Investigating Indigenous Knowledge Developed by Agro-Pastoralists to Cope with Climate Change and Variability in the Agro-Pastoralism Region of Rwanda

Théogène Habakubaho[1*]
Emmanuel Patroba Mhache[2]
Josephat Saria[3]

Abstract

The main objective of this research was to assess indigenous knowledge developed in the agro-pastoralism region of Rwanda to cope with climate change. The study was conducted in drought-prone area of Nyagatare and Gatsibo Districts. Four hundred and eighty (480) households of agro-pastoralists were sampled randomly in 40 villages and interviewed. Focus Group Discussion and interviews with key informants were also used for data collection. Data were analysed using SPSS Statistics 28.0.1. Results indicated that local communities are traditionally using cloud/sky colour (80.6%), change of temperature during the day (66.5%), direction and strength of winds (58.8%) and lightning and thunder (46.3%) in weather forecasting. Further, locally made pesticides (42.9%), burning of pastures and farm residues (41.3%), early hand-weeding (59.8%), early planting (61.5%), indigenous medicines (33.3%) and indigenous crops and livestock breeds (61.0%) are used for diseases and pest management. Further, farming and grazing along rivers and wetlands (61.3%) and tolerant or early maturing crops (51.9%) are used for drought. Based on these results, the researcher concludes that there is evidence of the role of indigenous knowledge in adaptation to climate change. I, therefore, recommend that indigenous knowledge should be incorporated into the adaptation process, especially at the community level. This would include formal recognition, empowerment of its custodians, and simplified training and awareness.

Keywords: Indigenous knowledge, Climate change, Adaptation, Agro-pastoralism

[1]Department of Environmental Studies, Open University of Tanzania (OUT)
[2]Department of Geography, Open University of Tanzania (OUT)
[3]Department of Environmental Chemistry, Open University of Tanzania (OUT)

*Corresponding author's email: habathe2008@gmail.com
Received on January 18th, 2023/Accepted on July 10th, 2023

Ghana Journal of Geography Vol. 15 (3), 2023 pages 48-91
Doi: https://dx.doi.org/10.4314/gjg.v15i3.3

Introduction

Recently, there has been increasing recognition of the importance of indigenous knowledge in climate change adaptation (IPCC, 2022b; IPCC, 2022c; IPCC, 2019). The IPCC defines indigenous knowledge as the "understandings, skills, and philosophies developed by societies with long histories of interaction with their natural surroundings" (IPCC, 2022a). Indigenous knowledge brings fundamental aspects of life, from day-to-day activities to longer-term actions and decision-making (IPCC, 2022a). Understanding the differences between knowledge systems and their roles in local decision-making is key to extending climate services and informing climate change adaptation actions. This approach is critical, especially in most sub-Saharan African countries, where climate data, weather forecasting infrastructure, and services are often lacking (Hansen et al., 2011, Africa Adaptation Initiative, 2018, Singh et al., 2018, Trisos et al., 2022).Literature has demonstrated that agro-pastoralists and small farmers in the world have historically coped with climate change effects (Graham et al., 2021; Turek-Hankins, 2021; Williams et al., 2021; Leal Filho et al., 2022b; Trisos et al., 2022). When adapting to climate impacts, agro-pastoralists in Sub-Saharan Africa have relied on available knowledge that they trust and can easily access in climate decision-making. This includes using indigenous knowledge (Filho et al., 2022) and the implementation of adaptation measures (Ajani et al., 2013; Zuma-Netshiukhwi et al., 2013; Nkomwa, 2014; Grey, 2019; Mekonnen et al., 2021). Case studies assessing and documenting how agro-pastoralists and small farmers developed and used indigenous knowledge has been conducted in the last decade. It is the case of research conducted in Malawi (Ngongondo et al., 2021; Bucherie et al., 2022); Namibia (Schnegg, 2019); Zambia (Mbewe, 2019); Zimbabwe (Jiri et al., 2015; Soropa et al., 2015; Gwenzi et al., 2016; Tanyanyiwa, 2018; Mafongoya et al., 2021); Botswana (Mogomotsi et al., 2020); Tanzania(Theodory, 2016); Ethiopia(Dereje et al., 2021); and South Africa (Kom et al., 2022, Rankoana, 2022).

While it has been established that indigenous knowledge developed by local communities is a valuable asset for climate change adaptation (Adger et al., 2014), this knowledge has not been utilized consistently in the adaptation efforts and has frequently been overlooked in policy formulation and project design (Adger et al. 2014; Jones et al., 2014; IPCC, 2014b). Further, this approach is privileged when developing countries like Rwanda do not have access to the scientific knowledge. This includes lack of access to financial resources and technical knowledge required for the implementation of the proposed actions. Consequently, persisting climate change and variability continue to cause heavy loss to the country and communities.

In the above context, this paper aims at contributing to the ongoing efforts in promoting the use of indigenous knowledge. There are two research objectives that guide the work. What are indigenous knowledge developed and used by agro pastoralists in study area? What are the challenges associated with the use of indigenous knowledge in adaptation process.

Theoretical framework of study

This research employed the Situated Learning Theory (SLT) to identify and assess indigenous knowledge developed by agro-pastoralists in the study area. According to Lave and Wenger (1991), every idea and human action is a generalization, adapted to the ongoing environment and it is founded on the belief. What people learn, see, and do is situated in their role as a member of a community (Lave and Wenger, 1991). The assumption in SLT is that knowledge is acquired through situations and is passed on to similar situations. Further, learning is the result of a social process that includes ways of thinking, understanding, problem solving and interaction (Lave, 1988).

SLT concurs with indigenous methods of learning whereby the acquisition of indigenous knowledge by any given community involves a process of learning and knowing. Indigenous knowledge must be learned, respected, shared and received by people who encounter it. It must also be understood and disseminated to others within the community through generations. In the African context, indigenous methods of learning and knowing did not begin with the arrival of Western knowledge systems, and their future is independent of Western knowledge. Like other human societies all over the world, all indigenous people have accumulated their own experiences and explanations from their surrounding environments for centuries (Kimwaga, 2010). This is because the learning process at the community level is specific to their culture.

Thus, specific ways of knowing and learning towards knowledge production are often referred to as indigenous, ecological, traditional, community or local knowledge systems (Kaya, 2015). Such knowledge includes systems of information, understanding, interpretation and interactions with the natural environment. It applies to farming and livestock keeping, fishing, hunting, natural resource management, health control, the naming and explanation of natural phenomena, as well as the adaptation strategies (Semali and Kincheloe, 1999; Kante, 2004; Horsthemke, 2004).

The benefits SLT are to illustrate the existing contradictions between the knowledge learned from school vis-à-vis the knowledge learned from day-to-day experiences. As it has been discussed earlier, indigenous knowledge is culture-specific and is transmitted from generation to generation through oral traditions and practices. The learning process of indigenous knowledge involves active participation as opposed to more passive methods often used in western learning. However, it is worth to note that learning processes can only be successful if they are integrated in all types of social activities, which provide the basis for learning (Tiu, 2007). On the other hand, in the process of learning in western knowledge, specifically for adaptation to climate change, local communities are constantly involved in co-participation to advance more their skills.

Materials and Methods

Study area description

This study was conducted in Nyagatare and Gatsibo Districts, formerly known as Umutara Region. These two districts are in the Eastern Province of Rwanda located on Tanzania and Uganda borders (Figure 1). A big part of the two districts used to be part of the Akagera National Park and was opened to human settlement in 1996 to host major influx of returning refugees and their livestock from neighbouring countries. According to the national statistics, agriculture including cattle keeping is the major source of income, with 70.4% of the total population (NISR, 2014). High dependence on rain-fed agriculture and livestock makes them more vulnerable to climate change induced hazards, especially prolonged drought, and reduced rainfall (REMA,2018).

