FRR Vol 7(36):453-473

Implications of Climate Data Application for the Enhancement of Extension Services Delivery to Smallholders Farmers in Tanzania

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Abstract

Like other developing countries, Tanzanian's economy is highly dependent on agriculture, with a high percentage attributed to smallholder farmers. However, the agriculture sector in the country is highly affected by the current climate change trends, whereby rainfall and temperature patterns make smallholder farmers' livelihoods vulnerable in terms of productivity, food security, and income. Approaches such as climate-smart agriculture are adapted to help people who manage agricultural systems to respond effectively to climate change. Therefore, this study presents the institutional setup and integration of information asymmetry of climate data among extension service providers and smallholder farmers in Tanzania using the Pangani District as a case study. First, we assessed the historical trend of climate data in the Pangani District and then examined the mode of production and flow of climate information from the Tanzania Meteorological Authority to the key stakeholders, including the agricultural sector. Thirdly, we analysed the awareness and integration of climate information in the extension services delivery system. Lastly, we assessed the smallholder farmers' knowledge, attitude, and practical use of climate data. Moreover, we have identified the effect of the climate change information breakdown on the productivity, incomes of the farmers, and food security. This study recommends policies to strengthen national and local institutions toward sustainable agriculture by linking climate change data with supporting institutions and human resources engaged in extension service delivery to the smallholder farmers in Tanzania in order to enhance adaptation strategies to climate change effects in agricultural production.

Keywords: Climate-smart agriculture, climate data, extension services delivery, smallholders farmers

1.0 Introduction

Like many African countries, agriculture significantly employs the majority (68%) of the Tanzania labour force, contributing about 25% to the gross domestic product (GDP) in the country [1]. About 83% of the agricultural sector in the country is highly dominated by smallholder farmers [2]. Currently, MALF has launched a campaign on Agenda 10/30, which aims to attain an impressive 10% annual growth rate for the agricultural sector by improving the productivity of different crops to improve the economic status of Tanzanian farmers. However, the agriculture sector is highly affected by the impact of climate change and its variabilities. Various weather phenomena, such as changes in temperature, severe drought, and floods, have been indicated to primarily affect the agricultural sector, especially in low-income and developing countries [3, 4]. Smallholder farmers are the ones most affected by climate change due to being highly dependent on rainfall [5]. In addition, most smallholder farmers have low adaptive capacity to climate change and insufficient knowledge and guidelines to support their production and productivity [4]. Therefore, most smallholder farmers are prone to food insecurity [6].

Climate change and variability are among the leading environmental issues that have caught global attention from different perspectives. Unfortunately, coastal environments and communities are highly vulnerable to climate change-related impacts [7]. For example, in the last two decades, the coastal region of Tanzania has been hit by the recurrence of droughts and floods with a severe effect on agricultural produces and the ecosystems in general [8]. Moreover, evidence has shown considerable submerging of the Islands such as Pangani and 'Fuvu la Nyani' in Rufiji due to the rising sea level in Tanzania [9]. Furthermore, the prevalence of crop pests and diseases has also increased due to increased temperature, posing more challenges to agriculture [9, 10]. Therefore, the climate change issue has become of much interest due to the growing impacts of environmental degradation on human survival, which limit the ability of humans to survive and meet their daily needs [11, 12].

Undoubtedly, agriculture productivity and climate changes are highly interlinked [13], and their relationships are essential in maintaining and improving the agriculture sector. To overcome the challenges that farmers face due to climate change, there is a need to form a multidisciplinary platform between expert and smallholder farmers to facilitate climate data collection, analysis, interpretation and their application in agricultural production [14]. Therefore, the agriculture sector should effectively use weather and climate data to inform farmers about the onset and end of the rains and advise them on how to plan, including purchasing type of agricultural inputs, time for planting, weeding, harvesting, and storage [15], in order to overcome the challenges caused by weather variability and climate change.

Climate-smart agriculture (CSA) is a farming approach that aims to increase agricultural productivity under the new realities of climate change [16]. Therefore, accurate and intensive climate data are required to predict the future climate to act accordingly. Unfortunately, compiling a national climate change statistics report is challenging in many developing countries, including Tanzania, due to data scattering across different institutions. This hinders coordination and harmonisation due to incomparable and incomplete datasets, with most of the required data not being produced [9]. Moreover, the use of weather data depends on their accessibility and familiarity to the user with particular areas and parameters [14]. Therefore, in this study, we assessed climate variability data and their implications and application for the enhancement of extension services delivery to smallholder farmers in the Pangani District, Tanzania.

2.0 Material and Methods

2.1 Description of the study area

This study used the Pangani District as a case study in Tanzania. This District is one of eight districts in the Tanga region, Tanzania. Tanga region is located in the North-East of Tanzania. Pangani district is located 45 km South of Tanga City between the Latitude 5° to 6° S and Longitude 38° to 39° E and covers approximately 1800 km^2 [17]. The District has a tropical climate condition characterised by two rainfall seasons: high rainfall season likely from March-May (*Masika*), and low rainfall season likely from October-December (*Vuli*), with the mean annual temperature and rainfall ranging from 26.6 - 26˚C and 1015 - 1214 mm, respectively [18, 19]. The main economic activities are fishing and crop production of cassava, maise, paddy, cowpeas, and green gram [7].

FARA Research Report

FRR Vol 7(36):453-473

2.2 Data Collection Methods and Tools

In the current study, several tools were purposely used to gather information regarding the implications of the climate data application [20] for enhancing extension services delivery to smallholder farmers in Tanzania. First, historical climate observations of rainfall and maximum and minimum temperatures from January 2001 to December 2019 were retrieved from the Soil and Water Assessment Tool (SWAT). From there, a desk study was conducted to explore the necessary information regarding climate change in Tanzania and the flow of weather information from the Tanzania Meteorological Authority (TMA) and extension officers to the targeted beneficiaries. Then, the relevant documents were reviewed to map and assess the institutional landscape in Tanzania regarding climate services development and delivery. The reviewed documents include national sectorial climate-relevant policies, plans, strategies and programs. At the national level, the documents reviewed were from TMA, the Ministry of Agriculture (MOA), Food Security and Cooperatives (MAFC), the Ministry of Livestock and Fisheries Development (MLFD), and the National Environment Management Council (NEMC). Then, the interview with key informants, including the agricultural officer and elders, was conducted.

Furthermore, a focus group discussion (FGD) was conducted. The FGD sessions at the village level involved eight participants, including village government leaders and community members. Lastly, the 30 farmers were randomly interviewed to assess their individual knowledge, attitudes and practical application of climate data in the Pangani District. Moreover, the selection focused on the community members with more than 5 years of farming experience in the study area, who were then purposely selected.

