approaches for building climate resilience. They are communities, NGOs, local government and national/central government. Communities include schools, parents, local citizens, children, and teachers. Local government include local/community leaders-agricultural officers, local officers, health workers, and volunteers. NGOs include all actors involved in improving the livelihoods of the communities-FBOs, CSOs, NGOs. These NGOs operate at national and community level.

These approaches, however, exclude the private sector which is paramount in bringing innovations (technologies, ideas, businesses, etc) that help communities to access the climate information services, advisory services, capacity building and financial services for effective climate change resilient building (Pietosi et al., 2021; Chiang, 2017). These levels must work together in the design and implementation of policies and programs that build climate change resilience, mitigation and adaptation for vulnerable livelihoods.

Private sector is crucial because climate is noted by the US National Academy of Sciences (Brasseur & Gallardo, 2016) as an essential component of both private and public decision- making process whose information services/products when delivered on time alleviate climate risks. Furthermore, effective delivery of climate services necessitates the active contribution of the public, private, CSO, and academia (Brasseur & Gallardo, 2016).

Climate information services

Climate services refers to the creation, interpretation, transfer, and consumption of climate information into decision making in agriculture planning and policing (Brasseur & Gallardo, 2016). It is the translation of climate into products like climate forecasts, projections, economic assessments, guidance and counselling on the best agricultural practices as well as knowledge that builds, farmers' climate risk management, mitigation and adaptation (European Commission, 2015), and the de-risking of livelihoods, farms and value chains from weather and climate shocks, as well as the realignment of policies and finance facilitated means of mobilizing and creating innovative delivery channels and financial mechanisms (Zougmoré et al., 2021).

Larosa and Mysiak (2019) posit that quality-assured climate information delivery is fundamental for policy formulation and informing decisions. Climate information services supports adaptation to climate variability, and change in agriculture by informing farmer and institutional decision making, producing local climate knowledge (Djido et al., 2021). Factors hindering the effective delivery of climate services to the end users are noted as lack of sufficient awareness by the social actors on their climate change vulnerability, lack of and accessibility to climate products and services being offered by climate services providers, inappropriate channels and formats in which the climate information services are provided and lack of adequate climate services business models (Brasseur & Gallardo, 2016).

Climate Change and environmental policies

The mitigation and adaptation measures of climate change and climate change policies and education are very clearly stipulated in the international agendas and forums- UNFCCC, Kyoto protocol, Hyogo framework for Action, MDGs, SDGs, (Anderson, 2010). Key of Rwanda's climate change and environmental policies and instruments are- Rwanda Green Growth and Climate Resilience Strategy (GGCRS), Environment and Climate Change Policy, Rwanda Meteorological Agency, Vision 2050, National Strategy for Transformation (NST1& NST2), National Determined Contributions (NDCs), Law No. 48/2018 on Environment, Strategic Programme for Climate Resilience (SPCR), National Adaptation Plan, and National Land Use and Development Master Plan (UNEP, 2022; GoR, 2021; MINECOFIN, 2020; REMA, 2019).

Non-governmental stakeholders advocating and supporting the climate change resilience in the national education curricula and at the community level include UNESCO, UNEP, Plan International, Save the Children, Action Aid, UNICEF (Anderson, 2010).

To achieve that, quality climate education needs to be strongly established by the national governments. Quality climate education is characterized by quality learning whose content knowledge is based on both the scientific and indigenous knowledge, develops and integrates adaptive technologies in learning, emphasizes disaster risk reduction and disaster adaptation, environmental and climate change education, critical thinking skills, safe and adaptive schools, green schools, history and causes of climate change, knowledge and skills to differentiate between climate certainties and uncertainties, environmental degradation, mitigation and adaptation practices that yield to climate resilience building and sustainability(Gatsinzi & Byandaga, 2020; Anderson, 2010).

Studies in 10 developing countries indicate that schools can play a vital rural role in raising community awareness about climate change adaptation, mitigation and resilience through outreach community plays and drama (Anderson, 2010). Education Sector in Rwanda is considered a catalyst in attaining its development agendas- social, economic and environmental sectors. According to the ESSP 2018-2024 (Tusiime & Maniriho, 2021), the education system aims at ensuring that the citizens acquire appropriate and sufficient knowledge and skills, quality learning outcomes are enhanced, innovation and responsive research for addressing community challenges and development are emphasized. It also reflects the SDGs- quality education, climate risk management, and gender equality (Tusiime & Maniriho, 2021).
Despite that, however, challenges remain and include overcrowding, teacher turn-over, teacher motivation, pupil-teacher ratio, language of instruction, insufficient instructional resources, colonial legacy, etc. despite their existence, remarkable progress is realised to address them (Tusiime & Maniriho, 2021; Gatsinzi et al., 2020, Gatsinzi et al., 2014; Gatsinzi, 2018).

Environmental education is specifically designed by REMA and it is enshrined in the EESP for adoption in all education learning institutions-primary, secondary and tertiary (Tusiime & Maniriho, 2021). How it is incorporated in the academic curriculum design at all levels of education and how, together with other climate capacity resilience strategies are articulated at the community level, lack clarity and harmonisation.

Anderson (2010) notes a disconnection and divergence between policies, strategies and communities in regard to climate change education. Besides, the education system is publicly critiqued of not empowering communities and individuals with the sufficient and appropriate knowledge and skills for resilience building in regard to economic, social and environment sustainability. This is because, it doesn't engage communities and parents, the assessment approaches used don't lead to appropriate acquisition of the required knowledge and skills, as it is still rooted in the colonial education system (Tusiime & Maniriho, 2021).

Developing countries' challenges of climate risks demand more resources injection yet they lack proper planning to mitigate and adapt policies in a long-term manner. Despite their illustrated commitment to address those climate change risks through accurate climate information provision, budget and policy prioritization doesn't match with the exhibited commitments. (Brasseur, & Gallardo, 2016). It is also noted that they make decisions based on the developed countries' experience, yet their vulnerability assessment is contextual and is done through short term consultancies due to budget constraints (Brasseur, & Gallardo, 2016).

Perrels et al. (2020) identified the need for strong emphasis of climate knowledge and innovation in the education institutions. This can only depend on knowledge, skills and behavior change provided by a strong education system that emphasises mitigation and adaptation for sustainable living (Anderson, 2010). Based on this, a strong demand for climate information knowledge in the agricultural sector utilization is shifting from a top-down to a bottom-up, user-centric process (Bruno Soares et al., 2017).

KAP of vulnerable communities on climate change hazard resilience

Building climate resilience should base on the knowledge, attitude and practices of the concerned communities. Their knowledge should be merged with the new knowledge on how to build resilience (Twigg, 2009). Lack of awareness, inappropriate data and resource limitations are highlighted as key challenges in the provision of climate services in the EU (Perrels et al., 2020). Bulkeley (2000) perceive ignorance levels as impeding the effective involvement of the public in the climate policy process.
In developing countries, including Rwanda, communities are relying on both the traditional climate information knowledge and the knowledge they obtain from the national Meteology Centres specifically to plan their agricultural activities. In Trinidad and Tobago coastal areas, Kanhai et al. (2016) found 57% of local communities use natural signs in the environment to predict the arrival of the Tsunamis, while 92 % are unaware of the Tsunamis that hit the Caribbean in the past, while 93% lack an emergence plan for any climatic hazard.

On the same note, local communities also use some natural signs like cloud gatherings, strong winds blowing and too much sunshine to predict some climatic events. They also rely on the information provided by the Meteo Rwanda to plan their agricultural activities. For example, Meteo Rwanda via the media provides morning, afternoon and

evening weather updates every day so that local farmers can take action/decision making on how to plan their activities.

The problem, however, lies in the fact that majority local communities who have access to the media are not sufficiently informed of those weather updates. This is because they miss that information when they are busy at work or don't know exactly the timing of that climate information on their working schedules. Others don't have access to the media, and this makes them vulnerable to climate shocks.