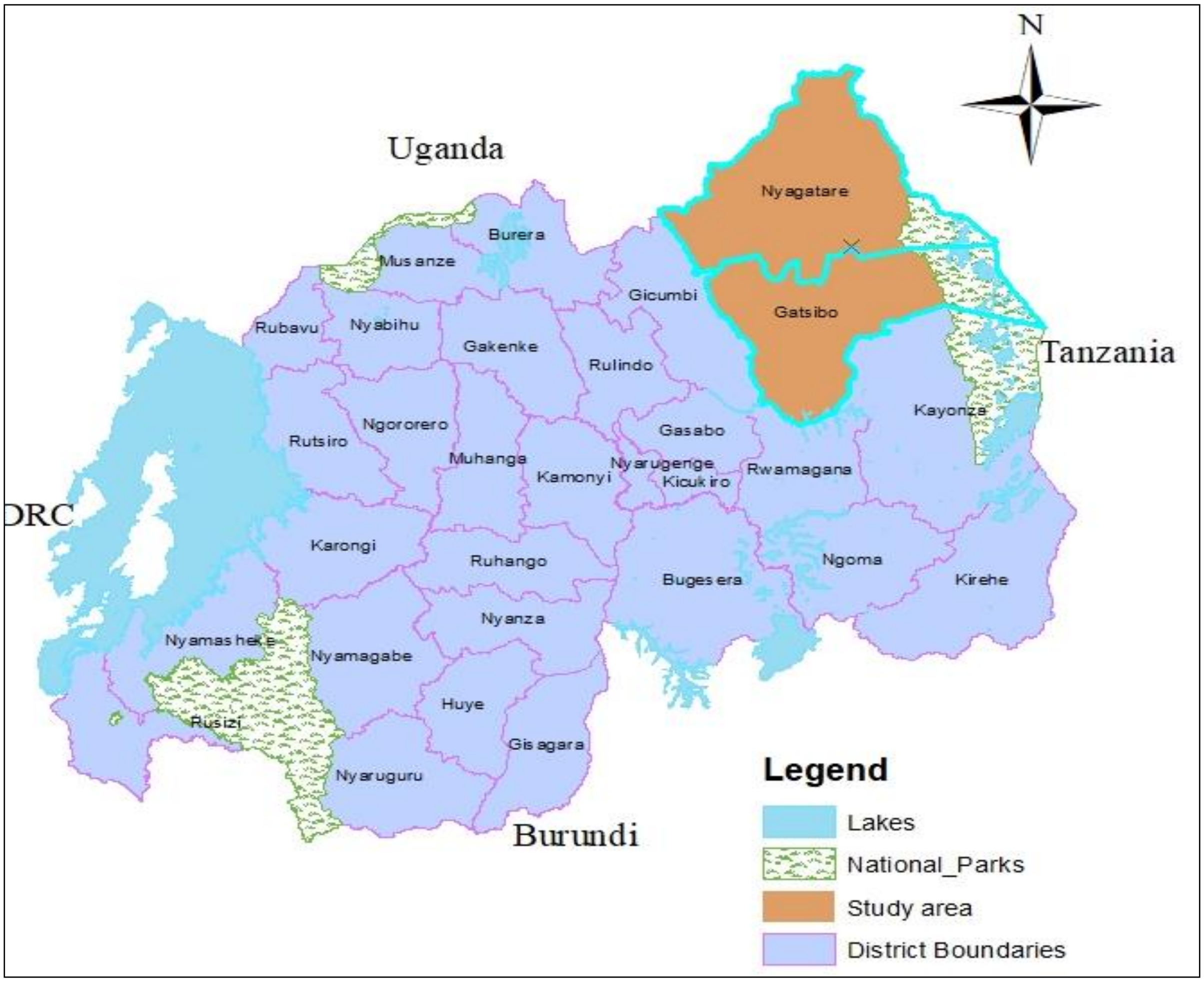

Figure 1. Location of study area on the administrative map of Rwanda

Source: Prepared by author-based national base map, 2022

The Eastern Province, the most drought-prone region in the nation, has been facing rainfall deficits for the past 20 years (Figure 2). According to the observations made between 1961 and 2018, 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. (Ministry of Disaster Management in Rwanda,2018). The two districts are experiencing a protracted drought, which is characterized by a substantial number of dry spells, late rainfall onsets, early rainfall cessations, and frequent rainfall deficits (MINAGRI, 2020). Famine, food shortages, a decline in plant and animal species, and the eviction of people in search of food and pasture are frequently the results of these 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 (Government of Rwanda, 2018).

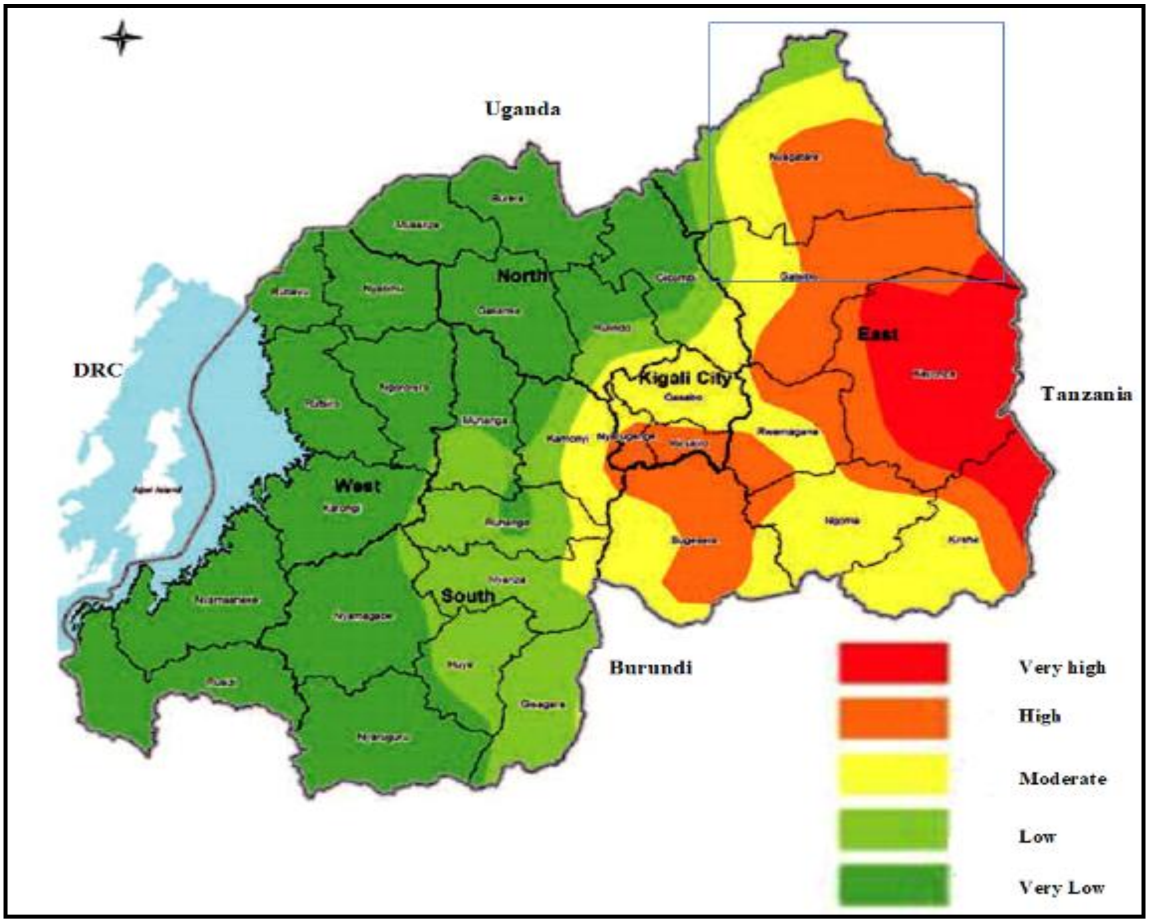

Figure 2: Location of the study area in drought susceptibility in Rwanda

Source: National disaster atlas, MIDMAR, 2018

Additionally, the research area was chosen because it is situated in an agro-pastoral zone where pastoralism is the primary source of income (Figure 3). Unfortunately, the pattern of the rains varies from year to year, and the weak (827 mm/year) and erratic annual rainfalls are insufficient to meet the demands of agricultural and pastoral activities (REMA, 2018).