2.3 Data management and analysis

Mann–Kendall (M.K.) [21] test was used to assess the monthly trend in rainfall, maximum temperature and minimum temperature from 2001 to 2019, As applied by [22] and [23]. In this test, the null hypothesis (H_0) is the presence of no trend, which indicates that data are independent and randomly ordered, and the alternative hypothesis (H_a) is the presence of a trend. The statistic (S) value of the M.K. test is calculated as indicated in equation 1 as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn = (Y_j - Y_i) \qquad (1)$$

The M.K. test results are more likely to have an autocorrelation issue in time series data. Therefore, the Modified Mann-Kendall (M.M.K) test was then applied to detect trends in hydrological and climatic data that address the issue of serial correlation by variance correction approach [24], as indicated in equation 2.

$$V^{*}S = V(S) \times \frac{n}{n^{*}} \qquad (2)$$

Where $\frac{n}{n^{*}}$ presents the correction factor, $V(S)$ is the calculation of the original M.K. test.

The data collected from 30 respondents were coded and analysed using IBM SPSS® software package version 25 and presented as frequencies. The significance between the proportions of demographic information, knowledge, access and constraints to applying climate data in agriculture was tested using Chi-square (χ 2) test at $p \leq 0.05$.

3.0 Results

3.1 Climate data trend analysis

Results on monthly trends in the Pangani District are presented in Table 1. The results of the climate data trend analysis show that there were varying trends in different months and seasons in the Pangani District. Generally, results show that February, May and July have a decreasing trend at 0.01 level of significance; January, March, and September to December have an increasing trend at 0.01 and 0.05 levels of significance, whereas April and August produce insignificant results. Trends in maximum and minimum temperature look the same for January, February, July, and October to December at 0.01, 0.05 and 0.01 levels of significance, whereby January, February, October to December show a positive trend, while July shows a negative trend. Further results indicate that August and September have an increasing trend for maximum temperature and a decreasing trend for minimum temperature, and March has a significant positive trend for maximum temperature and an insignificant trend for minimum temperature. May has an insignificant trend for maximum temperature and a significant positive trend for minimum temperature. April and June have insignificant results for both temperatures.

Table 1: Results of modified Mann–Kendall (MMK) test for monthly rainfall (mm), the maximum and minimum temperature in Pangani District

	Rainfall (mm)			Maximum Temp (˚C)			Minimum Temp (˚C)		
Months	**Mean**	**MMK**		**Mean**	**MMK**		**Mean**	**MMK**	
		Z-value	***P*-value**		**Z-value**	***P*-value**		**Z-value**	***P*-value**
January	1.531	0.089	0.006	33.045	1.786	0.032	24.226	0.985	0.074
February	1.424	-0.676	0.012	33.572	0.124	0.007	24.100	1.078	0.001
March	3.693	1.543	0.045	33.170	0.098	0.006	24.450	0.968	0.453
April	7.885	0.578	0.309	30.972	0.087	0.486	23.934	0.543	0.651
May	7.181	-1.298	0.000	29.777	-0.032	0.285	22.844	0.765	0.007
June	0.914	0.876	0.165	29.188	0.675	0.196	21.707	0.076	0.654
July	0.456	-0.387	0.005	28.908	-0.541	0.031	20.889	-0.876	0.045
August	0.590	0.564	0.785	29.200	1.654	0.063	20.576	-0.067	0.004
September	0.510	0.098	0.045	30.079	0.643	0.015	20.942	-0.209	0.026
October	3.530	1.096	0.009	31.235	0.869	0.034	22.260	0.053	0.031
November	3.953	0.563	0.003	31.657	0.097	0.004	23.286	0.074	0.009
December	2.996	0.098	0.035	32.560	0.763	0.038	24.106	0.786	0.079

Nevertheless, Figure 1 (a) shows that the yearly total rainfall trend was generally increasing, whereby there was a sharp increase in the year 2002 to the year 2003, a decrease from 2007 to 2008 and the year 2017 to 2018. The year 2019 shows the highest rainfall, followed by the year 2016. The annual maximum and minimum temperatures in Pangani District are shown to have a slightly increasing trend, with the lowest temperature being 30.06 in 2001 and 21.83 in 2001 and the highest being 31.58 and 23.61 in 2009 for maximum and minimum temperatures, respectively, as indicated in figure 1(b).

Figure 1(c) presents the annual SPI drought index whereby results indicate both periods of dry conditions with rainfalls below the median rainfalls and wet conditions with rainfall above the median. Furthermore, in Supplementary Table 1, results show that May 2016 was the extremely driest month, with the lowest value of -2.3, and July-2018 was the wettest month, with the highest value of 1.97.

FRR Vol 7(36):453-473

Unlikely, March 2013, 2014 and 2016; April 2013 and 2018; May 2004; and December 2003, 2008 and 2019 had a severe drought.