Other sources of climate information are through local community leaders who disseminate information to communities when an extra ordinary climatic event occurs. Although awareness alone is a necessity factor in climate change and vulnerability education, it doesn't alone, lead to knowledge creation when producing climate message (Gadzekpo et al., 2018).

Da Rocha et al. (2020) in their analysis of KAP for climate change education in schools, find that teachers face difficulties regarding understanding and practicing the climate change education in the classrooms.

This shows that communities use their own knowledge to develop climate resilience and therefore, lack climate resilience education and capacities. Such climate resilience education should thus be established to raise the awareness and increase knowledge through aspects such as climate and environmental education and sustainable development that change individual behaviour (Anderson, 2013).

Building climate hazards capacity resilience

Because of climate change effects aforementioned in the introduction, building capacities in communities is viewed as the solution to counter them. The UNDRR (cited in UNEP, 2021) define capacity as "the combination of all strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resiliency" (p18). Capacity includes information and skills. Information relates to the climate information that can be obtained from the climate services. Skills imply the competencies possessed by the communities to counter and cope with the climate risks and effects.

Resilience signifies the socio-ecological system's ability to absorb instabilities without losing its ultimate organisation and function (Macchi, 2011). "The greater a community's degree of built-in resiliency, the better it will be able to cope with and recover from climate hazard" (NEP, 2021, p.18). UNDP (2016) notes that climate resilience building depends on the provision of improved climate information to vulnerable communities in an accurate, timely, reliable effective manner. The result is improved decision making that enhance sustainable living and resilience.

Information provision, usability and access to the technologies (cell phones for climate information dissemination), participatory policy making and training, establishment of early warning systems, green agriculture practices, etc. are some of the highlighted ways used in building climate resilience (Hedger et al, 2010; UNDP, 2016). This capacity building would be realised through formal and informal trainings, sensitization and risk management practices and should be gender balanced-women and girls not left out (Anderson, 2010; Hedger et al., 2010).

Adaptive capacity resiliencies for crop farmers and cattle keepers in Uganda' cattle corridor regions are noted by the GCF (2019) as the climate smart agriculture practices-small scale communal irrigation practices, agro-forestry, high-breed resistant crops and grass, post-harvesting technologies, soil conservation, water conservation, land management practices, animal feeds storage for dry season preparations, market access, as well as access to drugs and medicine. In the philipines, capacity resilience is built through the engaging communities in the education sector. For instance, parents work together with the Ministry of education to teach children about climate adaptive measures as well as how to reduce climate vulnerabilities (Anderson, 2010).

Students, teachers, parents and communities must be involved in practicing early warning, simulation drills and evacuation for expected and recurring disasters. In Kenya's Mombasa region, UNICEF worked with communities to train children and teachers to adapt to the impacts of climate change that were expected to hit the area. This was done through training them to recognize the early warning signs of floods so as to prepare for the emergencies that would emanate (Anderson, 2016). Schools as agents of community can also adapt through developing contingency plans to continue learning activities in an emergency, adapting the school calendar and exam calendar, and text book distribution. And seasonal changes (Anderson, 2010).

Hedger et al. (2010) assessed two climate capacity resilience projects in Orissa state, India, which were funded by the DFID. Some of the identified approaches used in building capacities included designing courses that increase awareness about climate change, building and acquainting the communities with capacities to adapt and cope with the climate shocks. Lack of adaptation and coping strategies to climate shocks of droughts were found to cause men to migrate, leaving behind women and children alone. It also had tremendous effects on women's

health in Mahama Sector, Kirehe district, Rwanda (Gatsinzi & Byandaga. 2020).

In Uganda, crop farmers and cattle keepers were found severely affected by climate change variations and this tremendously affected their food security (GCF, 2019). Maachi (2011) assessed the existing indigenous coping and adaptive strategies relevant to climate resilience strategies in the high mountainous regions of the Himalayas. The study found that for longer dry spells and droughts, households employed the coping strategies of traditional water sharing, and rotational irrigation. For decreased rainfalls and unpredictable onset of monsoons, rice was replaced with finger millet, delayed sowing, improvised with new crops, as well as buying rice and barter.

With the increased interest by government and increased donor funding in environment and climate related projects, one would expect to see significant reduction in the effects of climate change and climate variability. The lack of a proportionate increase in resilience and reduction in losses might be attributed to education system's gaps which studies have not fully addressed. To sustain its economic growth, Rwanda has to address the challenges of climate change through its education system.

This study, therefore, contributed towards the co-creation and co-production of knowledge for improved climate resilience among the vulnerable populations in Rwanda's Eastern Province. It aimed at assessing vulnerable farmers' understanding of climate change and environmental policies, attitude and practices of the vulnerable communities on climate hazards resilience, and the required capacities to build climate hazards resilience and adaptation.

3. Methodology

Design: This study used a participatory survey design that employed a mixed methods (qualitative & quantitative) approach. It was done through desk review and primary data collection on gaps, insights, knowledge, attitude, practices and perceptions of the vulnerable communities on the climate change and environmental policies, climate change information services, and the required capacities to building climate hazards resilience for the vulnerable communities in the drought disaster-prone areas of Nyagatare District, Rwanda's Eastern province.
Site description:

Sampling procedures. The target population was the households (women inclusive) in Rwimiyaga and Rwempasha Sectors. They were drawn from the Ubudehe socio-economic categories 1 and 2. Their population was 20139. In Rwimiyaga, the households in category 1 are 1892 while for Category 2 are 12005. For Rwempasha, the house households in category 1 are 3221and 3021 for category two (data provided by Sector Authorities, September 2022). The following formulae was used to calculate the sample size:

n = Sample size; N = Total population (20139); 1-α = Confidence (95% of confidence)

P= Normal probability value associated with the chosen sample; Z = Level of confidence; (1.96) p = 0.50; q = 1-p' e = Acceptable error (0.05).

$$n = \frac{N z_{\frac{\alpha}{2}}^2 \sigma^2}{e^2(N-1) + z_{\frac{\alpha}{2}}^2 \sigma^2} = .$$

377 participants. Meaning that in each Sector approximately 188 participants were sampled.

Data collection tools. Questionnaires were used to gather data from the vulnerable participants/communities. It contained both structured and unstructured questions. It was validated through content and face validity tests and after, it was applied for final data collection.

Data collection procedures. Data collection was preceded by the recruitment and the training of 5 research assistants. They were trained on how to use the tools, how to conduct themselves, not asking harmful questions, and how to detect and deal with the anticipated challenges during data collection exercise. They were assigned a target population from which they collected data. On ethical issues, the research participants were requested to volunteer and participate in the research exercise by providing data. The anonymity of their identity and data they provided was assured. They were requested to sign informed consent forms that were given codes for anonymity. A data collection visa/ clearance letter was obtained from the University of Bristol before data collection and was given to data collectors to present it whenever applicable during the data collection exercise.

Data analysis procedures. The collected quantitative data was screened, entered in SPSS Software, Exploratory Data Analysis performed using descriptive statistics (frequencies, percentages, and histograms, bar charts) so as to check data missing values and mismatches. Final data was analysed according to each research question. Data was presented in tables, and charts as indicated in the proceeding sections. Qualitative data analysis was performed using content and thematic analysis (sorting data, developing data codes, categorising sorted and corded data, familiarising with data, relating data, checking for

data discrepancies). This was done manually. The findings from qualitative and quantitative data were triangulated with the secondary data for validation purposes.

4. Results and Discussion

4.1. Demographic characteristics of participants

Demographic characteristics was assessed to establish the participants' family size, age category, sex, occupation, and farm size. Results are presented in percentages, and charts below.