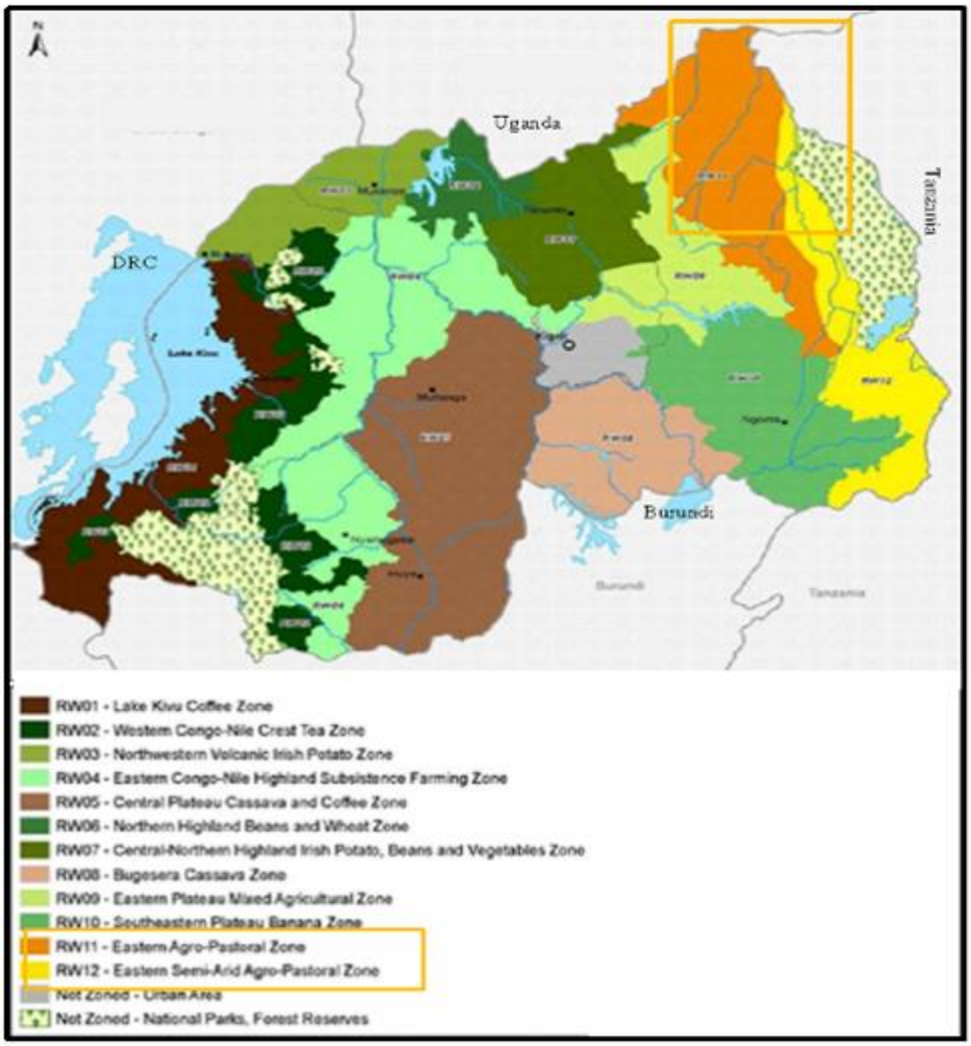

Figure 3: Location of the study area in the agro-climate zone of Rwanda

Source: USAID and FEWS NET, 2011

Research methodology

This study used a mixed research approach combining - qualitative and quantitative. Primary data were obtained through interviews with professionals, community leaders, chosen elders, and well-known members of the neighbourhood. On the other hand, focus group discussions involved cooperative leaders and chosen members of the community. Additionally, quantitative data were gathered using a household questionnaire. Secondary data were obtained from documents and reports held by various governments institutions, results of academic research, and research books on climate change and agro-pastoralism.

Given that this research aimed to identify and document indigenous knowledge developed by agro-pastoralists to deal with climate change, the researchers interviewed experts and officials dealing with environment and climate change, agriculture, natural resources and livestock from planning, research and technical selected.

At the district level, the interviews were conducted with officers dealing with the subject matter including agronomist, veterinary officer, and District Environment Officer. Further, two officers one dealing with agriculture and another dealing with livestock, were selected for each sector. At the central government level, 7 institutions dealing with agro-pastoralism, environment, and climate change were selected sectors. Institutions considered included the Rwanda Agriculture Board (RAB), Rwanda Environment Management Authority (REMA), Rwanda Green Fund (FONERWA), Ministry of Agriculture (MINAGRI), Ministry of Environment (MoE) and Rwanda Water Board (RWB). Further, researchers and experts in high learning and research institutions were interviewed based on their involvement in agro-pastoralism, environment, or climate research.

At the household level, the Researcher targeted agro-pastoralists in Nyagatare and Gatsibo Districts (Table1). Total agro-pastoralists in the area were obtained from the 4th National Census of Population and Habitat (NISR, 2012). The target population was 65,402 households, including 33,717 households in Nyagatare District and 30,822 households in Gatsibo District. The population is large, so the researcher sampled 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

Systematic random sampling was used to sample villages where households (with cattle) 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). Then, on a list sorted A-Z district by district where 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.

To determine the sample size at household level, the researcher relied 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 main target population for the study was the agro-pastoral households in Gatsibo and Nyagatare Districts. Table 2 shows the sample calculated for households.

Table 2: Sample distribution and selection for sectors in Umutara Region

Sectors	Total targeted population	Sample Size	Sampling Method
Number of sectors (14 of Gatsibo and 14 of Nyagatare Districts)	28	n=28/(1+(28*(0.3618730)^2)=6	Systematic sampling method
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, 2022

Households were selected in six sectors of Nyagatare (3) and Gatsibo (3) Distracts. For each sampled sector, a sample size was calculated based on a total sample of 480 households for two districts. Thus, from Rwimbogo, 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.

Data analysis and data presentation

The objective of data analysis is to obtain information that is usable and valuable. In this research, qualitative and quantitative data were analysed, interpreted, and presented using different methods. Focus group discussions and interviews with key informants were transcribed, translated, and entered word documents. Then, the responses were separated into two groups: local government officials and farmers/livestock owners. Using a content analysis methodology, all categories and themes were evaluated and filtered based on their utility in answering the research objectives.

Questionnaire-derived quantitative data were analysed using the Statistical Package for Social Science database (SPSS Statistics 28.0.1.). This software generated 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 and Discussion on Indigenous Knowledge Developed by Agropastoralists

This section presents and discusses findings on indigenous knowledge developed by agro-pastoralists, roles but also the challenges associated with their application in adaptation to climate change. Indigenous knowledge and practices identified in study area are grouped into four categories: knowledge used for weather forecasting, knowledge to address prolonged drought and reduced rainfall, knowledge against pests and diseases and knowledge against strong wind events.

Indigenous weather and meteorological practices in the study area

This section presents and discusses indigenous indicators used by the community to understand weather behaviour and plan their agriculture activities accordingly. Indigenous knowledge reported by local communities in terms of the weather forecast are presented in table 3.

Table 3: Indigenous weather forecast practice in the study area.

Indicators	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	%
Observation of cloudy/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 in 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: Questionnaire results, 2022

According to Table 3, the predominant traditional knowledge in the study area is the observation of sky colour 387(80.6%), change of temperature during the day 319(66.5%) direction and strength of winds 282(58.8%), followed by lightning and thunder with 222(46.3%). These results are in line with another study conducted in African countries (Tume et al., 2019) who reported the indicators of indigenous knowledge of weather forecasting including extreme temperatures (55.9%), star constellations (60%), as well as sequencing of yearly weather events (42.9%) to determine what the climate would be in a farming season. During an interview with community leaders, one respondent named Joseph Sebakire (65 yrs old) said:

> *"....unusual changes in temperature combined with heavy black clouds announces heavy rain while clear cloud there is good weather coming".*

The same person indicated that the presence of a rainbow suggests no rain. Though these indicators are not well documented and streamlined as scientific weather forecasting, they are almost the same as indicators used by meteorological services or scientists and weather forecasting. This highlights the critical role of indigenous knowledge in predicting and applying weather forecasting at the local level, thus agreeing with the recent regional and global findings by Trisos et al. (2022), Berrang-Ford et al. (2021) and IPCC (2022c). Further, this confirm recent IPCC findings on how indigenous knowledge can be a foundation for climate adaptation at the local level in Africa (Trisos et al., 2022).

Indigenous practices to cope with prolonged drought and reduced rainfalls.

The prolonged drought and shortfall of precipitation are the major concerns in the agro-pastoralism area of Gatsibo and Nyagatare Distracts. Over a decade, the local community has tried to overcome this challenging situation by developing different practices. Table 4 summarizes indigenous practices developed and used by agro-pastoralists.

Indigenous knowledge identified by respondents are dominated by farming and grazing along rivers and wetlands with 294 (61.3%) and planting drought tolerant and early maturing crops with 249(51.9%).

Farming and grazing along rivers and wetlands.