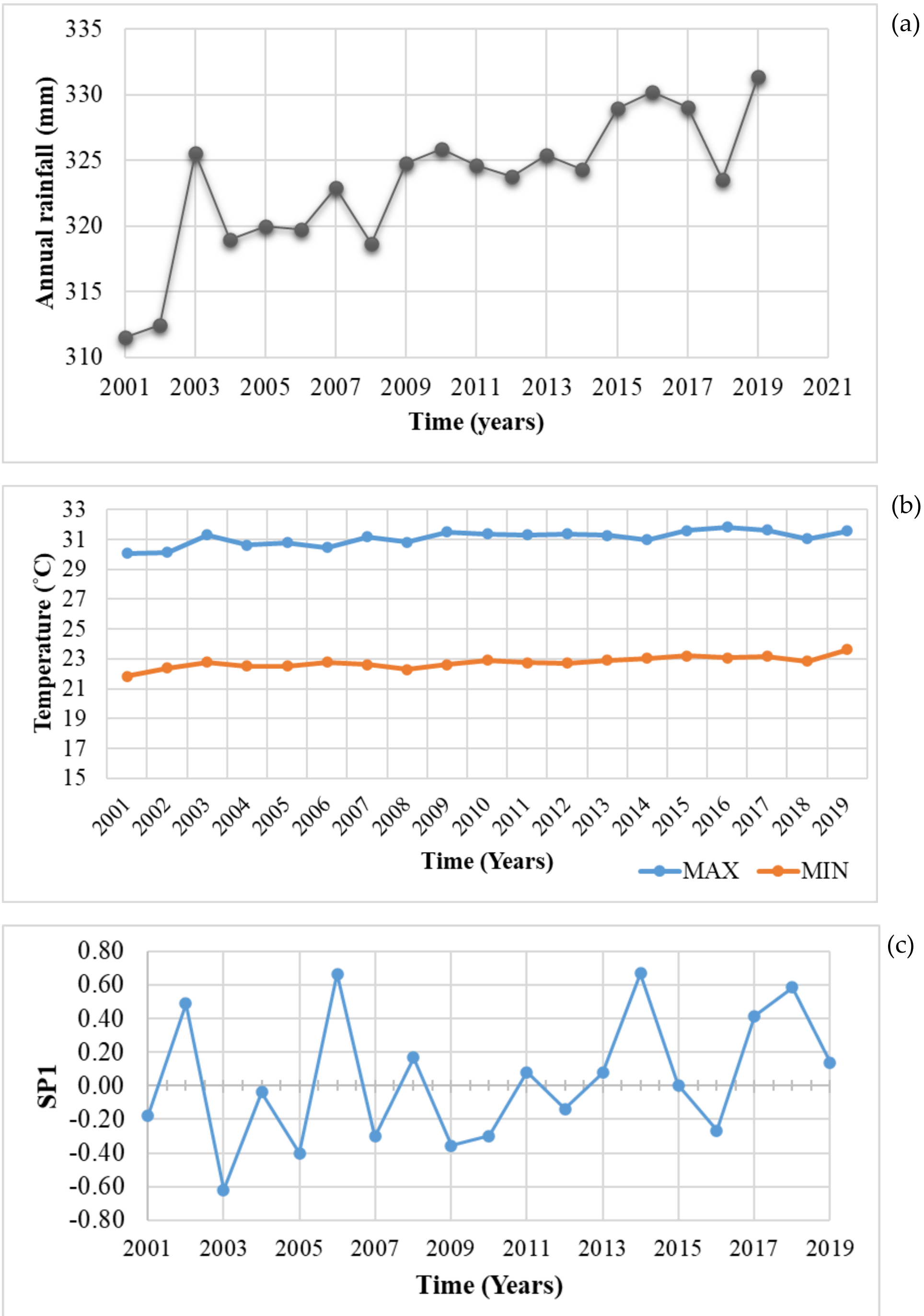

Figure 1: climatic data trends in Pangani District from 2001 to 2019(a) presents the annual total rainfall trend, (b) presents the mean annual maximum and minimum temperature, and (c) presents the annual standardised precipitation index (SPI) calculated as an average of monthly SPI in a particular year. The SPI for drought index is categorised as; mildly dry (0>SPI>-0.99), moderately dry (-1.0>SPI>-1.49), severely dry (-1.5>SPI>-1.99) and extremely dry conditions (SPI less than -2.0).

These results provide valuable information for understanding the climate patterns and trends in the Pangani District. This information can help policymakers, farmers, and other stakeholders to make informed decisions regarding land use, agricultural practices, and water resource management in the region. The results also highlight the importance of adapting to and mitigating the impacts of climate change, especially droughts, which can have severe consequences for agriculture and food security.

3.2 Mode of the production and flow of weather and climate information in Tanzania

Tanzania Meteorological Authority (TMA) is a government institution of the United Republic of Tanzania and is the only mandated institution to provide Meteorological Services within the country's boundaries. The Headquarters of the TMA is currently located in Dar es Salaam; however, the Authority also serves through several offices and stations located over regions of the country. TMA operates under the Ministry of Works, Transport and Communications of the United Republic of Tanzania. TMA is ISO 9001:2015 Certified in Aviation Meteorological Services in Tanzania. Currently, TMA has managed to operate two Radar stations that work for the whole country, and it has only 51 weather stations. However, many national and sub-national (district and local) institutions have a stake in producing and applying climate and meteorological information. For example, TMA also collects data for agricultural research for Tanzania Agriculture Research Institutes (TARI) through designated Agrometeorological stations (Hombolo, Tumbi, Ilonga, Kibaha, Naliendele, Mlingano, Lyamungu, Uyole, Mbimba, Kizimbani, Matangatuani, Igeri and Ukiriguru). However, the collected data are mainly rainfall-related information from the rain gauges. Moreover, NEMC also has a stake in producing climate services, including national climate change assessment reports, warnings on long- and short-term climate and extreme events, climate-related brochures, and various advisories to the public [25].

At the district and local levels, the production of climate information is done by district councils through the Departments of Agriculture and Water District and the Department of Livestock. For example, at the District Council, the Department of Agriculture at the district level generates weather data (rainfall, wind) for agricultural decision-making concerning farmers' advisories related to the timing of planting, cultivation, and harvesting crops. In addition, wind data is used to forecast armyworms in that particular year. Similarly, the Department of Water at the district level generates rainfall data for water resource use and management. The River Basin Authority uses the data for water resources management in the respective basin. Likewise, the Planning Department in the district level uses rainfall information for planning purposes at the district level [26].

The first stream involves communicating information to the public through mass media, mainly radios, television, newspapers, TMA websites, and mobile phones (for time-sensitive information of up to five days lead time). The second stream involves delivering information to government institutions through weather briefs and face-to-face delivery. Moreover, a special issue bulletin produced by TMA containing seasonal weather forecasts is also prepared and disseminated to users before the start of the planting season in September and February of each year. The bulletins are published in the local language (Swahili) and English. The bulletins are also disseminated through the mobile phone FarmSMS [25]. However, no extension officer and farmers in Pangani reported receiving such SMS services.

According to an interview with the extension officer, weather and climate changes are part and parcel of the curriculum of the extension services training programs. However, its integration to extension service delivery is challenging due to structural setups and limited infrastructure. Furthermore, there is poor coordination between extension/agricultural officers and the District Councils for collecting and sharing weather data among themselves and the farmers [26]. For example, the extension officers in Pangani reported that they have to travel to the District Council to obtain the weather data because there is no digital platform for sharing such data. Somehow, the local radio and T.V. stations play a significant role in disseminating weather forecast information and giving little advice to the community, including farmers.

3.3 Demographic information

The results of the demographic information of the farmers are presented in Table 1. The number of male participants was higher than females. The majority of respondents were between 51 to 70 years. Moreover, the majority (86.6%) had primary school education, 3.3% completed secondary school education, and 6.7% had no formal education.

Table 2: Proportions of farmers with awareness of weather and climate change

Factor	Category	Male (%)	Female (%)	Total (%)	*p*-value
The number of years engaged in agriculture	Less than 10 years	6.7	16.6	23.3	
	10 – 30	33.3	16.6	50.0	
	31 -50	6.7	3.3	16.6	
	51 – 70	10.1	0	10.1	0.583
Type of farming	Rained only	53.4	40.0	93.4	
	Irrigation only	0.0	3.3	3.3	
	Both	3.3	0	3.3	0.354
Heard of "climate change."	Yes	36.7	26.7	63.4	
	No	16.7	13.3	30.0	
	I do not know	3.3	3.3	6.6	0.974
Know about climate change	I do not know	20.0	16.7	36.7	
	Changes in rainfall patterns	10.0	0	10.0	
	Reduced rainfall	16.7	16.7	33.4	
	Reduced yield	3.3	0	3.3	
	Worldwide calamity due to deforestation and industrial activities	3.3	0	3.3	
	Increased temperature and reduced rainfall	3.3	7.7	10.7	
	Reduced rainfall and drought	0.0	7.7	7.7	
	Increased temperature, reduced rainfall and drought	0.0	7.7	7.7	0.463
Potential causes of climate change	I do not know	13.3	13.3	26.6	
	Natural changes	13.3	3.3	16.6	
	Deforestation	23.3	16.7	40.0	
	Deforestation and industrial activities	3.3	3.3	6.6	
	Religious beliefs	3.3	6.7	10.0	0.742
Long-term effects of climate change	Hunger	53.3	23.3	76.6	
	Hunger and diseases	3.3	0	3.3	
	Poverty	0	10.0	10.0	
	Drying of water sources	0	3.3	3.3	