4.1.1. Demographic information on Family size

Descriptive results on family size showed that 46.8% participants belonged to a family size of 5-8; followed by 39.1 % who belonged to a family of 3-5; and 5.1% for a family of above 8. The following chart illustrates results. These results indicate that in Rwanda's Nyagatare district, vulnerable households are characterized by large family members/ dependents which makes households impossible to make savings earned from the incomes they get from small holder faming. This results in continued poverty life living, poor welfare and unaccomplished education/dropout by children.

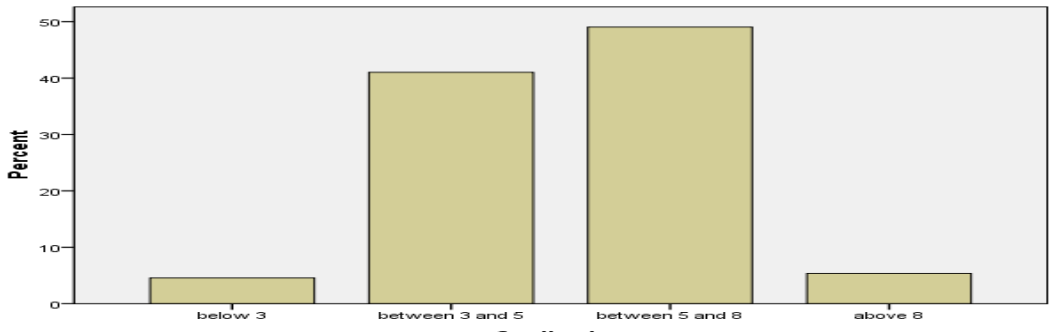

Figure 1. Participants' family size demographics

4.1.2. Demographic information on age category

Participants' age category was assessed to establish the category of participants in terms of age who are involved in agricultural activities. As indicated in figure 2, the majority participants (45.8%) belonged to age category of 20-40; 45.5% belonged to the age range between 40-60; while 3.6% were below 20 years and above 60 years respectively. This result indicates that there is no significant difference among those aged between 20-40 and 40-60. Besides, the results illustrate that both young people, medium and aged, are engaged in the farming practices in Nyagatare district.

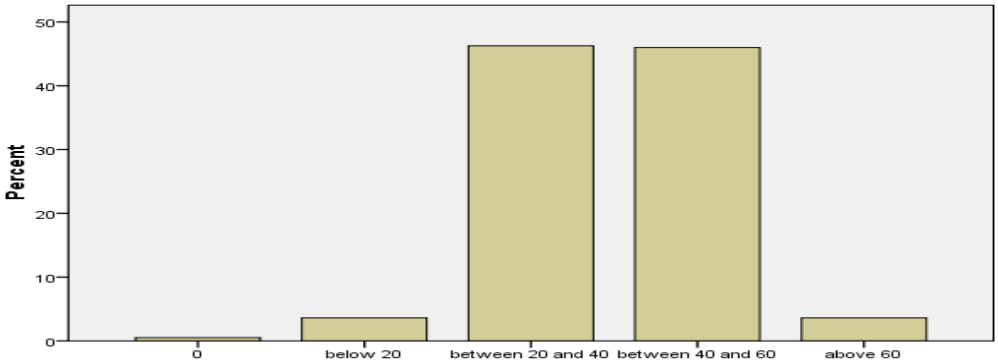

Figure 2: Participants' age category demographics

4.1.3. Demographic information on Sex

Sex differences were assessed to determine which sex is most involved in the agricultural practices which are affected by climate change and variability. As shown in the figure 3, the majority participants (60.6%) were female while 38.1% were males. The results show significant differences in percentages between female and men regarding agricultural occupation. This signifies how women are more involved in rural agriculture than men, a sector challenged by climate change risks.

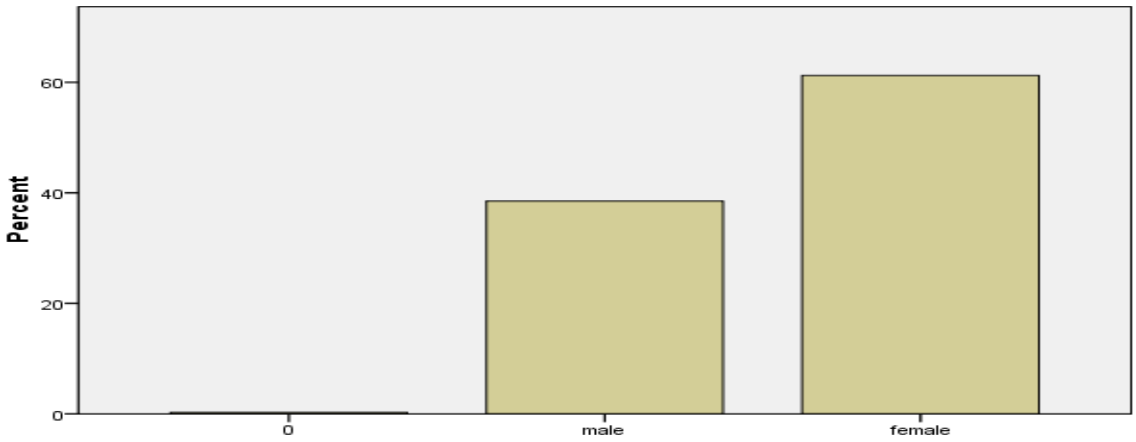

Figure 3. Participants' sex demographics

4.1.4. Demographic information on Occupation

An assessment was conducted to find out which type of agricultural practice participants were mostly occupied in. Figure 4 illustrates that the majority participants (45.5%) practiced cropping, 40.7% practiced mixed farming, while 11% practiced livestock. The results indicate most participants are involved in only cropping systems, followed by mixed farming where they both grow crops and rear livestock like cows, goats and sheep.

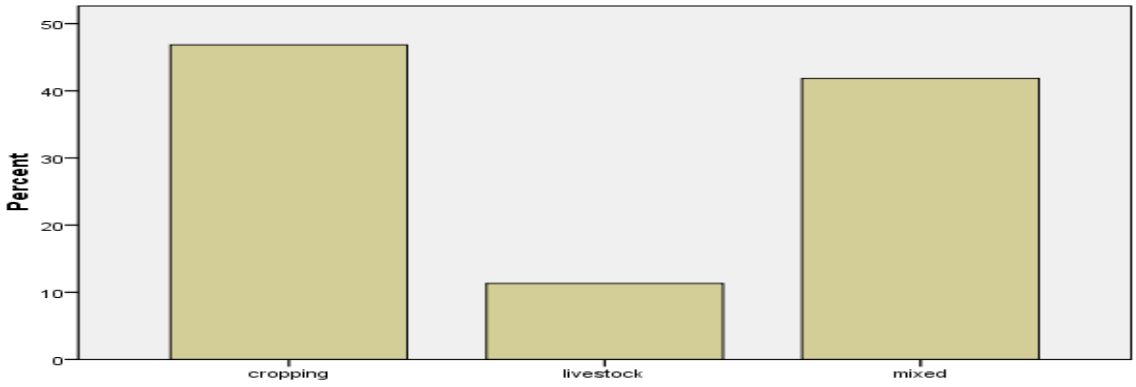

Figure 4: Participants' occupation demographics

4.1.5. Demographic information on Farm size

An assessment was conducted to find out the size of farm their participants practiced their agriculture. As illustrated in figure 5, the majority participants (47.8%) practiced farming on <05h; 28.1% practiced it on the farm having 05-1h; while 19.2% practiced it 1-1.5h respectively. This means that in the eastern province, majority are small holder farmers who need climate change intervention measures to build adaptation, mitigation and resilience against climate risks.