During prolonged droughts or reduced rainfall, wetlands and riverbanks remain the only resources viable for agriculture and livestock production in the study area because the hillsides were dried up. Respondents reported that agriculture and cattle keeping are done only in wetlands and on river buffer zone during these challenging periods. Some key water bodies mentioned by local people are Muvumba and Akagera rivers. The local community has practised this practice over decades. An interview with the Nyagatare district livestock officer revealed that over time “cattle keepers have been moving along Akagera and Muvumba rivers in search for water and fodder during prolonged dry seasons". It was observed that this practice is disappearing because of the law prohibiting any activity in the buffer zones of rivers and lakes.

Table 4: Indigenous practices against prolonged drought and reduced rainfall

Indigenous adaptation practices	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	%
Farming and grazing along rivers and wetlands	42	52.5	48	61.5	45	64.3	48	58.5	52	61.9	59	68.6	294	61.3
Planting of drought-tolerant and early-maturing crops	34	42.5	34	43.6	38	54.3	47	57.3	51	60.7	45	52.3	249	51.9
Mulching of farmland	58	72.5	54	69.2	47	67.1	43	52.4	56	66.7	52	60.5	310	64.6
Food reserve in Granary (ibigega)	23	28.8	31	39.7	24	34.3	32	39.0	25	29.8	6	7.0	141	29.4
Reducing livestock herds	18	22.5	21	26.9	13	18.6	13	15.9	19	22.6	27	31.4	111	23.1
Indigenous prayers	5	6.3	7	9.0	5	7.1	4	4.9	3	3.6	3	3.5	27	5.6

Source: Questionnaire results, 2022

According to the water pollution control officer in Rwanda Water Board, the law has established a buffer zone of 10 m from riverbanks and 50 m from lakeshores. In these buffer zones, only protection and conservation activities are allowed. However, local communities reported that they are still using these areas illegally with risks of being fined if caught.

To help local communities, the government supported the construction of valley dams, but they did not last and dried up only a few years after construction. The main reason for this failure, as reported by local communities, was the inadequate ecological studies that did not consider the local characteristics especially high level of evaporation in the observed in the area.

Even though such adaptation practice causes wetland degradation and conflicts between farmers, it remains essential in arid and semi-arid regions, especially in climate change. The same practice is also undertaken by other communities in neighbouring countries and regions affected by prolonged drought. For instance, in Tanzania, agro-pastoralists depend on lowlands to undertake grazing during long drought seasons. In Addition, varieties of crops including maize, rice, beans, sweet potatoes, cassava and cotton are grown in the lowland areas (Theodory, 2018).

Planting of drought-tolerant and early-maturing crops

In drought prone areas, local communities have adopted drought tolerant crops and early growing crops to prevent crop failure because of reduced rainfall or short rain season. Most of these crops were based on local seed varieties that do not provide high yields but are tolerant to reduced precipitation. Local communities reported that these crops are preferred to other crops introduced by government extension officers, mainly hybrids. According to agro-pastoralists, hybrid seeds have high yields, but the probability of failure due to short spells of rain is very high.

Other researchers have also confirmed the significance of drought-tolerant and early-maturing crops in climate change adaptation. Adoptions of climate-resilient crops was reported as one of the most important and as the practices combat food insecurity caused by unpredictable changes in weather patterns. Most importantly, this practice is essential for rural relying on domestic production for food security. Climate-resistant plant species have enhanced tolerance to biotic and abiotic stresses (Dankher et al., 2018). Such crops and crop varieties increase the climate change resilience of farmers. Nevertheless, despite their benefits, adoption rates of certain cropping systems by small-scale farmers are lower than anticipated (Lin, 2011; Gollin, 2005).

This practice has been reported in other African countries such as Ghana. Tambo (2016) also provided some of the most prominent measures that are used in Ghana. According to his research, the farmers use drought-tolerant or early maturing crop varieties, mixed cropping, crop switching and tree planting. The last one is usually used by cattle keepers as shade trees to protect their livestock during heat stress.

Mulching farmland

The practice of mulching is mainly known for horticulture, but local communities have adopted it for most crops, including a banana plantation. Long drought seasons contribute to moisture stress in the farmlands, and mulching practices reduce moisture stress. Furthermore, the mulching practice is known for its advantages in terms of water conservation and fighting the germination of weeds in farmlands. Currently, the government is doing a lot in terms of the provision of irrigation facilities to deal with climate change's effects. However, mulching practices remains popular among local communities, especially due to low investment.

Plate 1: Mulching practices in the study area

Source: Field observation, 2022

Plate A shows mulching practices in Banana Plantation, which aims to maintain moisture for long period to counter the effects of the prolonged dry season. On Plate B it's a mulching practice for vegetables (tomatoes) and is used for water conservation in small-scale irrigation schemes.

Mulching, which consists of coating the soil's surface with organic matter, is an ancient practice (Jacks et al., 1955) that has been utilized to control soil moisture, temperature, nutrient loss, salinity, soil structure erosion, etc. Mulching has regained significance due to climate change, high temperatures, landslides, and flash floods. It has been established that various mulches minimize soil erosion by more than 90 percent compared to bare agricultural land (Mostaghini et al., 1994). Similar indigenous knowledge and practices were reported especially in dealing with declining soil quality and productivity.

Some of these practices include bush fallowing, organic manuring, intercropping, crop rotation, agroforestry, and conservation tillage. Bush-fallow involves the use of natural fallows to regenerate or restore soil fertility by the farmers. In some areas, leguminous plants are used for quick restoration of soil fertility. Example, Centrosemaspp is used to fix nitrogen into the soil to improve its fertility (Ajani et al., 2013).

Establishing food reserves in traditional Granary (ibigega)

Prolonged drought is often accompanied by food insecurity due to the failure of planted crops and the huge investment made by farmers during planting. To overcome these problems, agro-pastoralists took preventive measures to constitute food reserves just in case one or two seasons failed. One of these measures was to construct a traditional granary and put a portion of different products, especially when there was sufficient rains and high crop yields. During such seasons, the households stored extra harvests that are not easily perishable such as maize, beans and cassava. The conserved products were then used during prolonged drought season. A member of the local communities interviewed acknowledged that saving food for future use was helpful to most households in terms of food security. The challenging part of this practice was that only specific crops were stored, especially the non-perishable ones like sorghum and maize.

Currently, the government is reintroducing this system in the form of post-harvest infrastructure. According to the chairman of the task force for post-harvest and food storage in the Ministry of Agriculture, these infrastructures improve food security. Unfortunately, this initiative was not built on a traditional granary system and communities were not involved in the design, which may justify the low rate of patronage. Communities are concerned with the security of their crops in the shared facility and the accessibility of this facility whenever they need to use their stored food. The same indigenous knowledge has been documented by other authors, especially in Africa. For example, Djekore (2016) reported that in Mali, the community has developed an endogenous crop storage technique in the form of granaries as a response to climate change. This approach has allowed the Massa community to develop capacities and build governance and planning tools to master the technique of food conservation for food security.

The transmission of knowledge has been passed down through the generations. As safeguards are taken to protect production and combat food insecurity, the technology contributes to the reduction of potential risk. It enables the selection of high-quality seeds in anticipation of the upcoming rainy season. Its execution requires the availability of biomass-powered eco-construction equipment. The granaries, which are constructed in banco-style structures with conical straw roofs, are simply modest storage buildings where harvest products are kept.

Undertaking non-farm activities

Diversification of income-generating activities is not new in the area. Repetitive long droughts and the decreased rainfall in the Eastern Province have reduced agriculture and livestock production, pushing community members to get involved in non-farm activities. Those include fishing in Umuvumba and Akagera rivers and small trading. Others were involved in hunting activities, since the area is closer to the Akagera National Park. However, this practice is disappearing because of the protection of the park and other protected areas. It has been established that non-agricultural activities would give an alternate source of income, especially in the light of climate change.

The rural communities have diversified their means of subsistence and income-earning portfolio across agricultural, non-agricultural, and non-rural endeavours. Thus, non-agricultural income-generating activities have become a crucial element of rural households' efforts for sustaining their livelihoods (Agbarevo and Nmeregini, 2019). According to Ovwigho (2014), farmers, and rural farm families in particular, engage in a variety of non-farm income-generating activities to compensate for the income shortfall caused by the seasonality of primary agricultural production and to create a continuous income stream to meet the various household needs.

Indigenous practices against climate change-induced pests and diseases

Table 5 summarizes the indigenous knowledge developed by agro-pastoralists to cope with an outbreak of climate-related pests and diseases.