FRR Vol 7(36):453-473

	I will stop farming	0	3.3	3.3	
	Increased pests	0	3.3	3.3	0.071

3.4 Awareness and access to weather and climate change information by farmers in the Pangani District

The results of farmers' knowledge of weather and climate change are presented in Table 2. The results indicate that more than 63% of farmers were aware of climate change and have heard about it from media such as radio and T.V., and personal experience of changes in weather patterns. In addition, the majority (40%) reported deforestation as the leading cause of climate change, whereas 26% had no idea what were possible causes of climate change were. However, farmers were more concerned about the long-term effect of climate change, including hunger, diseases, deaths of animals and humans and poverty. Therefore, some farmers suggested they should be included in planning and implementing several agricultural policies, especially those related to climate change.

The information regarding the access to weather and climate information by farmers in the Pangani District is presented in Table 3. Most farmers can access weather forecast information, mainly from local radio and some from T.V. stations. Many farmers reported that the weather forecast information was helpful, especially for timing the rainfall. However, the level of trust is lower among some farmers because the provided information is sometimes inaccurate. The results also show that about 16% of the farmers had access to weather and climate change information from the local extension officers. In contrast, the rest reported that they never made any effort to visit extension offices to inquire agricultural related information. The requested information included knowing suitable seed varieties and coping techniques for climate change and weather variability.

Table 3: Proportions of farmers that have access to weather forecast information

Factor	Category	Male (%)	Female (%)	Total (%)	p-value
Access to the weather forecast information	Yes	50.0	33.3	83.3	
	No	6.7	10.0	16.7	0.410
Usefulness of weather information	I do not know	3.3	6.7	10.0	
	Yes	46.7	33.3	80.0	
	No	6.7	3.3	10.0	0.665
Level of trust of weather prediction information in percentage	10	13.3	6.7	20.0	
	20	3.3	0.0	3.3	
	50	13.3	13.3	26.6	
	80	6.7	6.7	13.4	
	90	10.0	6.7	16.7	
	100	10.0	10.0	20	0.929
Reason for such a level of trust	Inaccuracy	20.0	16.7	36.7	
	Precision	16.7	16.7	33.4	
	Expert information	13.3	6.6	19.9	
	Religious beliefs	6.7	3.3	10.0	0.904
Provision of weather information by the extension officers	Yes	10.0	6.7	16.7	
	No	46.7	36.7	83.4	0.869
Weather information requests	Yes	13.3	6.7	20.0	

	No	43.3	36.7	80.0	0.580

3.5 Constraints farmers face in coping with climate change in the Pangani District

The constraints farmers face in coping with climate change are presented in Table 4. The results show three environmental issues primarily concerned farmers in Panganni District: strong winds, high temperatures, and drought. The majority reported a loss of farmers' income of up to 427.4 USD due to reduced crop production caused by increased temperature and drought in the last year (2022). Therefore, most farmers had to change their farming strategies, including changing farm preparation and planting times, switching to growing short-season crops, and improving seed variety for food. However, changing the way of farming is coupled with several challenges, including the high price of improved seeds, fertilisers, and pesticides. As a result, some farmers have to engage in other activities, such as exploiting foresty resources, including cutting trees to sell timber and charcoal, to get side income to purchase agricultural inputs.

Table 4: Proportions of farmers that face constraints to coup with climate change

Factor	Category	Male (%)	Female (%)	Total (%)	*p*-value
Three environmental issues that concern farmers the most	Strong wind, high temperature and drought	43.3	33.3	76.6	
	Strong wind, low temperature and drought	6.7	3.3	10.0	
	High temperature, low temperature and drought	6.7	0	6.7	
	Flood, high temperature and drought	0.0	3.3	3.3	
	Drought, strong wind, and flood	0.0	3.3	3.3	0.371
The estimated loss in production (in USD as of August 2022)	Below 42.7	10	3.3	13.3	
	42.7 – 213.6	13.3	20.0	33.3	
	2137 -427.3	30.3	13.3	43.3	
	427.4 and above	3.3	6.7	10.0	0.365
Changed farming practices within the past 5 years	Yes	40.0	26.7	6.7	
	No	6.7	16.7	33.4	0.602
Constraints or difficulties faced/encountered when changing farming practices	Finding resistant variety	15.8	0	15.5	
	Getting technical know-how and resistant seed variety	5.3	0	5.3	
	Wasting resources to replant crops	10.5	5.3	15.8	
	High prices of improved seeds	21.1	31.6	52.7	
	High prices of improved seeds, fertilisers, and insecticides	10.5	0	10.5	0.213

3.6 Support to the farmers to relieve the effect of climate change in the Pangani District

The information regarding the available support for farmers to relieve the effect of climate change in the Pangani District is presented in Table 5. Currently, most farmers do not receive any support to cope with the effects of climate change. For example, the results, as presented in Table 5, show that only 10% received the seed subsidiary in the last 10 years, whereas only 3% received ongoing support from the Tanzania Social Action Fund (TASAF) every 6 months.

Table. 5: Proportions of farmers who received agricultural input support

Factor	Category	Male (%)	Female (%)	Total (%)	p-value
Receive any external support to adapt to the changing farming practices?	Yes	6.7	3.3	10.0	
	No	50.0	40.0	90.0	0.713
Type of support received (n=3)	Seed fund from the Government	3.3	0	3	
	Seed fund from TASAF	0	3.3	3	
	Seed subsidiary by the Government	3.3	0	3	0.415
Free support received (n=3)	Yes	3.3	3.3	6.6	
	No (had to pay half price)	3.3	0	3.3	0.665
For how long has the support been in existence?	2 years	3.3	0	3.3	
	After every 6 months	0.0	3.3	3.3	
	In the past 10 years, for 3 years	3.3	0	3..3	0.415
Practicability of the support received	Increased yield	3.3	0	3.3	
	It helped us to have more yield, but if you delayed harvesting, the maise would be invaded by insects	3.3	0	3.3	
	Reduce cost burden on family	0.0	33.3	3.3	0.415

4.0 Discussion

Weather is measured in short periods or periods and refers to changes in the atmosphere, including sunny, windy, cloudy, or rainy at a specific place and time. On the other hand, climate happens over longer periods and is the calculated average state of the weather over seasons, decades, or centuries. Tanzania has a tropical climate with regional disparities due to its topography. For example, the coastal regions of Tanzania are warm and humid, with temperatures ranging from 17-25°C throughout the year, while the highland regions are more temperate, with temperatures around 20-23°C throughout the year [6].

