Evaluating the effectiveness of climate information services on farmer preparedness for climate events in Zambia

REPORT

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Accelerating the Impact of CGIAR Climate Research for Africa

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Executive Summary

This report evaluates the effectiveness of Climate Information Services (CIS) in enhancing the preparedness of smallholder farmers in Zambia, particularly within the context of the Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) project. Given the increasing challenges posed by climate change, including erratic rainfall patterns and extreme weather events, the study aimed to assess how CIS supported agricultural decision-making and improved resilience among farmers. The study focused on several key objectives: identifying the knowledge and sources of CIS among smallholder farmers, investigating the magnitude of access and usage of these services, examining the specific needs of male and female farmers, analysing the characteristics of demanded CIS, and exploring the factors influencing the choice and application of CIS products. Additionally, the study sought to investigate the impact of CIS on crop yields, particularly for staple crops such as maize and groundnuts.

Findings indicated that while there was a general awareness of CIS, access remained uneven across different regions, with significant gaps particularly affecting female farmers. The majority of farmers relied on local and national radio broadcasts, community networks, and agricultural extension officers for climate-related information. However, challenges such as delayed information dissemination and scepticism regarding forecast accuracy hindered the effective use of CIS in decision-making processes.

The study highlighted the need for tailored interventions that improved access to CIS, addressed gender disparities, and provided localised, actionable information. Recommendations included enhancing knowledge through training programmes, improving communication infrastructure, and fostering trust between farmers and CIS providers. In conclusion, strengthening Climate Information Services was essential for equipping smallholder farmers in Zambia to better cope with the challenges of climate variability and change, ultimately contributing to improved food security and sustainable agricultural practices.

Contents

1. Background

Globally, there is increasing evidence that climate change is one of the greatest challenges to sustainable development of agriculture and food systems food security and nutrition (IPCC, 2014). Climate change is already stalling progress towards food security in sub–Saharan Africa (SSA) especially since more than 90% of producers are dependent on rain-fed agriculture for their livelihoods (Rao et al., 2011). Climate change, climate variability and increasing extreme hydro-meteorological events are a major threat to agriculture and especially to the smallholder farming systems in Africa (Collier and Dercon, 2014). Like other countries in Africa, Zambia is at significant risk from climate change due to its variable climate and other compounding factors, including widespread poverty, poor infrastructure, dependence on rain-fed agriculture, insecure land rights, degradation of natural resources, and limited capacity to cope with increased variability (Stern and Cooper, 2011).

Unpredictable rainfall patterns and extreme weather events such as droughts and floods frequently disrupt agricultural production, exacerbating food insecurity and poverty in Zambia. Climate change is measurably altering the amount, distribution, timing and quality of water. For example, as air temperature increases, water temperature rises, causing the solubility of oxygen and other gases to decrease (Shrestha et al., 2014). More intense precipitation leads to increased run-off and decreased oxygen solubility in water bodies and hence more stress on the fish and other aquatic animals that rely on oxygen dissolved in water.

Several initiatives aimed at enhancing stakeholders' adaptive capacity such as drought-tolerant crops, improved agronomic practices, and soil and water conservation techniques have been promoted. Lately, timely provision and access to weather and climate information has been introduced to help reduce the impacts of unpredictable rainfall patterns and extreme weather events such as droughts and floods through adequate preparedness and planning, thereby helping farmers increase their resilience to climate variability and change (Tall et al., 2013). From a gender perspective, women and men may be differentially vulnerable to climate change in SSA (Diouf et al., 2019). In comparison to men, women can face different challenges to take advantage of climate-smart agricultural (CSA) practices and technologies such as high-yielding improved seeds, climate information services (CIS), agroforestry, crop diversification, agricultural insurance, etc., promoted as innovative options to avert climate-related risks and help poor and marginal farmers to build resilient livelihoods.

The use of climate information services (CIS) is widely considered as a key adaptation strategy for the agriculture sector in dealing with the challenges posed by climate variability and climate change. CIS has been described as the production, translation, transfer, and use of scientific information for decision-making (Vaughan et al., 2019). CIS involve the timely production, translation, and delivery of useful climate data, information and knowledge for societal decision-making and climate-smart policy and planning (Machingura et al., 2018). The upscaling of weather forecasting systems for risk management in agricultural practices sounds relevant as it provides timely weather information, helping producers to make appropriate decisions (Hansen et al, 2011). Using climate information can help the water sector to predict how water resources in Africa will be impacted and will lead to better management of the existing resources to prepare for droughts and floods if and when they come. Climate information services focus mostly on the climate and weather forecasts which are useful immediately to users in the short term. The forecasts refer to the daily prediction, 10-day forecasts, or even seasonal forecasts. The forecast information includes the onset date of main rains, amount of rainfall, cessation date of the main rains, the temporal and spatial distribution of the main rains, as well as timing and frequency of active dry periods (Rutty and Andrey, 2014).