Table 5 Indigenous knowledge developed by agro-pastoralists

Indigenous knowledge	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	%
Use of Locally made pesticides	23	28.8	31	39.7	28	40.0	53	64.6	34	40.5	37	43.0	206	42.9
Burning of pastures and farm residues	23	28.8	18	23.1	37	52.9	38	46.3	32	38.1	50	58.1	198	41.3
Early hand-weeding	47	58.8	47	60.3	46	65.7	53	64.6	42	50.0	52	60.5	287	59.8
Early planting	65	81.3	46	59.0	35	50.0	51	62.2	48	57.1	50	58.1	295	61.5
Use of indigenous medicines	13	16.3	22	28.2	33	47.1	28	34.1	35	41.7	29	33.7	160	33.3
Use of indigenous crops and livestock breeds	48	60.0	45	57.7	47	67.1	45	54.9	58	69.0	50	58.1	293	61.0

Source: Questionnaire results, 2022

The indigenous knowledge reported by respondents includes the use of locally made pesticides 206 (42.9%), Burning of pastures and farm residues 198 (41.3%), early hand-weeding 297 (59.8%), early planting 295 (61.5%), use of indigenous medicines 160 (33.3%) and selection of indigenous crops and livestock breeds 293 (61.0%).

According to Kumar and Lassaad (2009), management of crops and pests vary among indigenous farmers practicing indigenous farming systems in different countries. This is attributable to the differences in indigenous knowledge accumulated over generations and which are found appropriate for developing a sustainable and locally adapted agriculture system. This dual knowledge has been recognized and scientists are taking a keen interest in traditional agriculture. Traditional farmers and their techniques may be of considerable assistance in addressing the weaknesses of modern pest management (Sofia et al., 2006).

Other reported practices such as Burning of pastures and farm residues are not recommended because has other detrimental effects such as release of soot particles and smoke causing human and animal health problems. It also leads to emission of greenhouse gases namely carbon dioxide, methane, and nitrous oxide, causing global warming and loss of plant nutrients like N, P, K and S (IARI, 2012).

Adaptation practices against strong wind events

The wind is another climate hazard that has hit the Eastern Province over decades especially due to its topographic conditions characterized by lowlands. In the face of these effects, agro-pastoralists have developed practices with the aim of reducing the effects of strong winds on crops and properties. Coping practices reported by respondents are presented in Table 6.

Table 6: Indigenous knowledge to cope with strong wind events

Indigenous Knowledge	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	%
Sylivo-Pastoralism and Agro-forestry practices	58	72.5	53	67.9	44	62.9	55	67.1	57	67.9	53	61.6	320	66.7
The use of tree poles to support banana crops	40	50.0	39	50.0	32	45.7	45	54.9	44	52.4	40	46.5	240	50.0
Indigenous Vertical roof	14	22.5	17	21.7	12	17.1	9	10.9	11	13.1	19	22.1	82	17.1
The use of supernatural power	6	7.5	5	6.4	4	5.7	7	8.5	8	9.5	7	8.1	37	7.7

Source: Questionnaire results, 2022

Indigenous knowledge reported by respondents includes agroforestry with 320(66.7%) of respondents, the use of tree poles to support bananas with 240 (50%), traditional construction techniques with 82(17.1%) and the use of supernatural power with 37(7.7%) of respondents. Similar practices have been reported in the region. According to Theodory (2016), the Haya community in Tanzania uses tree poles to support banana trees when the trees yield heavy fruit. The farmers have widely used this practice to adapt to strong wind events, which may fall into the banana plants. Further, Gyampoh et al. (2009) noted that the rural communities in Ghana recognised the relevance of having trees on their firm to shade their crops from high sunshine and protect them against strong wind.

Plate 2: Banana supported by Tree poles

Source: Field observation, 2022

Plate 2 presents the use of a pole to support the banana. Local communities reported that they have practised this knowledge for decades to reduce losses encountered during strong winds, which often accompany heavy rains. However, according to respondents, the use of poles to support bananas had been challenged by the lack of poles because these poles were collected in natural forests and National Park, which are now protected. Local communities must, therefore, rely on a few trees collected in their woodlots or modern poles made of steel, but the latter is very expensive. Tree planting in rangelands or farmlands is another technique still used to encounter the effects of strong winds. These trees are mainly intercropped with other crops or planted in rangelands to increase land cover and provide shade for cattle during the hot season. Soil scientists also recommend such practice as it increases soil fertility. According to the District Environment Officer (DEO), the Nyagatare district has received funds from the National Adaptation Program (NAP) to implement Sylivo-Pastoralism in the district. These funds will supplement local communities' efforts and contribute not only to controlling wind but also to improving pastures.

Construction of traditional houses with steep roof pitches is another indigenous knowledge to cope with strong wind disasters in agro-pastoralists. As seen in Plate 3, these houses with round forms have walls made of trees and mud and steep roof pitch made of grasses and bamboo. Local communities reported that such design was introduced to face strong winds that were blowing out the roof of their houses. Elsewhere, it has been proven that building geometry has a significant impact on the distribution of wind pressure on the surface of the roof and walls of the building. A pyramidal roof was found to have the lowest uplift compared to a gable roof and hip roof (Shreyas, 2015).

Plate 3: Indigenous steep roof pitch

Source: Field observation, 2022

It is difficult to find such structure in the area because they were removed in 2020 when the Government of Rwanda decided to eradicate all structures made of grasses in the" Turwanye Nyakansi" campaign. It worth noting that the same roofing techniques can be seen on modern housing but with tiles in the place of grasses and this design is now popular around Rwanda. This shows how indigenous knowledge can inspire modern design, as presented on Plate 4.

Plate 4: Modern steep roof pitch

Source: Field observation, 2022

Indigenous coping practices against water shortage

Water shortage is another effect of climate change in the study area. Table 7 summarizes indigenous technologies employed to cope with water shortage as reported by respondents.

Table 7: Indigenous technology to deal with water shortage in the study area.

Knowledge used by the local community	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	%
Rainwater harvesting for irrigation	66	82.5	61	78.2	55	78.6	69	84.1	67	79.8	66	76.7	384	80.0
Planting of indigenous trees	29	36.3	34	43.6	23	32.9	36	43.9	34	40.5	38	44.2	194	40.4
The use of indigenous wells	38	47.5	37	47.4	31	44.3	49	59.8	55	65.5	52	60.5	262	54.6
Supernatural power	3	3.8	5	6.4	5	7.1	6	7.3	4	4.8	8	9.3	31	6.5

Source: Questionnaire results, 2022

As presented in Table 7, indigenous knowledge against shortage of water includes rainwater harvesting which was reported by 384(80.0%) of respondents, planting of indigenous trees by 194 (40.4%), the use of traditional wells by 262 (54.6%) and traditional taboos 31(6.5%). These findings are in line with earlier works of Olatokun and Ayanbonde (2008) where 44% of respondents reported the use indigenous knowledge in farming and drought risk reduction. Moreover, these findings corroborate those of the UNEP (2008), where indigenous knowledge is still an integral part of most African local communities involved in agriculture.

On the other hand, irrigation methods are the most reported adaptation response and implemented by most communities and farmers across the African continent. This includes expanding the irrigation capacity in Kenya, Zimbabwe, Zambia, and Ethiopia and improving irrigation water use efficiency through adoption of efficient irrigation systems and local irrigation water saving techniques, such as drip irrigation, using local initiatives in countries such as in Morocco (Aziz and Sadok, 2015); South Africa (Elum et al., 2017); Uganda (Nakabugo et al., 2019); and Ethiopia (Yohannes et al., 2019).

Other technique used for water management include tree planting whereas agroforestry is used as a catchment management approach used to control soil erosion and retaining water in the soil. Radical or progressive terraces accompanying with ditches are also used with indigenous trees which do not consume a lot of water. Indigenous trees planted include species such as *Dracaena afromontana*, *Ficus thoningii*, *Erythrina abyssinica*, *Euphorbia tirucalli* and *Verminia amygdalena*. Some of these species are presented on Plate 5.

Markhamia lutea (umusave)

Acacia sieberiana (umunyinya)

Plate 5: Indigenous trees identified in study area

Source: Field observation, 2022

Using trees and agroforestry in climate change adaptation is not unique among agro-pastoralists in Rwanda. Scientific research has documented that forest and tree products, including timber and non-timber products are essential in many communities especially those affected by climate variability and climate hazard risks. For example, McSweeney (2005) reported that during and after the dry spells of 2005–2006 in the semi-arid areas of Tanzania, households consumed forest products directly as part of their food intake and earned 42% of their total income from selling wild fruits, firewood, timber, and charcoal. In rural areas of Peru, gathering forest fruits, palm hearts, and other products is an important strategy for coping with floods (Gordon et al., 2008). Forest products also play a part in post-disaster strategies in Honduras: rural households sold timber and other products to recover from land losses during Hurricane Mitch (Takasaki et al., 2005).