In recent years, Tanzania has experienced increased frequency and intensity of extreme events such as strong wind, heavy rainfall, hailstorm and higher temperatures. Given their reduced adaptive capacity, small-scale farmers are more likely to suffer adverse effects [14]. For instance, rain-fed agriculture is currently challenging in Pangani District due to unreliable rainfall. At the same time, irrigation farming is challenging due to the lack of water infrastructure and problems of destruction of crops by animals across the river Pangani. Therefore, the current study focused on climate data trend analysis, awareness and access to weather and climate change information, constraints farmers face in coping with climate change and support available to farmers to relieve the effect of climate change in the Pangani District.

The standardised precipitation index (SPI) proposed by McKee and Doesken [27] was used to characterise drought based on the amount of precipitation in a specified time. The application of this index in drought monitoring has been recommended by the World Metrological Organization (WMO) [28], and it eliminates the problem of the temporal and spatial differences of precipitation [29]. The SPI for drought index on a 1-month time scale was calculated as it provides short-term values in the growing season, which are important in relating moisture in the soil and crop stress [30].

Climate projections suggest an increase in temperatures by 1.4°C by 2030 and 2.1°C by 2070; the West and North West will most likely encounter faster warming (+1.9°C) relative to the coastal regions (+1.7°C) [10]. The current study showed that yearly maximum and minimum temperatures in the Pangani District slightly increased. Moreover, the SPI indicated more dry periods with rainfalls below the median rainfalls and wet conditions with rainfall above the median. Similarly, CANTZ [7] reported that Pangani is more likely to experience climate change impacts expected to escalate as time passes. Generally, a 10% decrease in rainfall would make most areas unsuitable for cultivation [9]. Therefore, long-term shifts in weather conditions identified by changes in temperature, precipitation, winds, and other indicators, including extreme events [9], should be documented and communicated to farmers to act accordingly. For example, in the past, farmers in the Pangani District used to plant crops on the 14th of March of every year because the rain used to come precisely from the 15th of March till mid-May of each year. However, currently, the rainfall patterns have completely changed. Similarly, the climate data analysis trend showed severe drought in March and May for several years (Supplementary Table 1). Thus, there is a need to redefine the climate information of the Pangani District to adjust to climate change.

For the general public and other average users of climate information, it is difficult to understand and interpret what is "normal to above normal" rain conditions would imply for localised actions without an in-depth understanding of the region's climatology [6]. Therefore, a capacity-building program should equip the extension officers with the knowledge to interpret and integrate the climate data and climate change assessment reports into their routine extension services. That would help the stakeholders in the agricultural sector predict future events that may directly or indirectly affect the sector.

Climate change will affect most smallholder African farmers [14]. Notably, a significant decrease in annual rainfall, precisely long rain (*Masika*), has been observed over the years in Tanzania [6]. Similarly, farmers in Pangani District reported decreased rainfall from March to May. Decreased annual rainfall may result in low or no crop yield [6, 31]. Furthermore, considering that much of Tanzania's population relies on agriculture-based livelihoods, onsets of drought may cause many of them to have poor nutritional status due to food insecurity [6].

The adverse impacts of climate change are already evident in Tanzania, leading to major economic costs and loss of life, properties, and other human capital [9]. For example, extreme climatic events, such as increases in temperature and rainfall changes, affect the length of the growing season, and this, combined with increased pest populations and plant disease outbreaks, affects crop yields [6] and, thus, people's livelihoods [32]. The current problems of strong wind, high temperature, and drought are reported to cause a lack of food and financial loss of up to 428 USD in a season due to reduced crop yield. However, unfortunately, the affected households had no agricultural insurance; thus, they received no compensation. Therefore, accessing their social needs, including clothes and paying hospital bills, has become difficult.

Due to the failure to return the cost used in farming and the lack of reserve food in households, some people in Pangani District have opted to engage in activities such as harvesting trees for charcoal and timber to get alternative income to sustain their livelihoods. However, deforestation is one of the main factors causing climate change (Kumar and Pooja). As a result, deforestation will continue to affect river discharge rates, notably in the Pangani River, resulting in a gradual decline in total annual instream flows [11]. Therefore, there is a need to conduct more community awareness programs in Panggani District.

In principle, the extension officers should advise which type of crops to be planted according to the rainfall patterns and amounts. However, one-to-one consultation between farmers and extension/agricultural officers was challenging due to limited human resources and facilities. Therefore, periodic village meetings would allow extension officers to talk to a large community. Extension officers reported using the opportunity of village meetings to pass important information to farmers. Nevertheless, most farmers rarely attend village meetings. According to FGD, the poor attendance is due to a lack of specific development agenda in the village meetings. Therefore, the farmers advised that specific agricultural meetings should be set and not mixed with political agendas

On the other hand, media, such as local radio and T.V., play a significant role in advocating against climate change and environmental conservation. However, using radio broadcasts is only helpful if broadcasts occur when farmers can listen [18]. Moreover, unfortunately, the farmers only have access to mostly coming 24 hours weather forecast information, mainly from some local radio and T.V. stations. The local radio and television (T.V.) stations play a significant role in disseminating information about the weather forecast [37, 38] but provide little advice to farmers [26]. Alternatively, extension officers also suggested that the local community could access real-time climatic information through various digital platforms. However, accurate, intensive and timely climate data are required to predict the future climate to act accordingly [34, 35].

Reliable sources of climate information, such as telecenters, extension officers, or agricultural research institutes, may be better than traditional sources like community elders or superstitious beliefs [36]. For instance, Sokoine University of Agriculture (SUA) does crop modelling and simulations to predict and advise farmers on varieties of crops and when to plant such crops according to weather variability [33]. Therefore, adapting CSA through integrating climate data would help farmers cope with the current climate, increasing agricultural productivity [16].

To overcome the shortage of extension officers, several digital platforms have been developed to increase extension information efficiency flow from various sources to the farmers [34, 35]. Using technology, including smartphones by extension officers, is reliable, affordable, sustainable and real-time. So far, The United Republic of Tanzania (URT), through the Ministry of Agriculture, is offering digital extension services through Mobile Kilimo (M-Kilimo) and Kilimo Call Centre platforms [39]. The Mobile

Kilimo connects several stakeholders in agriculture, including extension officers, farmers, livestock keepers and traders.

Moreover, several public and private projects also focus on developing and using mobile applications to provide real-time data to extension service providers and farmers are in progress. For example, the “Bi Shamba” mobile application is designed to connect extension officers and farmers on the digital platform. The application has features which can be retrieved online, stored and used when someone is offline. In addition, the app tracks weather information based on longitude and latitude. Furthermore, the app advises farmers on actions to take based on weather changes. Also, it can analyse past weather data and predict future weather events, but still under development. Furthermore, it has integrated the TMA weather alerts based on emergency weather changes example, strong winds. Therefore, real-time weather variability and climate change information would help farmers adjust to the changes, leading to coping with their farming practices under climate change effects.