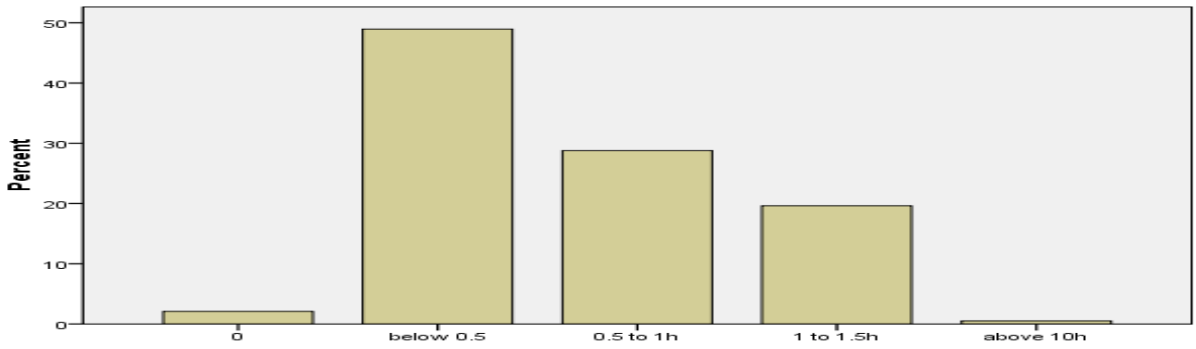

Figure 5: Participants' farm size demographics

4.2. Research Question1: Understanding of Climate Change and Environmental Policies

The first research question assessed participants' understanding ofclimatee change and environmental policies. Figure 6 indicates that the majority participants (88.7%) had climate change knowledge. Climate change was perceived as changes in seasonal onset for planting and harvesting seeds and yields caused by droughts and unpredictable rains. This climate change awareness was attributed to the prevailing seasonal calendars that differ from the traditional known ones that affect their agricultural practices and produce. They also learn it from various government campaigns about the effect of climate change and adaptation measures through MINAGRI.

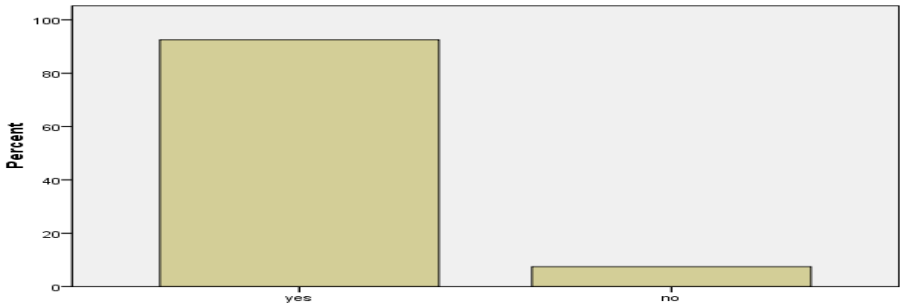

Figure 6: Descriptive statistics on climate change knowledge

4.2.1. Climate change and variability risks

A related question was asked to find out the prevailing climate change and variability risks affecting their livelihoods. Participants noted dry spells, prolonged droughts, hailstorms, unpredictable rains, and windstorms/destructive winds as the main associated risks to climate change. These climate risks do affect the seasonal onset where unpredictable rains occur and disappear, and a dry spell ensues and resultsino droughts and prolonged droughts.

These risk affects some farmers to delay planting, those who plant their seeds don't germinate. Again, some planted seeds after germination become liable to dry spells and droughts. By the time rains re-emerge, it is late for the seed plants to flower and bear fruit. Similarly, dry spells and droughts do onset when seed plants are at the stage of flowering, especially beans, thereby making them dry and produce very little no yields. Sometimes hails storms and windstorms do affect the glowing plants by destroying their leaves/branches, pods, etc. The most affected crops are maize, beans and bananas. Livestock are affected specifically by the droughts where water sources and fooder dry up, causing livestock (specifically cattle) to starve and die. All these climate risks affect the vulnerable farmers' livelihood in terms of food security, income, and health.

Challenges to adaptive measures against climate change and variability effects

While assessing the challenges farmers face when adapting and building resilience to climate change effects, the following themes emerged. We categorize them as natural, institutional behavioral and capacity challenges. Lack of adaptive knowledge, capacity in terms of resources/ facilities, poverty, capacity to harvest rain water, access to

media, climate change knowledge, expensive selected seeds, lack of information, lack of understanding to translate climate information, lack of adequate knowledge of climate information, irrigation capacity, lack of accurate information, little knowledge on climate change, lack of capacity building, access to water are the farmers' capacity challenges.

Accessibility to trees for planting, delays in getting selected seeds and fertilizers, lack of awareness, walking long distance to water sources, lack of funders, lack of land to plant trees, lack of dam sheets, high demand for firewood, and lack of agro-forestry seeds are the institutional challenges.

Behavioral challenge's themes include some farmers' minds set to adapt, resistance to change, grazing livestock in planted trees, ignorance, low participation in environmental protection, tree poachers (thieves), deforestation, bush burning, and using firewood as a source of fuel. Natural challenge's themes include unpredictable rains, too much rains, prolonged droughts, dry spells, termites that destroy planted trees and harvested fooder, soil erosion and floods due to heavy rains. These results indicate how empowering vulnerable farmers with accurate and adequate climate information and knowledge through capacity building and climate information services is crucially needed. This is based on the participants' assertions that:

> *I lack knowledge of climate information. I lack sufficient knowledge about climate information services. I need to know how to use climate information, sometimes we receive climate information of planting on time but rains delay. By the time we plant, others who received it on time are already at the second weeding stage, our planted crops then don't give the expected yields. Some farmers plant before planting time or late because they use their traditional seasonal knowledge other than basing on climate information provided by the local community leaders.*

Besides capacity building, raising their awareness on environmental protection through capacity building is utmost in changing their behavior of making livestock loiter, bush burning, deforestation, tree theft, as well participation in the environment management and protection activities and programs. This is supported by the participants' assertions that:

> *When authorities teach us about planting trees and protecting them for our benefits, some people don't value it. You find them grazing their livestock in the planted trees. Some even hide themselves and still them or cut them when they are not mature for firewood and construction purposes. You find them burning bush so that new grass grows for feeding livestock. This destroys the trees we planted as well as environment. They show less concern about the concerted efforts of others to protect environment.*

Furthermore, results illustrate how climate risks ruin the efforts farmers put in managing and protecting the environment. For example, droughts cause the planted trees to dry yet farmers have no capacity to irrigate them. They also destroy their crops and livestock when they become prolonged. For example, one participant stipulated that "we plant trees hoping they will grow old. But too much shine through droughts and dry seasons make them dry at the young age.

Termites are also reported as very active in the region and adversely attack planted trees. "Planted trees that survive droughts don't survive termites." Some participants asserted. Droughts also cause the few available water sources to dry up. Heavy rains do cause high runoffs, erosion and floods destroying the quality of soil, crops, livestock and humans. Results further indicate how farmers lack financial, equipment and knowledge capacity to practice irrigation for crops, fodder for livestock, and planted trees. They also lack capacity to harvest water for irrigation purposes as well as termite control. Some participants stressed that:

> *When we plant trees, they are attacked by termites during dry seasons and droughts. We don't have capacity to control them." This region lacks water sources nearby where we can draw water for irrigation. Even the distant existing ones become dry during droughts." Local leaders urge us to harvest rain water but we don't have capacity to buy storage facilities to store it. The ones we have are too small to store large quantity of water. The little water harvested is just used for domestic use in a short period. I cannot get capacity to travel long distance to collect water that irrigates the whole garden.*

The institutional challenges are because local leadership institutions lack financial/budget capacities to aid farmers with water bodies' construction and accessibility like dam sheets, irrigation equipment to help farmers collect and store water for irrigation, among others. These local institutions also lack budget to finance the distribution of cooking facilities like gas cookers that are environmentally friendly so that citizens abandon using firewood as a source of fuel which leads to deforestation and greenhouse emission generation.