Challenges and opportunities in using traditional knowledge

It would be fallacious to believe that indigenous knowledge alone can address climate change impacts. The present research has identified significant challenges that need to be urgently addressed to enhance the benefits offered by indigenous knowledge.

Challenges of sustaining and promoting the use of indigenous knowledge

Different challenges were identified during an interview with experts and local communities as presented in Table 8.

Table 8: Causes of the disappearance of indigenous knowledge

Challenges	Ranks
Socio-economic transformation	1st
Poor reputation	2th
Decrease of the custodians	3nd
Exclusion in the formal adaptation	4rd
Absence of knowledge-sharing culture	5th
Vanishing of indigenous seeds, plant species	6th

Source: Results of Focus Group Discussion, 2022

As portrayed in Table 8, socioeconomic transformation and poor reputations were ranked 1st and 2nd-second major reasons for the disappearance of indigenous knowledge, respectively. This is in line with other research findings; for instance, Theodory (2016) reported that in the Ngono River Basin, Tanzania, one of the main indigenous knowledge challenges is poor reputation within the community. Most the elders who perform those practices are considered by the community to be wizards, which has a negative connotation.

For instance, during discussions, some participants associated indigenous knowledge with sorcery or considered them as outdated practices. Some custodians of this knowledge are considered by some wizards (abapfumu). This perception discourages those who want to learn more about this knowledge, especially the young generations. In addition, the government institutions have failed to recognize and support indigenous knowledge. The absence of knowledge-sharing culture or the disappearance of indigenous culture were also reported as challenges in the preservation of indigenous knowledge.

According to respondents, addressing this challenge requires awareness and adequate documentation of the indigenous knowledge of the people. The awareness campaign should focus not only on the custodians or users of the indigenous knowledge, but also on scientists or experts since some of them have a biased understanding of the role of indigenous knowledge.

On the other side, there are challenges such as socio-economic development or exclusion of indigenous knowledge in the formal adaptation processes that require changes in policy formulation and investments. The socio-economic development brings new practices, beliefs, and cultures, ultimately altering indigenous knowledge. For instance, the savannah region of the eastern province was primarily dedicated to cattle keepers, but now they are mixed with other communities. This has disturbed the social structures used to generate indigenous knowledge among the agropastoral system. Further, urbanization, market development introduction of a new education forms and religion have exposed indigenous knowledge.

Other areas that need more thought are the disappearance of indigenous seeds and medicinal plants. Over the last few years, research and outreach have focused on scientific discovery to the neglect of indigenous knowledge. For instance, agriculture agencies are putting their efforts into developing hybrid seeds not adapted to a prolonged drought season. In the same time context, respondents indicated that traditional medicinal plants had disappeared due to the lack of proper support for their conservation and multiplication. This has also been exacerbated by population pressure on forest resources.

Furthermore, approved policies and strategic plans indicate that indigenous knowledge has been excluded in climate change assessment and adaptation. As highlighted earlier, national adaptation and mitigation plans are developed based on western knowledge which excludes local knowledge.

Consequently, the important role of indigenous knowledge in climate change adaptation and local characteristics are not well captured.

Another challenge reported during the focus group discussion (Table 8), is the exclusion indigenous knowledge when it comes to funding. Participants indicated that much attention and investments are put into technologies imported from western countries. According to most of the participants, traditional knowledge should be given the same attention, researched, documented, and validated, which can help in climate change adaptation initiatives.

Importantly, the omission of indigenous knowledge is not accidental but rather systematic. According to Berenstain et al. (2021); Cooke (2004); and Lloyd and Wolfe (2016), the suppression of indigenous knowledge has been and remains a characteristic of settler colonialism and the oppression of indigenous peoples in general.

On the other hand, interviews with key informants confirmed that the current adaptation practices focus on scientific knowledge, although with some challenges. For instance, during an interview with experts in national authority dealing with climate change (REMA), it was revealed that even some of the introduced technologies are harmful to human beings and the general environment. For instance, the recent study commissioned by REMA in 2018, indicated that farmers are moving away from conventional and organic farming practices and now are using agrochemicals (REMA, 2018). This change is motivated by the introduction of the inputs subsidy policy. According to the same report, the use of agrochemical inputs has negative impacts on the ecosystems. These impacts include but are not limited to soil degradation and pollution, water pollution and disturbance of water table, new crop diseases, loss of micro-organisms, an increase of invasive species and low quality of products where pesticides and inorganic fertilizers are applied (REMA, 2018).

Opportunities offered by indigenous knowledge into formal adaptation strategies

According to the research findings, indigenous knowledge still plays a role in climate change adaptation. This includes the data required for climate change assessment and predictions and can constitute a basis for designing adaptation strategies, especially at the household and community level. Further, indigenous knowledge can provide a platform for community engagement and consultation, enhancing participation and ownership. Finally, indigenous knowledge can provide information in formulating policies and procedures that address the real climate change issues affecting communities.

Adaptation is fundamentally a local activity, and local knowledge should play a critical role in all adaptation-related decision-making processes (Karki et al., 2013). Therefore, there is an urgent need to consider traditional knowledge and build an adaptation plan based on local understanding and characteristics. Without such an approach, the proposed actions and strategies in the National Adaptation Plan will not address the real community challenges. To succeed, these actions and strategies need to be contextualized to a specific culture, location, and society (Karki et al., 2013). Thus, adaptation plans should therefore, be customized to local socio-ecological systems and institutional frameworks.

Fortunately, globally, governments and donor agencies have started using both traditional knowledge and scientific knowledge systems to deal with threats, hazards and vulnerability related to climate change. This approach is recognized with a good number of organisations (IPCC, 2007; UNFCCC, 2013). Acknowledging the role of traditional and local knowledge systems in climate change would pass through the integration of these two knowledge systems. At this same time, both knowledge should be mainstreamed in all national policies and plans, especially those related to climate risk management.

It has been documented that both traditional and scientific knowledge systems have limitations in responding adequately to climate change challenges (Ajani et al., 2013; Iseh et al., 2013). These limitations are mainly due to the fact future climate is uncertain. Further, conditions and specific location of traditional and local knowledge have shortcomings when dealing with the high-exposure nature of climatic shocks (Karki et al., 2013). Additionally, in many local communities, it is difficult to access western knowledge. Thus, traditional knowledge remains the only resource at their disposal to cope with climatic and natural disasters at the local level.

Additionally, research has demonstrated that the cost of adaptation technology can be a challenge in communities, especially when the specific characteristics of that community are not considered. For example, in introducing hybrid seeds as a response to seed and food insecurity in Zimbabwe, it was found that hybrid seeds' high cost, unavailability and unsustainability hindered their adoption (Progressio, 2009). Further, an interview with experts in the Ministry of Agriculture indicated that the high cost of irrigation technologies introduced under different irrigation projects, has hindered the implementation of projects. It was indicated that operational and maintenance costs remain high for small farmers.

Based on the above findings, this research recommends changing the current approach used in policy formulation and implementation by combining traditional and western knowledge as a way of designing appropriate adaptation strategies. Such an approach allows policymakers to develop multi-level, multi-hazard and multi-disciplinary adaptation plans and create policies, strategies and programmes that build the resilience of communities. Some governments and donor agencies worldwide are already using indigenous and scientific knowledge systems to deal with risks, hazards and vulnerability induced by climate change (Karki et al., 2012). This approach is also advocated by several national and international organizations (IPCC, 2007; UNFCCC, 2013).

Furthermore, to maximize opportunities offered by indigenous knowledge, there is a need to sustain the existing indigenous knowledge. This pass-through addressing causes of disappearance of these valuable knowledge. The key causes of disappearance of indigenous knowledge are summarized in Table 9.