NEMC has issued several national climate change assessment reports with recommendations. However, dissemination and access to information may constrain decision-making, and the access, skills and willingness to use information may vary due to low literacy levels or preference for traditional sources over modern ones [36]. Similarly, most respondents (86.6%) had primary school education, and 6.7% were illiterate. Therefore, getting information from the bulletins and mobile SMS may be difficult. On the other hand, gender might also be a barrier to accessing agricultural information in Pangani District because the proportion of women aware of climate change, the causes of climate change, and access to weather forecast information were lower than men. Therefore, women must be intellectually empowered because research shows that educating women considerably impacts society [40].

Despite the institutional challenge being a technical and human resource challenge, there is a need to link climate data and agriculture to facilitate agricultural decision-making [14]. Therefore, understanding climate information requires mechanisms and policies to support improvements in generating, disseminating and using climate information in agriculture [32]. For example, in Kiteto District Council, the Department of Agriculture at the district level generates weather data (rainfall, wind) for agricultural decision-making concerning farmers' advisories related to the timing of planting, cultivation, and harvesting of crops [6].

Reducing the impact of climate variability and change on food production and livelihoods may be achieved, in part or whole, by using available climate information to anticipate and manage annual climate-related risks [32]. This information can help farmers and pastoralists manage their crops and livestock to minimise risks during unfavourable seasons and maximise opportunities during favourable conditions [32]. For example, information on anticipated rainfall patterns would enable farmers to decide whether to cultivate short-rotation or long-rotation crops [14].

So far, there are ongoing supportive campaigns through government programs, international organisations, and NGOs for crop production systems, including research and distribution of improved seed varieties which are drought-resistant and early maturing. For example, climate financing opportunities such as the U.N. Adaptation Fund (A.F.), the Least Developed Country Fund (LDCF), the Special Climate Change Fund (SCCF), and the Green Climate Fund (GCF) are already available in Tanzania [41]. Moreover, the country has developed and implemented programs and projects, including the Adaptation Fund project implemented in the Coastal regions of Tanzania (2017), Developing Core Capacity to Address Adaptation to Climate Change in Productive Coastal Zones of Tanzania (2012- 2018);

Implementation of Concrete Adaptation Measures to Reduce Vulnerability of livelihood and economy of Coastal Communities of Tanzania (2012-2018) [9]. However, most farmers reported never receiving financial or food support from the government or non-governmental organisations.

The Government has also established the National Carbon Monitoring Centre at the Sokoine University of Agriculture (SUA) in Morogoro. The centre is responsible for developing, maintaining, analysing and updating the carbon database, which facilitates taking stock of the country's contribution to sequestering carbon dioxide. Moreover, Tanzania developed the Forest Reference Emission Level in 2018, which makes the country qualify and benefit from the Reducing Emissions from Deforestation and Forest Degradation (REDD) financing mechanism [9]. Also, Tanzania has promoted and encouraged small and medium-scale irrigation schemes, developing drought-tolerant seeds, water harvesting, using weather data and weather forecasts, and strengthening early warning systems [9]. Furthermore, in cooperation with the President's Office, Regional Administration and Local Government (PO-RALG), the Ministry of Agriculture, Livestock and Fisheries (MALF) promote CSA practices such as irrigation and utilisation of improved seed varieties. In addition, PO-RALG acts as a policy working bridge between sector ministries, government institutions and local government authorities, being mandated to implement policies, build capacity, and monitor, evaluate and provide technical backstopping of CSA activities at local levels [9].

Moreover, climate change adaptation and mitigation in Tanzania, including the National Adaptation Programme of Action (NAPA) of 2007, acknowledged climate change as an important economic threat, providing the first stimulus for sectoral intervention to address climate impacts. Later, the National Climate Change Strategy (NCCS) of 2012 and the Agriculture Climate Resilience Plan (ACRP) were formulated in 2014 to improve water use efficiency and promote land, soil and water management climate-resilient crop varieties and disaster risk management strategies. Besides, the formulated National Agricultural Policy (NAP) from 2013 aims to increase productivity and farmers' adaptive capacity through reduced dependency on rainfall. Other policy frameworks, programmes and strategies supportive of increased productivity and resilience, such as the Agricultural Sector Development Programme (ASDP) I and II (2006 and 2015), focus on the development of irrigation infrastructure, investments in research (science and technology) and among others. So far, implementing these initiatives has enabled the country to build resilience to climate change impacts in various areas, including reconstructing the 860m sea wall in Pangani [9]. However, the majority of the farmers who are smallholder farmers are not aware of the ongoing international and national programmes. Therefore, smallholder farmers need to be involved in all levels of planning and implementation of the initiatives to overcome the effect of climate change.

Despite inconsistent and unreliable rains, soil fertility is relatively high in the Pangani District [7]. The presented results suggest that policies and initiatives are necessary to address and control the effect of climate change on agriculture and livelihoods in the Pangani District. Examples of the policies and initiatives that various actors have taken to reduce climate change are presented in Supplementary Table 2. However, farmers' awareness level about these policies and initiatives is relatively low, indicating a need for improved communication and outreach efforts. Therefore, the study recommends that farmers should be included in planning and implementing several agricultural policies, especially those related to climate change, and the government should provide more support to farmers to help them cope with the effects of climate change.

4.0 Conclusions and Recommendations

4.1 Conclusions

This work provides the institutional setup and integration of information asymmetry of climate data among extension service providers and smallholder farmers in Tanzania by using the Pangani District as a case study. The work presents climate data trend analysis explicitly from January 2001 to December 2019; the mode of the production and flow of weather and climate information in Tanzania; knowledge, attitude, and practical use of climate data by the smallholder farmers in the Pangani District and climate-smart agricultural technologies and practices in Tanzania. The key results indicate that minimum and maximum temperatures in the Pangani District were slightly increased, and rainfall generally increased with a sharp decrease in 2008 and 2018. On the other hand, the District is currently reported to face severe drought, which endangers human and animal lives. Furthermore, although more than 63% of farmers are aware of climate change and have heard about it, only 16% of them had access to weather and climate change information and advice from the local extension officers. Thus, this study concludes that the available institutional setup and provision of climatic information from mandated intuitions to extension service providers to local people as smallholder farmers is not straightforward and does not favour smallholder farmers in the country. Finally, the presented initiatives, such as Mobile Kilimo and Bi Shamba, which provide real-time weather and agricultural information, can be crucial in helping farmers to cope with climate change by improving their access to timely and accurate information. Nevertheless, such initiatives need continuous improvement and development to make them more effective and efficient in supporting farmers' adaptation to climate change.

4.2 Recommendations

Based on the key findings and conclusions of this study, the following key recommendations are put forward:

(i) First, from the policy point of view, it is recommended that there is a need for inter-sectorial partnerships and linkages to sufficiently utilise the data and technologies that have already been developed on coping with climate change for the benefit of farmers are other users of the information.

(ii) Secondly, there is a need to improve technical expertise and knowledge of climate change within national and local government institutions. This should include increased training of government employees who are responsible for climate and weather data and the creation of specific staff positions or divisions tasked with overseeing climate change issues within the several sectoral ministries, departments and agencies.