Furthermore, these local government institutions lack capacity to create tree nursery beds that are accessible to farmers, and the capacity to establish research institutions

that help in the creation and distribution selected seeds to farmers on time, as well capacity to establish local weather stations that generate timely and accurate micro weather forecasts. Institutional challenge is further evidenced in the lack of private sector participation in the provision of weather and climate information and advisory services, establishing tree nursery beds and research centers for fertilizers and selected seeds accessibility and distribution to farmers. Furthermore, there are very few NGOS and CSOs in the region that provide capacity building and funding in climate change and environmental management, agro-climate and weather advisories, etc.

4.2.2. Climate change and environmental policies

Similarly, an assessment was done to find out whether participants were knowledgeable about climate change and environmental policies. Figure 7 demonstrates that 90.5% were knowledgeable of climate change and environmental policies. The Known climate change and environmental policies were noted as tree planting, afforestation, agro-forestry, avoiding bush burning, avoiding deforestation, irrigation, planting selected seeds with short life span, protecting environment that bring rain fall like forests and water bodies, preventing greenhouse emissions, collecting plastic bags and avoiding burning them, water management, rain water harvesting, water canalization in gardens, terracing, tying roofs, controlling soil erosion, planting, harvesting and storing fodder for livestock, land management, planting seeds basing on the weather and climate forecasts, removing households from settlements that are liable to climate risks of flooding, landslides and mass wasting, irrigating environment during dry season, marshland management, avoiding bush burning, avoiding the use of cars whose emissions harm the environment, and leaving a distance of 15 meters from the stream/river banks to farm land. These results indicate that vulnerable farmers are knowledgeable of the climate change and the existing climate change and environmental policies in their community.

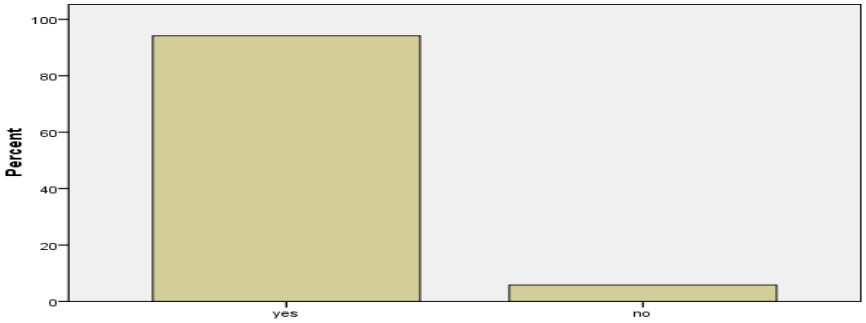

Figure 7: Descriptive statistics on knowledge of climate change and environmental policies

Results further indicated that the above climate change and Environmental policies were learned through meetings with local leaders. However, environmental policies formulated at higher levels were noted to be disseminated disharmoniously to local leaders for implementation. This caused them to lack proper implementation and community understanding at community level for sustainability because local communities lack full participation in their design.

On the question about whether those climate change and environmental policies were implemented and how the implementation was done, results showed that households didn't cut trees anyhow, sought permission from local authorities to cut them, bush burning and deforestation were punishable by government laws, they planted trees, fodder, harvested rain water to avoid causing soil erosion, cut terraces and water canalization in their gardens, tied roofs to avoid windstorms from destroying them, planted selected seeds according to weather forecasts, planting on time, agro-forestry, among others. On how they were implemented, large scale implementation was noted to be specifically done through the obligatory monthly community work (locally known as umuganda rusange).

On the question about how each individual implemented the above policies, results indicated that they abide with environmental laws, use their energy to protect environment, participate in Umuganda rusange, avoid bush burning and deforestation, seek permission to cut trees for home use and developmental activities, cut terraces and water canalization in their gardens, as well as tie their roofs against the risk of wind storms, listen to climate and weather forecasts to be updated on the seasonal changes, provide information against those who destroy environment.

Literature indicate policy gaps in Rwanda as related to policy implementation due to limited institutional capacity especially at the district and local levels, reliance on external funding, inadequate data to track progress on adaptation, emissions, and resilience for evidence-based decision making, limited private sector engagement due to unwaress, lack of incentives, or regulatory uncertainty; as well as weak inter-sectoral coordination where different sectors work in silos (AfDB, 2024; GIZ, 2023; Ndahimana et al., 2023; World Bank, 2023; NISR, 2022)

4.3 Research Question 2: Knowledge, attitudes and Practices on Climate Information Services

Research question 2 assessed participants' KAP on the climate information services. The following are results on various climate information services themes.

4.3.1 Climate information reception

An Investigation was conducted to establish whether participants receive climate information. Figure 6 demonstrates that majority of participants (87.5%) received climate information. This shows that at least the majority livelihoods have access to climate information. How they translated the received climate information, however, was the an issue hampering their resilience against climate shocks

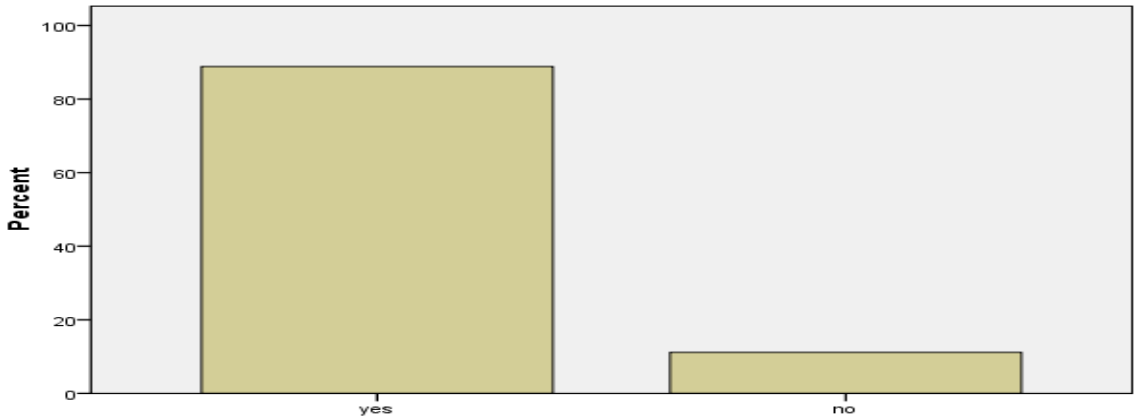

Figure 8. Descriptive statistics on climate information reception

4.3.2 Source of climate information

The main source of the climate information participants received was also investigated so as to understand from which source it was generated from. Figure 9 highlights that the majority participants indicated Radio (52%) as the main source of climate information, followed by Television (14%) and community leaders (10.2%) respectively. This means that radio is the most affordable media source that is easily accessible by the rural vulnerable farmers.

On the other hand, Television is affordable by just a few and is useful in disseminating the climate information. Community leaders and neighbors are also of vital importance in disseminating the climate information despite being few. Meaning that a small portion of community leaders and neighbors do access climate information as well as are committed to disseminate it to the farmers. This climate information is disseminated through media channels by the concerned institutions (Meteo Rwanda, RAB and MINAGRI for community uptake.