Table 1: Causes of disappearance of Indigenous Knowledge

Challenges	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	%
Socio-economic transformation	69	86.3	65	83.3	64	91.4	71	86.6	69	82.1	70	81.4	408	85.0
Poor reputation	58	72.5	61	78.2	55	78.6	61	74.4	64	76.2	65	75.6	364	75.8
Decrease of the custodians	52	65.0	61	78.2	47	67.1	54	65.9	56	66.7	63	73.3	333	69.4
Exclusion in the formal adaptation	65	81.3	59	75.6	50	71.4	62	75.6	66	78.6	67	77.9	369	76.9
Absence of knowledge sharing culture	56	70.0	52	66.7	47	67.1	54	65.9	52	61.9	43	50.0	304	63.3
Disappearance of traditional culture and practices	19	23.8	26	33.3	24	34.3	27	32.9	36	42.9	25	29.1	157	32.7
Vanishing of indigenous seeds, plant species	32	40.0	33	42.3	37	52.9	50	61.0	38	45.2	47	54.7	237	49.4

Source: Primary data, 2022

As portrayed in Table 9, socio-economic transformation is the major reason of disappearance of traditional knowledge and was reported by 408(85.0%) of respondents. Another cause reported by most respondents is poor reputation of traditional knowledge with 364(75.8%). This is in line with other research findings. For instance, Theodory (2016) reported in that in the Ngono river basin in Tanzania, one of the main challenges of indigenous knowledge is its poor reputation within the community as it is widely perceived as being outdated. Most of elders who perform those practices are considered by the community to be wizards, a term that carries negative connotation.

While some of the causes are based on people perception others are due to lack of support or planning process. Further, some causes such as poor reputation of traditional knowledge, absence of knowledge sharing culture or disappearance of traditional culture and practices easily addressed. However, this requires awareness and proper documentation of traditional knowledge and their importance.

Conclusion

The objective of this research was to identify and document traditional knowledge developed by local communities to deal with climate change effects. The research assess also challenges as well as opportunities associated with sustaining indigenous knowledge. Identified traditional practices include adaptation practices against are grouped under key effect. Adaptation practices against drought and reduced precipitations, adaptation practices against pests and diseases, adaptation practices against strong wind events and adaptation practices in facing water stress. This research concludes that much of this knowledge are still applied by local communities and have important role in climate change adaptation especially at community.

Despite various challenges affecting sustainability and use of indigenous knowledge such as socio-economic transformation, poor reputation, decrease of the custodians, exclusion in the formal adaptation, absence of knowledge sharing culture and vanishing of indigenous seeds, plant species, it has been documented that these knowledge offers a solid foundation for adaptation process especially when designing community-based adaptation initiatives. Therefore, it is critical to assess potentials of traditional knowledge in adaptation to climate change. The same approach should also be applied to modern or western adaptation practices, which at some point has failed to live to the expectation especially when addressing challenges of local community. The approach would be to integrate indigenous knowledge into modern adaptation technologies to provide accessible and affordable which addresses the real problems of communities.

Recommendations

The successful adaptation to climate change will depend on the relationship between scientific knowledge and indigenous knowledge. Therefore, this study recommends that:

1. Formal recognition of indigenous knowledge with its values should be established and incorporated into National Climate Assessment and adaptation framework.
2. Agro-pastoralists and local communities should be empowered and trained to facilitate the adoption and integration of indigenous knowledge into adaptation practices through simplified training and awareness, such as the Farmers Field School approach and formal training.
3. All indigenous knowledge that can address climate change adaptation and assessment across the country and sectors should be identified and documented. This would include an evaluation of their efficacy, applicability, and acceptability.

4. 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.
5. Indigenous knowledge found effective and acceptable within the community should be effectively incorporated into the design of adaptation actions especially the community-based ones.

References

Adger, W Neil; JM Pulhin, J Barnett and GD Dabelko. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge & New York: Cambridge University Press, 755–791*.

Agbarevo, M.N.B. and Nmeregini, D.C. 2019. Effect of non-farm income-generating activities on poverty reduction among rural households in Abia State, Nigeria. *International Journal of Agriculture and Research*, 2(1): 15 -25.

Ajani E.N, R.N. Mgbenka, M.N. Okeke. 2013. Use of indigenous knowledge as a strategy for climate change adaptation among farmers in sub–Saharan Africa: implications for policy. *Asian J. Agric. Ext. Econ. Sociol.,* 2 (1) (2013), pp. 23-40.

Aziz L, Sadok W. 2015. Strategies used by the saffron producers of Taliouine (Morocco) to adapt to climate change. *J Alpine Res* 103, *2:113. https://doi.org/10.4000/rga.2902*.

Bucherie. A, M. Werner, M. Van Den Homberg, S. Tembo. (year missing). Flash flood warnings in context: combining local knowledge and large-scale hydro-meteorological patterns. *Nat. Hazards Earth Syst. Sci*., 22 (2) (2022), pp. 461-480,

Debora M. 2018. A socio-economic Analysis of the role of indigenous Knowledge and external interventions in pastoral livelihood resilience in West Pokot County, Kenya.

University of Nairobi. Journal of Development and Agriculture Economics. (page numbers, volume and issue missing)

Douglas Gollin; Michael Morris and Derek Byerlee. 2005. Technology Adoption in Intensive Post-Green Revolution Systems. *American Journal of Agricultural Economics, 87, (5), 1310-1316.*

Egan, A. 2013. Knowledge Management Strategy on Climate Change Adaptation for Cameroon. *Ministry of the Environment, Protection of Nature, and Sustainable Development: Yaoundé, Cameroon, pp. 17–19*

Elum ZA, Modise DM, Marr A. 2017. Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. *Clim Risk Manag 16:246–257. https://doi.org/10.1016/j.crm.2016.11.001*.

Glaser, B. G., & Strauss, A. L. 2009. The discovery of grounded theory: strategies for qualitative research*. New Brunswick: Aldine*

Gopal, K. N.C and Lassaad B. 2009. Indigenous pest and disease management practices in indigenous farming systems in northeast India. *Manipur University, 150 Route de Presinge, 1254 Jussy, Switzerland.*

Gordon. L.J Enfors, EI.2008. *Dealing with drought:* The challenge of using water system technologies to break dryland poverty traps. *Glob Environ Change*,18:607 – 616.

Government of Rwanda. 2018. The National Risk Atlas of Rwanda. *Ministry of Disaster Management, Kigali.*

Green, D., J. Billy, and A. Tapim, 2010: Indigenous Australians' knowledge of weather and climate*. Faculty of Science, Climate Change Research Centre, Red Centre, UNSW, Kensington, 2052, Australia.*

Gyampoh, B.A., Idinoba, M., Nkem, J. & Amisah, S. 2007. Adapting watersheds to climate change and variability in West Ghana. *Helsinki, Finland, Finnish Environment Institute (SYKE).*

IARI. 2012. Crop residues management with conservation agriculture: Potential, constraints, and policy needs. *Indian Agricultural Research Institute, New Delhi, vii+32 p*

IPCC, 2022a. Annex II: Glossary. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [*H.-O. Pörtner, D. C. R., M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (ed.)]. Press, C.U., Cambridge, UK and New York, NY, USA, pp. 2897–2930*.

IPCC, 2022b. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change *[Pörtner, H.-O., D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem and B. Rama (eds.)]. Cambridge University Press, Cambridge University Press, Cambridge, UK and New York, NY, USA, p.*

IPCC. 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. *10.1017/9781009325844*.

Iseh, A. J., Woma. T. Y. 2013. Weather Forecasting Models, Methods and Applications, *International Journal of engineering research and technology (IJERT) Volume 02, Issue 12 (December 2013),*

G.V. Jacks, W.D. Brind, R. Smith. 1995. *Mulching*. *Commonwealth Bur. Soil Sc. England Technical Comm No 49, Commonwealth Bureau, UK.*

Jones, P.G., Thornton, P.K., Alagarswamy, G., Andresen, J. and Herrero, M. 2010. Adapting to Climate Change: Agricultural System and Household Impacts in Eastern Africa Agricultural Systems. *https://doi.org/10.1016/j.agsy.2009.09.00*

J.W. Hansen, S.J. Mason, L. Sun, A. Tall. 2011. Review of seasonal climate forecasting for agriculture in Sub-Saharan Africa. *Exp. Agric.*, 47 (2) (2011), pp. 205-240, 10.1017/S0014479710000876.

Kante, P. 2004. Indigenous Knowledge and Environmental Concerns in Africa. *In Economic and Political Weekly* 4 (22), pp. 31–44

Kaya, O. H. 2015. Revitalizing African Indigenous Ways of Knowing and Knowledge Production. *In African Traditional Herbal Research Clinic. pp* 4-6

Kimwaga, S. (2010): African Indigenous Psychology and Eurocentrism. *Unpublished Manuscript. College of Business Education. Dar es Salaam*

Komba, C. and Muchapondwa, E. 2012. Adaptation to Climate Change by Smallholder Farmers in Tanzania. *ERSA Working Paper. No. 299, Cape Town.*

Leal Filho, W., Matandirotya, N.R., Lütz, J.M. 2021. Impacts of climate change to African indigenous communities and examples of adaptation responses. *Nat. Commun. 12 (6224). Wachemo University, Animal Science department, Hosanna.*

Lloyd, David & Wolfe, Patrick. 2016. Settler colonial logics and the neoliberal regime. *Settler Colonial Studies. 6. 1-10. 10.1080/2201473X.2015.1035361*.