(iii) Thirdly, there should be a capacity-building program among the climatic data producers and users and establishing a mechanism to link climate data producers and potential users, including smallholder farmers.

(iv) Fourth, further studies should be conducted on improving local users' credibility, salience, and legitimacy of climate information. After all, appropriate and enough resources should be budgeted and allocated accordingly, primarily to facilitate climate change research and extension workers' activities which should also include farmers in this research.

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References

1. Benson, T., Randriamamonjy, J., Fang, P., Nyange, D., Thurlow, J., & Diao, X. (2018). Prospects for the sectoral transformation of the rural economy in Tanzania: A review of the evidence.
2. Wineman, A., Jayne, T. S., Isinika Modamba, E., & Kray, H. (2020). The changing face of agriculture in Tanzania: Indicators of transformation. *Development Policy Review*, *38*(6), 685-709.
3. Praveen, B., & Sharma, P. (2020). Climate change and its impacts on Indian agriculture: An econometric analysis. *Journal of Public Affairs*, *20*(1), e1972.
4. Zerssa, G., Feyssa, D., Kim, D. G., & Eichler-Löbermann, B. (2021). Challenges of smallholder farming in Ethiopia and opportunities by adopting climate-smart agriculture. *Agriculture*, *11*(3), 192.
5. Gezie, M. (2019). Farmer's response to climate change and variability in Ethiopia: A review. *Cogent Food & Agriculture*, *5*(1), 1613770.
6. Taylor, A., Rubens, J., Masanja, M., Devisscher, T. and Jeans, H. (2011). Final Report: Tanzania Study Ecosystems, Development, and Climate Adaptation: Improving the knowledge base for policies, planning and
7. management. WWF-UK commissioned the Stockholm Environment Institute (SEI) 2011. Oxford
8. CANTZ. (2022); Climate Services: Come in out of the rain: Baseline Study of the contribution of climate services to the adaptability of smallholder end users in four selected Districts of Tanzania. Climate Action Network Tanzania. Dar Es Salaam, Tanzania.
9. Mwiturubani, D. A. (2019). The Impact of Climate Variability and Change on Communities' Access to and Utilization of Coastal Resources in Pangani District, Tanzania. *Climate Change and Coastal Resources in Tanzania*, 17–34. doi:10.1007/978-3-030-04897-6_2
10. URT. (2019). National Climate Change Statistics Report. National Bureau of Statistics, United Republic of Tanzania Dodoma, Tanzania. https://www.nbs.go.tz/nbs/takwimu/Environment/National_%20Climate_Change_Report_2019.pdf (Accessed 25th August 2022).
11. CIAT; World Bank. (2017). Climate-Smart Agriculture in Tanzania. CSA Country Profiles for Africa Series. International Center for Tropical Agriculture (CIAT); World Bank, Washington, DC 25 p. https://hdl.handle.net/10568/83482 (Accessed 15th August 2022).
12. Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, *13*(3), 1318.
13. Campbell, B. M., Hansen, J., Rioux, J., Stirling, C. M., & Twomlow, S. (2018). Urgent action to combat climate change and its impacts (SDG 13): transforming agriculture and food systems. *Current opinion in environmental sustainability*, *34*, 13-20.
14. Enete, A. A., & Amusa, T. A. (2010). Challenges of agricultural adaptation to climate change in Nigeria: A synthesis from the literature. *Field Actions Science Reports. The Journal of Field Actions*, *4*.
15. Ziervogel, G., Cartwright, A., Tas, A., Adejuwon, J., Zermoglio, F., Shale, M., & Smith, B. (2008). Climate change and adaptation in African agriculture. *Stockholm environment institute*, 17-19.

16. Msemo, H. E., Taylor, A. L., Birch, C. E., Dougill, A. J., & Hartley, A. (2021). The value of weather and climate information to the Tanzanian disaster risk reduction sector using nonmonetary approaches. *Weather, climate, and society*, *13*(4), 1055-1068.

17. Kirina, T., Groot, A., Shilomboleni, H., Ludwig, F., & Demissie, T. (2022). Scaling Climate Smart Agriculture in East Africa: Experiences and Lessons. *Agronomy*, *12*(4), 820.

18. Robertson, M. D., Midway, S. R., West, L., Tillya, H., & Rivera-Monroy, V. H. (2018). Fishery characteristics in two districts of coastal Tanzania. *Ocean & Coastal Management*, *163*, 254-268.

19. Mwanga, S. S., Bejumula, J., and Tondelo, V. M (2019). Climate-induced Loss and Damage in coastal areas: Evidence from Bagamoyo and Pangani districts in Tanzania. CAN-TZ, Dar es Salaam.

20. Kijazi, A. L., & Reason, C. J. C. (2009). Analysis of the 2006 floods over northern Tanzania. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *29*(7), 955-970.

21. Brinkmann, S. (2014). Doing without data. *Qualitative inquiry*, *20*(6), 720-725.

22. Mann, H. B. (1945). Nonparametric tests against trend. *Econometrica: Journal of the econometric society*, 245-259.

23. Tabari, H., Marofi, S., Aeini, A., Talaee, P. H., & Mohammadi, K. (2011). Trend analysis of reference evapotranspiration in the western half of Iran. *Agricultural and forest meteorology*, *151*(2), 128-136.

24. Gadedjisso-Tossou, A., Adjegan, K. I., & Kablan, A. K. M. (2021). Rainfall and temperature trend analysis by Mann–Kendall test and significance for Rainfed Cereal Yields in Northern Togo. *Sci*, *3*(1), 17.

25. Yue, S., & Wang, C. (2004). The Mann-Kendall test modified by effective sample size to detect trend in serially correlated hydrological series. *Water resources management*, *18*(3), 201-218.

26. TMA. (2022). Tanzania Meteorological Agency. Available at https://www.meteo.go.tz/

27. Yanda, P. Z., West, J. J., & Daly, M. E. (2015). Institutional analysis for climate services development and delivery in Tanzania. CICERO Report.

28. McKee, T. B., Doesken, N. J., & Kleist, J. (1993, January). The relationship of drought frequency and duration to time scales. In Proceedings of the 8th Conference on Applied Climatology (Vol. 17, No. 22, pp. 179-183).

29. Pei, Z., Fang, S., Wang, L., & Yang, W. (2020). Comparative analysis of drought indicated by the SPI and SPEI at various timescales in inner Mongolia, China. Water, 12(7), 1925.

30. Liu, C., Yang, C., Yang, Q., & Wang, J. (2021). Spatiotemporal drought analysis by the standardized precipitation index (SPI) and standardized precipitation evapotranspiration index (SPEI) in Sichuan Province, China. *Scientific Reports*, 11(1), 1280.

31. Somorowska, U. (2022). Amplified signals of soil moisture and evaporative stresses across Poland in the twenty-first century. *Science of the Total Environment*, *812*, 151465.