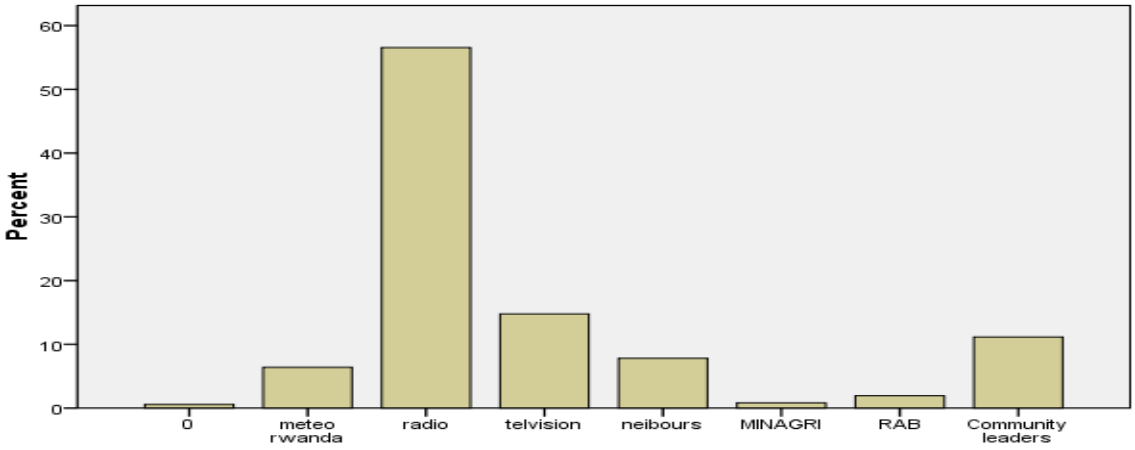

Figure 9: Descriptive statistics on the source of climate information received

4.3.3. Frequency of the reception of the climate information

The study further assessed the frequency at which participants received climate information figure 10 illustrates that 30% received weather information once a week, 26.3% received it once a day and 21.5% received it twice a day. These results show that whether they receive climate information daily or weekly, the number of those who receive it is still below. This means that majority households do practice agriculture without putting much emphasis on climate information.

On the same note, participants were assessed on the type of information they received. They highlighted that climate information they received was related to daily weather forecasts, climate change, climate change variability, when to prepare land for planting seeds, whether it will rain or shine, whether it will be hot or cold, whether it will be cloudy, the nature of humidity, among others.

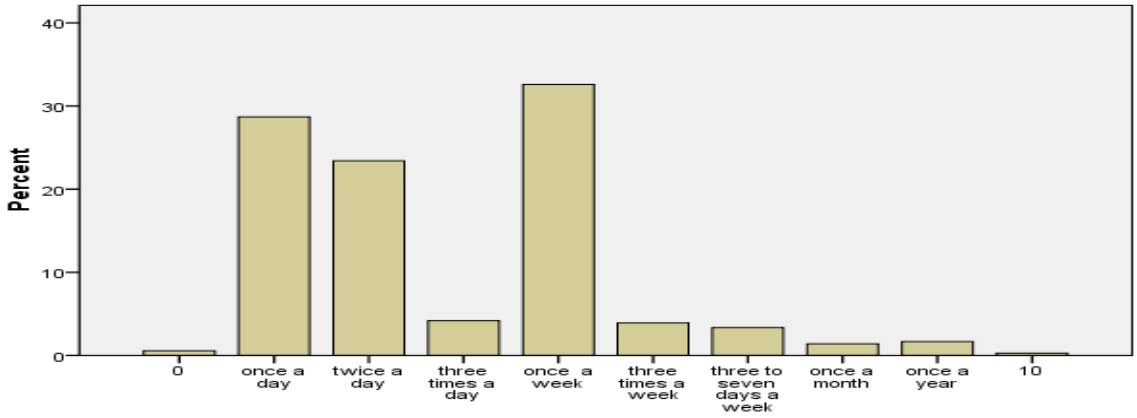

Figure 10: descriptive statistics on the frequency at which climate information is received

4.3.4. Relevancy of climate information services

The relevancy of the climate information received was assessed so as to get insights on the importance rendered to it by the participants. Figure 11 indicates that 97% noted climate information as relevant. Reasons they gave included- it helps to plant on time, do early land preparation, plan well their farming and home activities, when to dry the harvest, tying roofs against wind storms and heavy rains, when to apply fertilizers and pesticides, which seeds to plant, when to plant fodder for livestock, rain water harvesting, cutting terraces and how to plan their day. These results therefore show the relevancy vulnerable farmers render to any climate information they receive. The results further illustrate that climate information helps them to practice smart agriculture.

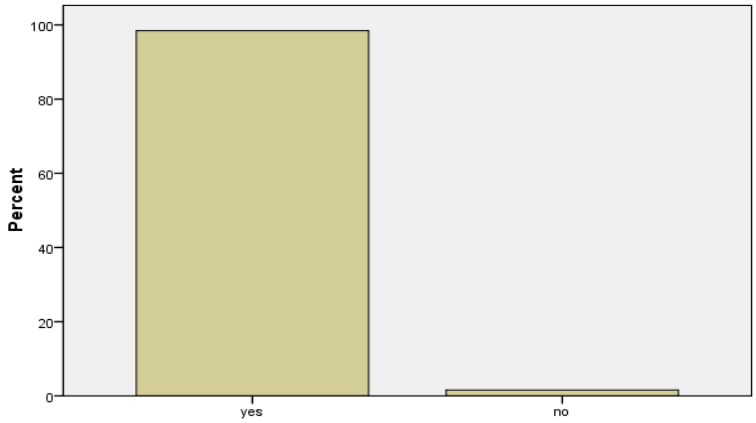

Figure 11: Descriptive statistics on the relevancy of climate information received

4.3.5. Outcomes on decisions taken for using climate information received

Results on the question that investigated the outcomes of the climate information decisions showed participants asserting that the outcomes were increased yield, yield doubles, get surplus and donate to others, plan well activities, get yields on time and become food secure, plant on time and avoid hunger, get yields and develop myself, plant early when little rain is forecasted, loss of life if climate information is not followed, monitor planting season well, measures are taken to prevent climate risks, realize changes in my planted crops, selected seeds for planting are brought on time, land preparation is done on time, losses are prevented, planting before season onset plants die, climate change/weather changes and variation knowledge is obtained. This result indicates that vulnerable farmers are aware of the outcomes of translating climate information into farming activities.

4.3.6. Level of trust of climate information services

The level of trust participants rendered to climate information was assessed to establish at what level they trust it. Figure 12 highlights that majority 48.8% trusted the weather information at the level of 75%; 32% trusted it at the level of 50%, while 10% trusted it at the level of 100%. This lack of trust by majority signifies that the provided climate information lacks locality and regional accuracy and is not precisely provided on the predetermined time. One participant, for example, highlighted the following:

> "*Someday, I received climate information via radio that it will not rain today. The whole day will be sunny. I harvested 4 tons of cassava and was drying it so that I may thresh and sell them as cassava flour. After receiving that information, I put them on a tent in the courtyard to dry in sunshine and I travelled hoping to come back in late afternoon. Surprisingly, after a couple of hours after leaving, it rained. It spoiled all the cassava and saved nothing to sell. This was a great loss for the whole season, yet I had put in investments to get the yield of 4 tonnes. That day I decided not to trust weather forecasts."*

Other participants asserted that they don't trust climate information services because when they are told dates of the season onset so that they prepare to plant, they prepare their gardens, plant seeds, and wait for the rain in vain. Their crops don't germinate. Yet their colleagues in the neighboring villages receive it.

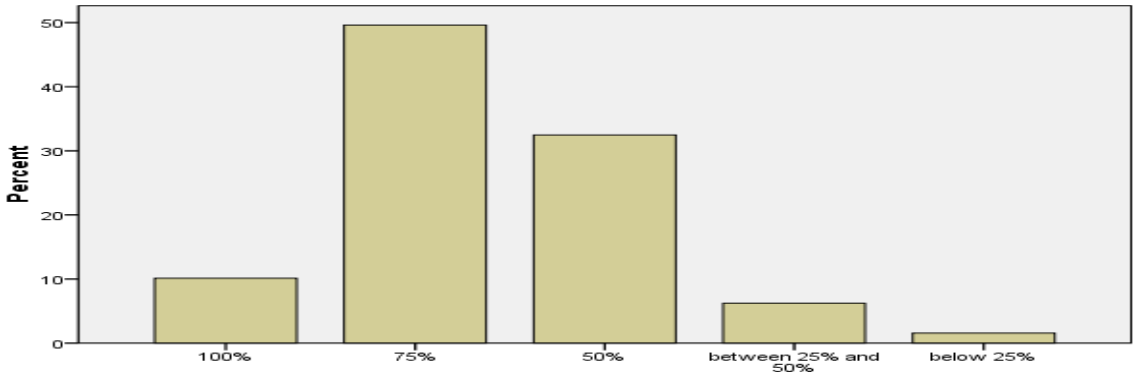

Figure 12: descriptive statistics on participants' level of trust for the climate information received

4.4. Research question 3: Required capacities for building climate hazards resilience

This research question attempted to investigate what participants perceived as the capacities they needed to build their resilience and adaptability to climate change risks. It also assessed what needs to be done for farmers to build resilience. The results were indicated in the following themes which are further classified into capacity building, materials and equipment.