Mafongoya, P.L. and Ajayi, O.C. (editors). 2017. Indigenous Knowledge Systems and Climate Change Management in Africa. *CTA, Wageningen. The Netherlands, 316pp.*

McSweeney K. 2005. Natural insurance, forest access, and compounded misfortune: forest resources in smallholder coping strategies before and after Hurricane Mitch, *World Dev, 33:1453–1471.*

MIDIMAR. 2018. The National Risk Atlas of Rwanda. *Ministry of Disaster Management and* Refugees,Kigali.*https://www.gfdrr.org/sites/default/files/publication/National_Risk_Atlas_of_Rwanda_01.pdf*

MINAGRI. 2020. Strategy for mainstreaming climate change in agriculture. *Ministry of* Agriculture,Kigali.*https://www.rema.gov.rw/rema_doc/IMCE_Doc/Guidelines%20-Agriculture.pdf*

Nakabugo R, Mukwaya IP, Geoffrey S .2019. Agriculture and ecosystem resilience in sub–Saharan Africa: livelihood pathways under changing climate. *Springer International Publishing, Cham, pp 541–568 (**ISBN 978-3-030-12974-3**)*

Nakashima, D.J., Galloway M. K., and Thulstrup, H.D. 2012. Weathering Uncertainty: Indigenous Knowledge for Climate Change Assessment and Adaptation. *UNESCO & Darwin, UNU: Paris, France, p. 120*.

NBDF. 2015. Community Based Climate Change Adaptation Recommend Documents Community-based adaptation to climate change - *iied.org Community-based adaptation to climate change* - *pubs.iied.org Dec 4, 2015*

Ngabitsinze J, Mukashema A, Ikirezi M, Niyitanga F. 2011. Planning and costing adaptation of perennial crop farming systems to climate change: Coffee and banana in Rwanda. *International Institute for Environment and Development (IIED), London, UK*.

Ngigi MW, Mueller U & Birner R, 2017. Gender differences in climate change adaptation strategies and participation in group-based approaches: An intra-household analysis from rural Kenya. *Ecological Economics 138: 99–108*.

Cosmo Ngongondo, Miriam Kalanda-Joshua, Maurice Monjerezi and F. Chipungu.2021. Exploring linkages between indigenous knowledge systems and conventional flood forecasting in the aftermath of tropical cyclone Idai in Chikwawa, Malawi. *In: Nhamo, G., Dube, K. (Eds.), Cyclones in Southern Africa: Volume 2: Foundational and Fundamental Topics. Springer International Publishing, Cham, pp. 207–226. ISBN 978-3-030-74262-1*.

NISR. 2012. The 4th National Census of population and Habitat in Rwanda. *National Institute of Statistics in Rwanda. Kigali, Rwanda. Fourth Population and Housing Census - 2012 | www.statistics.gov.rw*.

Nyadze, E., Ajayi, O.C., Ludwig, F., 2021. Indigenous knowledge and climate change adaptation in Africa: a systematic review. CAB Rev. 16 (029), 1–29.

Olatokun, W.M. & Ayanbode, O.F., 2008, 'Use of indigenous knowledge by rural women in the development of Ogun state'. *African Journal of Indigenous Knowledge Systems 7(1), 47–63.*

Ovwigho, Bishop. 2014. Factors Influencing Involvement in Nonfarm Income Generating Activities Among Local Farmers: The Case of Ughelli South Local Government Area of Delta State, Nigeria. *Sustainable Agriculture Research. 3. 10.5539/sar.v3n1p76.*

Radeny, Maren & Ayal, Desalegn & Mubiru, Drake & Kyazze,et al. (2019). Indigenous knowledge for seasonal weather and climate forecasting across East Africa. Climatic Change. *Journal of Geoscience and Environment Protection***,** *Vol.9 No.2, February 10, 2021*

REMA.2018. State of the Environment and Outlook Report 2018 RWANDA Greening agriculture with resource efficient, low carbon and climate resilient practices. *Rwanda Environmental Management Authority, Kigali, Rwanda*.

M. Schnegg, 2019.The life of winds: knowing the Namibian weather from someplace and from no place. Am. Anthropol., 121 (4) (830-844, 10.1111/aman.13274

Semali, L. M. and Kincheloe, J. L (1999): *Introduction: What is Indigenous Knowledge and Why Should We Study It?* New York and London: Falmer Press

Joseph Daron, Amir Bazaz, Gina Ziervogel, Dian Spear Singh, Joseph Daron, Amir Bazaz, Gina Ziervogel, Dian Spea 2018. The utility of weather and climate information for adaptation decision-making: current uses and prospects in Africa and India. *Clim. Dev., 10 (5) (2018), pp. 389 405, 10.1080/17565529.2017.1318744.*

Sikha Karki, Paul Burton and Brendan Mackey. 2020. Climate change adaptation by subsistence and smallholder farmers: Insights from three agro-ecological regions of Nepal. *Cogent Social Sciences, 6:1, 1720555, DOI: 10.1080/23311886.2020.1720555*

Sofia.G.K, Niroula Chhetry and Lassaad Belbahri. 2006. Indigenous pest and disease management practices in traditional farming systems in northeast India. *A review University, Department of Life Sciences, Imphal 795003.*

Shreyas, Keote DK. 2015. Construction of low-rise buildings in cyclone prone areas and modification of cyclone construction of low-rise buildings in cyclone prone areas and modification of cyclone. *J Energy Power Sources* 2, 247–252.

Takasaki, Y. & Barham, Brad & Coomes, Oliver. 2005. Risk coping strategies in tropical forests: Floods, illnesses, and resource extraction. *Environment and Development Economics.* 9, 203-224.

Tambo J.A. 2016. Adaptation and resilience to climate change and variability in north-east Ghana', *International Journal of Disaster Risk Reduction 17, 85–94.*

Tanyanyiwa, V.I. 2018. Weather forecasting using local traditional knowledge (LTK) during climate change in Domboshawa, Zimbabwe *W. Leal Filho, E. Manolas, A.M. Azul, U.M. Azeiteiro, H. McGhie (Eds.), Handbook of Climate Change Communication: Vol. 2: Practice of Climate Change Communication, Springer International Publishing, Cham (2018), pp65-69.*

Tiu, A. S. 2007. The Role of Indigenous Knowledge in Biodiversity Conservation: Implications for Conservation Education in Papua New Guinea. *Master's Thesis. The University of Waikato, Papua Guinea.*

Trisos, C.H., et al., 2022: Africa. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate *Change [H.-O. Pörtner, D. C. R., M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (Eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1285–1455.*

Theodory Theobald Frank. 2016. Dealing with Change: Indigenous Knowledge and Adaptation to Climate Change in the Ngono River Basin, Tanzania. *University of Bonn. Germany.*

Thornton, P.K., Jones, P.G., and Alagarswamy, G. 2010. Adapting to Climate Change: Agricultural System and Household Impacts in East Africa', Agricultural Systems. *Global Environmental Change, 19 (2009), pp. 54-65*

Tume, S. J. P., Kimengsi, J. N. and Fogwe. Z. N. 2019. Indigenous Knowledge and Farmer Perceptions of Climate and Ecological Changes in the Bamenda Highlands of Cameroon: Insights from the Bui Plateau. *Climate 7 (138), 1- 18*

United Nations .1992. United Nations Framework Convention on Climate Change. *Geneva.*

*UNFCCC***.** *2013. Annual report: Clean Development Mechanism. (FCCC/CP/2010/7/ Add.1), Cancun, Mexico 29 November – 10 December 2010. Bonn.*

USAID and FEWS NET. 2011. Climate Change Risk profile, *Rwanda.Climtelinks.org.*

Vinyeta, Kirsten; Lynn, Kathy. 2013. Exploring the role of traditional ecological knowledge in climate change initiatives. *Gen. Tech. Rep. PNW-GTR-879. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 37 p.*

World Bank. 2006. Rural Access Index: A key development indicator. *The International Bank for Reconstruction and Development/The World Bank 1818 H Street NW, Washington, DC 20433.*