32. Field, C. B., Barros, V. R., Mastrandrea, M. D., Mach, K. J., Abdrabo, M. K., Adger, N., ... & Yohe, G. W. (2014). Summary for policymakers. In 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 (pp. 1-32). Cambridge University Press.

33. Ziervogel, G., & Opere, A. (2010). Integrating meteorological and indigenous knowledge-based seasonal climate forecasts for the agricultural sector: lessons from participatory action research in sub-Saharan Africa. CCAA learning paper, 1.

34. Sanga, C., Magesa, M. and Tumbo, S. D. (2005). Agricultural systems simulation I Annex B23 of the Final Technical Report of project R8088A. Sokoine University of Agriculture, Morogoro, Tanzania.

35. Tumbo, S. D., Mwalukasa, N., Fue, K. G., Mlozi, M. R., Haug, R., & Sanga, C. (2018). Exploring information seeking behavior of farmers' in information related to climate change adaptation through ICT (CHAI). *International Review of Research in Open and Distributed Learning*, 19(3).

36. Sanga, C., Mussa, M., Tumbo, S., Mlozi, M. R. S., Muhiche, L., & Haug, R. (2014). On the Development of the Mobile based Agricultural Extension System in Tanzania: A Technological Perspective. *International Journal of Computing & ICT Research*, 8(1).

37. Misaki, E., Apiola, M., & Gaiani, S. (2016). Technology for small scale farmers in Tanzania: A design science research approach. *The Electronic Journal of Information Systems in Developing Countries*, 74(1), 1-15.

38. Ahsan, M. N., & Khatun, A. (2020). Fostering disaster preparedness through community radio in cyclone-prone coastal Bangladesh. *International journal of disaster risk reduction*, 49, 101752.

39. Mudombi, S., & Nhamo, G. (2014). Access to weather forecasting and early warning information by communal farmers in Seke and Murewa districts, Zimbabwe. *Journal of Human Ecology*, *48*(3), 357-366.

40. Bago, B. (2021). Tanzania: M-Kilimo Platform to Reach Six Million Farmers – Bashe. Tanzania Daily News 6 July 2021. Dar es Salaam, Tanzania. https://allafrica.com/stories/202107070290.html

41. Duflo, E. (2012). Women empowerment and economic development. Journal of Economic literature, 50(4), 1051-1079.

42. Mulinda, F. and Jangu, M. (2022). Accreditation to Global Climate Funds: The Urgent Need For Tanzania Institutions to Address Wide Spread Climate Change Impacts. National Environment Management Council (NEMC). The United Republic of Tanzania. Dodoma, Tanzania.

Supplementary Table 1. Monthly Standardized Precipitation Index (SPI) of Pangani district

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	1.50	1.00	0.29	0.20	-0.91	0.96	-0.97	-0.63	-0.23	-1.62	-1.03	-0.67
2002	0.99	-0.37	0.40	1.44	-0.73	-0.49	0.30	0.42	1.54	1.10	0.28	1.01
2003	-1.96	-0.07	-0.80	-2.04	0.34	-0.51	0.68	-0.63	0.76	0.20	-1.65	-1.74
2004	1.57	1.92	-0.75	0.66	-1.85	-0.53	-1.02	-0.63	-1.38	0.10	0.75	0.70
2005	0.58	-0.72	0.10	0.01	0.43	0.00	-0.53	0.09	-1.28	-0.98	-1.02	-1.49
2006	0.36	0.40	0.73	0.33	0.07	1.96	0.56	-0.31	-0.52	1.28	1.67	1.46
2007	-1.11	0.28	0.38	-0.41	1.04	-0.03	-1.25	0.04	-1.06	-0.10	-0.05	-1.38
2008	0.62	-0.08	0.35	1.20	-0.97	-1.25	1.49	-0.63	1.33	1.15	0.62	-1.82
2009	-0.50	0.96	-0.14	-0.49	-0.84	-0.49	-1.02	-0.63	-1.62	0.23	-0.25	0.51
2010	-0.15	-0.44	-1.09	-0.44	-0.36	1.02	-1.25	-0.26	0.11	-0.01	-0.55	-0.14
2011	0.84	-0.12	-0.58	0.10	0.26	-1.25	-0.10	-0.63	1.08	0.79	0.09	0.51
2012	-0.63	0.13	-0.48	-0.41	-0.17	1.09	0.75	0.28	0.22	-1.11	-1.05	-0.29
2013	0.20	-0.91	1.76	-1.68	-0.26	-0.56	-0.42	1.39	1.08	0.00	0.85	-0.52
2014	-1.29	1.90	1.57	0.13	1.05	0.61	0.93	1.29	0.40	-0.70	1.17	1.01
2015	-0.80	-0.15	0.70	-1.14	1.18	-0.60	0.45	0.55	-1.24	-0.23	1.42	-0.08
2016	1.05	-0.16	-1.89	1.26	-2.36	0.98	0.01	0.53	0.17	-1.49	-1.36	0.08
2017	-1.22	0.12	-0.59	0.58	1.43	0.55	0.62	1.71	0.35	0.27	0.71	0.47
2018	0.61	-1.77	1.35	1.55	1.01	0.85	1.98	0.07	1.25	-0.12	-0.41	0.65
2019	-0.42	-0.88	-0.85	-0.65	1.33	-1.10	0.00	1.28	-0.98	2.01	0.26	1.65

The "drought" part of the Standardised Precipitation Index (SPI) range is arbitrarily divided into four categories; mildly dry (0>SPI>-0.99), moderately dry (-1.0>SPI>-1.49), severely dry (-1.5>SPI>-1.99) and extremely dry conditions (SPI less than -2.0).

Supplementary Table 2. Proportions of farmers that are aware of policies and initiatives that various actors take to reduce climate change

Factor	Category	Male (%)	Female (%)	Total (%)	*p*-value
Are you aware of the agenda for 10/30?	Yes	3.3	3.3	6.6	
	No	53.3	40.0	93.3	0.844
Are you aware of the local policies or initiatives taken by various actors (extension officers, NGOs, etc.) to reduce	Yes	23.3	13.3	36.6	
	No	33.3	30.0	63.3	0.558

climate change/global warming?					
If Yes, please specify (n=7)	Forestry officers arrest people who cut trees, but still, people cut trees	0	3.3	3.3	
	I heard about soft loans to farmers	3.3	0	3.3	
	I heard the news that the minister talked about climate change and planting trees as a solution	3.3	0	3.3	
	Cut the tree, plant the tree (Kata Mti Panda Mti)	3.3	0	3.3	
	National plans but not reach the targeted groups	0	3.3	3.3	
	Planting more trees	3.3	0	3.3	
	Planting trees, but I just heard on the radio	3.3	3.3	6.6	
	Prayer	0	3.3	3.3	
	They visited the source of the water, but I have no in-depth information	3.3	0	3.3	
	To plant short-season crops	3.3	0	3.3	0.563