Capacity building category is composed of the need for adequate and Constant Capacity building on climate change, climate change risks, measures against climate change and associated risks, irrigation, accessing water for irrigation, adequate climate change awareness raising, counselling against disasters, establishing climate change and adaptive capacities' awareness promoters, knowledge on weather forecast, adequate information on climate and weather forecast information, knowing seeds adapting to the climate/season changes, understanding effects of climate change basing on climate information, how to store water for irrigation, knowledge about the nature of the climate of their region, understanding and interpreting climate information on terraces, equipment, preparing tree nursery beds, tents for taping water, capacity building on resilient measures every season, how to protect environment, having training of trainers, access on training materials on climate disasters and climate information services , how to make terraces, knowledge on preventing effects of disasters, knowledge on when it shall rain, training on disasters, rain water harvesting, aid on basic equipment for adapting to disasters, government support, knowledge on fodder storage for livestock, government subsidies on equipment, cooking facilities affordability and adaptability, cooperating with government, capacity to access climate information, accurate and trusted climate information, forming cooperatives and getting funding, and having experts to conduct capacity building,

Equipment and materials capacities include irrigation machines, water storage facilities, tents for tapping and storing water, getting fertilizers and selected seeds on time, planting grass for livestock fodder, yields storage facilities, termites, pesticides, dam sheets installation in each local entity, and access to tree seed beds for planting. All these results indicate how majority farmers are ready for adaptation and building resilient to cope with climate change and variability risks affecting their livelihoods. Empowering farmers with such capacities is therefore needed and its success would involve the public sector, private sector, CSOs, NGOs and donor agencies.

CIS capacity building and accessibility by vulnerable farmers is tremendously important to build their resilience and adaptability to climate change shocks. This is evidenced in above results where farmers regard CIS a relevant (97%), 87% receive it, while only 52% and 14% can access it through radio and Television communication channels respectively. Despite a big number of farmers receiving CIS, their trust to it is only reflected by 10% and its use is specifically limited to understanding seasonal onset. Meaning that although they receive CIS, they lack capacity building on how to translate it into livelihood practices to gain trust. FAO (2021) highlight capacity building as involving the dissemination of what works best and training on how to understand and interpret information. The accessibility and customization of CIS to users is critical (Sanfo et al., 2022). A relationship also exists between policy and building of climate resilience to farmers (Larosa & Mysiak, 2019). Myers et al. (2017) pinpoints capacity as the main constraints the world is facing in regard to appropriately reoriented resources-water, land, etc for food sustainability.

Weather and climate information services mainly emphasize the quality production of data and lose focus of providing context specific data (Findlater et al., 2021). The channels through CIS delivered is supported by Zougmoré et al. (2021) where community radio channels were the main transmissions of the weather and climate information in Senegal. Knowledge gaps on the farmers' understanding and implementation of climate change and environmental policies is witnessed by Tusiime and Imaniriho (2020) regarding the monitoring and evaluation of environmental resources, limited coordination of initiatives and mainstreaming across sectors, as well as weak engagement of the private sector, civil society, public awareness raising capacity building and communication strategies. The more farmers easily translate the environmental policies, the more they participate in their implementation. Farmers need understanding of what climate change is, its related risks and how to overcome them, interpretation and implementation environmental policies, understanding and access to climate information services, raising awareness on climate change effects and use of climate information services (Pietosi et al., 2021).

Addressing capacity constraints faced by farmers to build their resilience is fundamental to building sustainable food security and food systems. Conducting CIS capacity building without providing materials and equipment like irrigation equipment, water for irrigation, etc. won't build farmers resilience against climate shocks. Instead, CIS capacity building should be backed by materials and equipment capacity provision so that the farmers became ready when climate shocks of dry spells and droughts

ensue. Such provisions should be appropriately established water, (Myers et al., 2017), irrigation facilities, water storage facilities, etc.

5. Conclusion and Recommendations

5.1 Conclusion

The study demonstrates that building adaptive capacity through CIS is a critical enabler for enhancing resilience among vulnerable farming communities in Rwanda's Eastern Province. While climate change and environmental policies exist, they have not sufficiently translated into community-level action due to weak policy harmonization, limited local participation in formulation processes, and inadequate dissemination mechanisms. Evidence from this study shows that project interventions improved farmers' awareness, knowledge, and engagement with CIS. However, gaps persist in trustworthiness, timeliness, and localization of climate data. Many farmers lack the technical skills to interpret forecasts and transform climate information into actionable, climate-smart agricultural decisions. Furthermore, resource limitations particularly access to irrigation exacerbate their vulnerability to increasingly frequent and severe climate hazards.

The study also highlights the value of social capital and knowledge co-production, as multi-stakeholder interactions during the project fostered networks between researchers, communities, and local and global TESF hubs. These relationships constitute an important pathway for sustainable learning and resilience building, as described in resilience theory and community-based adaptation approaches.

This study was however, limited to communities in Rwanda's Eastern Province's two Sectors of Nyagatare District, which may restrict the generalizability of its findings to other agro-ecological zones. The study was also conducted within the timeframe of TESF project cycle, which limited the ability to assess long-term behavioral changes and sustainability of resilience practices. In addition, reliance on self-reported knowledge, attitudes, and practices may have introduced some bias.

5.2 Recommendations

Integrate CIS capacity building into resilience strategies by establishing structured, iterative training programs grounded in participatory learning frameworks (e.g., farmer field schools) to strengthen skills in interpreting, evaluating, and using climate information for adaptation, mitigation, and risk management. Enhance accuracy, timeliness, and localization of climate data through deploying decentralized weather monitoring infrastructure and data-sharing platforms that deliver hyper-local forecasts, thereby improving trust and enabling evidence-based decision-making at household and community levels.

Promote inclusive and co-produced climate governance through institutionalizing community participation in the formulation, dissemination, and implementation of climate and environmental policies to ensure contextual relevance and to reinforce bottom-up resilience planning. Strengthen Access to Climate Adaptation Resources through investing in small-scale irrigation, rainwater harvesting systems, and climate-resilient agricultural inputs to reduce reliance on rain-fed agriculture and buffer communities against climate shocks. Support knowledge networks for resilience by consolidating and expanding multi-actor partnerships created during the project to facilitate knowledge co-production, innovation diffusion, and long-term resilience building across scales. By prioritizing these actions, the study contributes to the discourse on sustainable futures by demonstrating how locally embedded CIS interventions, aligned with resilience and adaptive capacity frameworks, can transform vulnerable livelihoods in climate-stressed regions into sustainable livelihoods.

Future research should focus on:- conduct longitudinal studies to evaluate the long-term impact of CIS interventions on behavior, adoption of climate-smart practices, and livelihood outcomes. They should compare different models of CIS delivery (e.g., digital platforms, farmer cooperatives, extension services) across multiple agro-ecological zones. They should also explore the role of trust, social learning, and co-production in sustaining the uptake and effective use of localized climate information. Lastly, they should investigate how gender, age, and socio-economic differences influence access to and benefits from CIS. Such studies will generate robust evidence for scaling up CIS interventions as part of national climate resilience strategies.

Conflict of interest

All authors declare that this work was done without competing interests or personal relationships that might have resulted in the bias of work. It was also done without competing interests emanating from the institutions the authors are affiliated to.