Many studies have demonstrated farmers' interest in Africa in seasonal and day-to-day alerts of CIS for better environmental management to improve agricultural productivity. A review of the literature indicates that information provided by the climate forecasts could be used in many sectors, especially in agriculture, enabling farmers to make some better livelihood choices so that they can reduce their vulnerability, especially to climate variability (Roncoli et al., 2003; Ziervogel et al, 2005; Ziervogel, 2004). The use of CIS may change the ways households cope with climatic variation by reducing the magnitude or frequency of surprise and by providing more time to prepare for climatic events (Hansen, 2005). The results are likely to be beneficial overall although there may be different effects on different socio-economic systems and on different individual households (Hansen, 2005).

The potential for CIS to reduce the adverse impacts of climate variability and enhance agricultural production, including fisheries, as well as rural livelihoods has therefore motivated this study. There is a realisation that the high variability within the African climate makes CIS a potentially useful tool to help farmers in decision making and could enable them to better manage risks and exploit good years, tailoring management decisions to the seasons. Although there are several examples of CIS programmes with varying degrees of success in promoting the use of CIS in the agriculture sector, barriers to its successful use by agricultural decision makers still exist (Kettle et al., 2014). Evidence of the value of CIS in SSA is limited and could come from a combination of understanding how climatic uncertainty impacts agriculture; model based ex-ante analyses, and empirical *ex-post* evaluations (Hansen et al., 2011). Few studies have tried to quantify the resulting production or livelihood benefits that result from the use of forecasts. *Ex-ante* methods have mainly been used as means of estimating their benefits to agriculture (Hansen, 2005). There are few studies that assess the *ex-post* impacts (Figure 1) of using CIS (Msagi, et al., 2006).

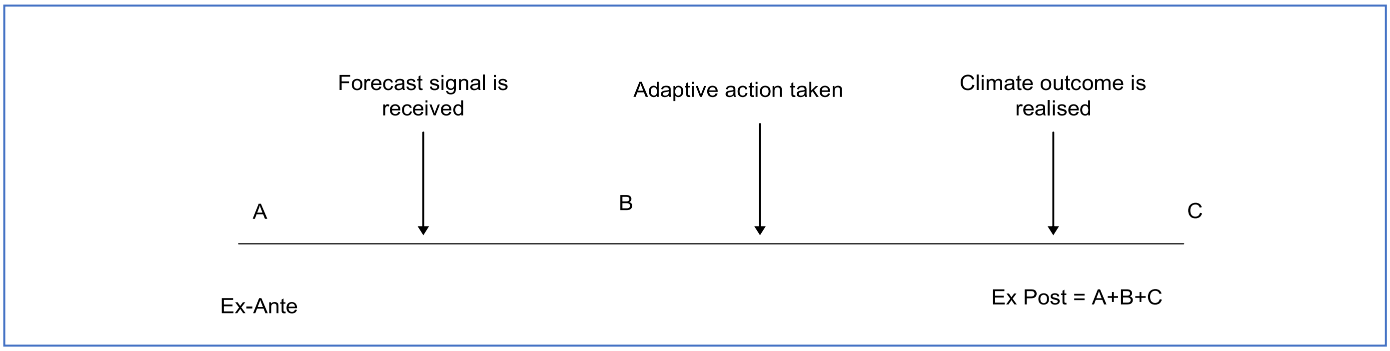

Figure 1: Timeline of information, adaptation and climate outcomes to show ex-post evaluations on climate risk studies

2. Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) Bundles

AICCRA works to deliver a climate-smart African future driven by science and innovation in agriculture. As part of the accelerator programme, AICCRA in Zambia awarded five (5) for profit business and social enterprise partnerships (bundles), to pilot an inclusive market systems approach. The bundles integrated CIS delivery and CSA technology scaling, to de-risk scaling innovations and to enhance climate resilience of value chains, social inclusion, and sustainable use of land and water. These comprised the following; (i) **Bundle 1:** Sustainable finance for off-grid solar irrigation that sought to design cost-efficient financial products for off-grid solar pumps aimed to increase productivity for ordinarily rainfall-dependent smallholder farmers; (ii) **Bundle 2:** Integrated agriculture/aquaculture systems that sought to promote integrated aquaculture agriculture systems through on-farm demonstration and use of socio-cultural innovations to disseminate climate information, while increasing productivity of fish farms; (iii) **Bundle 3:** Drought-tolerant seed varieties that sought to strengthen the climate resilience of the groundnut, maize, and soybean value chains in southern, central, and eastern Zambia by scaling climate-smart inputs and agricultural practices; (iv) **Bundle 4:** Diversified integrated mixed chicken/goats (legume systems) that sought to give equal opportunity to women and youth to become more profitable and food secure by adopting an agroforestry and legume-based farming system with their inherent conservation benefits; and (v) **Bundle 5:** Gender and social inclusion bundle that sought to increase food and economic household security among females living with HIV (FLHIV), women-led households, gender-based violence survivors, and young women through dissemination climate-smart agronomic practices via a mobile application in Central Province.