Author contribution

Patrick Gatsinzi contributed through study conceptualization, design and methodology; coordinated

data collection exercise and participated in the analysis and report writing.

Livingstone Byandaga contributed in the study conceptualization, data screening, literature review, methodology, analysis, report writing and editing.

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References

Anderson, A. (2010). *Combating climate change through quality education.* Washington, DC: Brookings Institution.

AfDB. (2024). *Green finance and private sector engagement in East Africa*. African Development Bank Group.

Brasseur, G.P., & Gallardo, L. (2016). Lesson learned and future prospects. https://doi.org/10.1002/2015EF000338.

Byandaga, L., & Gatsinzi, P. (2020). Innovative approaches to the co-production of climate services in Rwanda. *Jriiejournal.com*/content/uploads/2020/08/Jriiejournal.com-4-3-015.pdf.

Bulkeley, H. (2000). Common knowledge? Public understanding of climate change in Newcastle, Australia. *Public Understanding of Science, 9*(3). https://iopscience.iop.org/article/10.1088/0963-6625/9/3/307/meta

Chiang, E. (2017, December 15). ICT4Ag trends: to bundle or not to bundle? *Blog.* https://taroworks.org/ict4ag/.

Crespo Cuaresma, J., Fengler, W., Kharas, H., Bekhtiar, K., Brottrager, M., & Hofer, M. (2018). Will the Sustainable Development Goals be fulfilled? Assessing present and future global poverty. *Palgrave Communications*, *4*(1).

da Rocha, V. T., Brandli, L. L., & Kalil, R. M. L. (2020). Climate change education in school: knowledge, behavior and attitude. *International Journal of Sustainability in Higher Education*, *21*(4), 649-670. https://doi.org/10.1108/IJSHE-11-2019-0341.

European Commission (2015). *European research and innovation roadmap for climate services*. Directorate-General for Research and Innovation, https://data.europa.eu/doi/10.2777/702151

Findlater, K., Webber, S., Kandlikar, M., & Donner, S. (2021). Climate services promise better decisions but mainly focus on better data. *Nature Climate Change*, *11*(9), 731-737.

Gatsinzi, P., Byandaga, L. (2020). Effects of climate changes in women's health in Mahama Sector. *Jriie journal.com*. https://jriiejournal.com/category/vol-4iss-3/.

Gatsinzi, P., Ndacyayisenga, W., Mukamazimpaka, C., & Mugisha, J.K. (2020). Ensuring quality education in poorly resourced and over-crowded classrooms. *Jriie journal.com.* https://jriiejournal.com/wp-content/uploads/2020/04/Jriiejournal-4-2-12.pdf.

Gatsinzi, P. (2018). School facility planning in Rwanda. An assessment survey on the nature of public school libraries in the selected public schools of Muhanga, Nyanza, Karongi and Ngorero districts. *Baraton Inter-disciplinary Research Journal.* https://www.ueab.ac.ke/wp-content/uploads/2019/03/Patrick-Gatsinzi.pdf.

Gatsinzi, P., & Byandaga, L. (2020). Climate change and gender issues: The effects of climate changes on the women's health in Mahama sector, Kirehe district, Rwanda. Available at: https://jriiejournal.com/category/vol-4iss-3/.

Gadzekpo, A., Tietaah, G. K., & Segtub, M. (2018). Mediating the climate change message: Knowledge, attitudes and practices (KAP) of media practitioners in Ghana. *African Journalism Studies*, *39*(3), 1-23.

GCF. (2019). *Advancing adaptive capacity and resilience of vulnerable communities and ecosystems to climate change.* https://www.greenclimate.fund/sites/default/files/document/22730-enhancing-adaptive-capacity-

and-resilience-vulnerable-communities-and-ecosystems-climate.pdf.

GIZ. (2023). *Enhancing Climate Services in Rwanda: Gaps and Opportunities*. Deutsche Gesellschaft für Internationale Zusammenarbeit.

GoR. (2020). *Updated Nationally Determined Contributions (NDCs)*. Ministry of Environment.

GoR. (2021). *Green Growth and Climate Resilience Strategy: Revised Edition*. Ministry of Environment.

Hedger, M., Singha, A., & Reddy, M. (2010). *Building climate resilience at state level: Disaster risk management and rural livelihoods in Orissa*. UK: Institute for Development Studies

Jeans, H., Castillo, G.E., & Thomas, S. (2017). *The future is a choice: absorb, adapt, and transform resilience capacities.* Oxford: Oxfam UK.

Kanhai, L. D. K., Singh, D., Lauckner, B., Ebi, K. L., & Chadee, D. D. (2016). Knowledge, attitude and practices of coastal communities in Trinidad and Tobago about tsunamis. *Natural Hazards*, *81*(2), 1349-1372.

Macchi, M. (2011). *Framework for community-based climate vulnerability and capacity assessment in mountain areas*. Nepal: ICIMOD.

MINECOFIN. (2020). *National Strategy for Transformation (NST1)*. Ministry of Finance and Economic Planning.

Myers, S. S., Smith, M. R., Guth, S., Golden, C. D., Vaitla, B., Mueller, N. D., ... & Huybers, P. (2017). Climate change and global food systems: potential impacts on food security and under nutrition. *Annual review of public health*, *38*, 259-277.

Ndahimana, F., Uwizeyimana, D., & Umutoni, M. (2023). Decentralization and climate adaptation in Rwanda. *Rwanda Journal of Policy Studies*, 8(2), 45-63.

NISR. (2022). *Rwanda Statistical Yearbook 2022*. National Institute of Statistics of Rwanda

MINEMA. (2020) *Annual Report 2020*. Available at: Disaster_Damages_January-December_2020.pdf (minema.gov.rw).

MINEMA. (2021 February 24). Submission of MINEMA during the National Climate Outlook Forum on 24th Feb 2021. Kigali.

Mugambiwa, S. (2021). Multilevel Approach to Climate Change Adaptation in Rural Zimbabwe: A Well-articulated Framework Devoid of Effective Implementation. *African Journal of Development Studies*, *11*(4), 159.

Perrels, A., Leb, T, cortekarc, J., Hoab, E., & Stegmaierd, P. (2020). How much unnoticed merit is there in climate services? *Climate services, 17*, 10053. doi:https://doi.org/10.1016/j.cliser.2020.100185.

UNEP. (2021). *A practical guide to climate-resilient buildings and communities*. Nairobi: UNEP

UNISDR. (2015). *Sendai framework for disaster risk reduction 2015-2030*. Geneva: UNISDR.

REMA. (2019). *Environment and Climate Change Policy*. Rwanda Environment Management Authority.

Twigg, J. (2009). *Characteristics of a disaster resilient community: A guidance note*. University College London.

Tusiime, M., & Imaniriho, D. (2020). *TESF Rwanda background paper*. Bristol, TESF. https://doi.org/10.5281/zenodo.4331474.

UNDP. (2016). *A new vision for weather and climate services in Africa*. New York: UNDP.

Pietosi, M., Tricarico, D., & Chassin, L. (2021). *Agri-DFS: Emerging business models to support the financial inclusion of small holder farmers.* London: GSMA.https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/10/Agri-DFS-Emerging-business-models-to-support-the-financial-inclusion-of-smallholder-farmers.pdf.

UNDP. (2023). *Rwanda Climate Resilience Programme Mid-Term Review*. United Nations Development Programme.

UNEP. (2022). *Africa Climate Policy Implementation Outlook*. United Nations Environment Programme.

World Bank. (2023). *Rwanda Climate Finance Tracking*

Report. Washington, D.C.: The World Bank.

Zougmoré, R. B., Läderach, P., & Campbell, B. M. (2021). Transforming food systems in Africa under change pressure: Role of climate-smart agriculture. *Sustainability*, *13*(8), 4305.