Despite optimism that climate services can improve decision-making, thereby reducing the need for aid and bettering aid outcomes, extensive research has documented the technical, political, and socio-economic challenges of realizing these benefits. Precipitation forecasts often do not provide sufficient detail regarding the timing, intensity, or distribution of rainfall to facilitate agricultural, fishery or humanitarian decisions. Communication channels, trust in forecasts, community power dynamics, politics, and the resources to act are among the factors that constrain individual and humanitarian responses to CIS. There are arguments that smallholder farmers in southern Africa do not have the necessary ability in terms of resources, and knowledge to respond to seasonal climate forecasts. Different social groups are expected to react differently to the seasonal climate forecasts, that is (i.e.), resource availability has been identified as a factor that constrains farmers on how they respond to forecasts (Roncoli et al., 2002).

3. Study Objectives

To assess how CIS are useful, there is a need to assess their production impacts, although some of the responses that the farmers might give may not necessarily correspond to the entire range of possible adaptive strategies. However, there are many factors that converge in shaping farming decisions, hence, difficulties may arise in identifying the direct causal links between what the CIS provide and behavioural outcomes.

This study therefore aims to examine the effectiveness of climate information systems in AICCRA Zambia, with a focus on their contribution to adaptive capacity and productivity improvement within the different bundles. This study aims to investigates the actual benefits of CIS to individual resource poor farmers in AICCRA Zambia and the main objectives include the following:

1. To identify the knowledge and main sources of CIS (weather and climate-related information) for smallholder farmers/producers and whether they use this information in decision making
2. To investigate the magnitude of access/use to CIS within the farming communities (including smallholder fish farmers) in Zambia
    - To investigate what are the specific needs for climate information services for men and women producers
    - To identify the characteristics of climate information services demanded by smallholder farmers; and
3. To investigate factors that influence farmers' choice and use of CIS products.
4. To investigate the impact of CIS on yield of commonly grown crops

3.1 Study methodology

Data were collected from nine (9) Zambia districts, namely Chama, Chibombo, Chisamba, Kasama, Kawambwa, Mansa, Mumbwa, Mungwi, Nyimba. A total of 1356 farming households were interviewed through a quantitative questionnaire that was administered by well-trained enumerators. A total of two (male only and female only) focus group discussion per district were also conducted in Kawambwa, Kasama, Mungwi, Chisamba, Mansa Nyimba and Mumbwa. The distribution of interviews across the nine districts is in Table 1.

Table 1: Household interviews

District	Number of interviews.	Distribution of interviews (%)
Chama	189	13.9
Chibombo	151	11.1
Chisamba	153	11.3
Kasama	144	10.6
Kawambwa	131	9.7
Mansa	154	11.4
Mumbwa	146	10.8
Mungwi	126	9.3
Nyimba	162	12.0
Total	1,356	100.0

Percentages and means were used to analyse collected data. A log linear regression model was used to analyse the impact of CIS on commonly grown crop yields, for example maize and groundnuts. The model was chosen because it was assumed that crop yields were an exponential variable which was linearly influenced by economic, agronomic and climatic factors.

4. Results

4.1. Household demography

In the surveyed nine districts, they were notable variations in socioeconomic conditions of household as shown in Table 2. Most household were male-headed (79.1%), while education levels remained generally low, with mean years of schooling for household heads averaging 7.6 years and even lower for spouses (6.6 years). In addition, access to non-agricultural employment opportunities in the surveyed districts were limited (11%), with Kasama showing a particularly low rate (2.8%), indicating a heavy reliance on agriculture. Household size averaged 5.7 members, with Mumbwa having the largest and Kasama the smallest. Access to mobile phones was widespread (over 90% in most districts), while radio and television ownership were 52% and 28% respectively. Notably, access to Climate Information Services (CIS) was relatively high (72.7%), particularly in Mungwi (83.3%).

Poverty levels, as indicated by the wealth index, average 33.3%, with Chama experiencing the highest rate (46.6%) and Mumbwa the lowest (25.3%). Wealth index was a composite indicator for access or ownership of radio, television, motorcycle, car or truck, solar panel, animal draft plough, improved stove, generator (petrol or diesel), battery (large, e.g. car battery for power), water pump, refrigerator, electrical fan, internet access, bank account, water storage tank, running or tap water in the dwelling, access to electricity from a grid, improved housing (e.g. concrete, bricks etc), improved roofing (e.g. tin, tiles) and a separate housing for farm animals.

Table 2: Household demography

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Household head gender (% male)	83.6	80.8	69.3	74.3	81.7	83.8	79.5	80.2	77.8	79.1
Household head education (mean years)	8.0	7.6	7.6	7.6	8.3	8.4	7.5	6.8	6.7	7.6
Household head spouse education (mean years)	5.9	7.3	7.3	6.9	7.2	7.2	6.8	5.6	5.5	6.6
Household member working in non agriclture sector (%)	11.6	16.6	15	2.8	6.1	11.7	13.7	7.9	11.7	11.0
Household size (mean)	5.9	6.3	5.3	4.9	5.9	5.3	6.4	5.3	5.4	5.7
Households with radio (%)	45.0	51.7	49.0	51.4	53.4	63.0	55.5	54.8	46.9	52.0
Households with television (%)	30.2	39.7	27.5	18.8	29.8	26.0	22.6	31.0	27.2	28.1
Households with a cellphone (%)	90.0	93.4	96.7	77.1	97.7	90.3	93.8	77.8	92.6	90.1
Household with access to internet (%)	12.2	25.2	28.1	25.7	17.6	20.1	15.1	28.6	17.9	20.8
Households with access to Climate Information Services (CIS)	70.4	72.2	69.9	71.5	71.8	74.7	72.6	83.3	70.4	72.7
Wealth index (% poor household)	46.6	27.8	33.3	42.4	31.3	33.1	25.3	34.9	22.8	33.3

4.2. Activities for food and income

4.2.1. Food production

As shown in Table 3, maize production was dominant across all districts, grown by 93% of households overall, with the highest production in Chama (97.9%) and the lowest in Mungwi (74.6%). Sorghum and pearl millet were minor crops, cultivated by only 2% of households on average, primarily in Mungwi and Kasama. Finger millet was mainly grown in Kasama (28.5%) and Mungwi (25.4%), averaging 9% overall. Rice production was significant in Chama (77.8%) but minimal elsewhere, averaging 15%. Common beans were a major crop in Kasama (70.1%) and Kawambwa (28.2%), while soya beans were widely grown in Mumbwa (69.9%) and Chisamba (56.2%), contributing to an average of 26%. Groundnuts were broadly cultivated, with 70% of households engaged, peaking at 96.8% in Mungwi. Cowpeas were less common, averaging 4%, with slightly higher production in Nyimba (11.1%). Generally maize and groundnuts were common food crop across all the surveyed districts.

Table 3: Food production

Crop	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Maize	97.9	97.4	94.8	89.6	95.4	85.7	97.3	74.6	96.9	93
Sorghum	2.6	1.3	2.0	2.1	0.0	1.3	0.0	4.0	2.5	2
Finger millet	6.3	0.0	0.7	28.5	18.3	2.6	0.0	25.4	3.7	9
Pearl millet	0.5	0.0	0.0	4.9	3.8	0.0	0.0	6.3	0.0	2
Rice	77.8	0.0	0.0	0.0	16.8	3.9	0.0	14.3	3.1	15
Common beans	0.0	2.6	4.6	70.1	28.2	28.6	6.8	21.4	1.2	17
Soya beans	4.8	25.2	56.2	13.9	6.9	7.1	69.9	7.1	44.4	26
Groundnuts	75.7	61.6	58.2	67.4	69.5	56.5	67.1	96.8	76.5	70
Cowpeas	0.0	2.6	6.5	4.2	0.0	2.6	2.1	11.1	5.6	4

4.2.1.1. Involvement of household members in food production by gender

Across all districts household members contributed labour in the production of maize and groundnuts which were the highly cultivated crop in the surveyed districts as shown in Table 4. In maize production, household heads—mainly male—accounted for a significant portion of participation, ranging from 37.3% in Chama to 62.8% in Kasama. Spouses, typically female, contributed less, with percentages varying from 18.2% in Mansa to 28.1% in Chama. Interestingly, combined participation of heads and spouses was highest in Chama (50.3%), suggesting a more collaborative approach in the district. Children also played a role, particularly in Nyimba (40.8%). For groundnuts, the trend was similar; male household heads were most involved, with participation high at 59.8% in Kasama. Spouse participation was relatively higher in groundnuts than in maize, particularly in Chama and Chibombo, where percentages exceed 30%. Overall, while men dominated household decision-making and labour in food production, there was notable involvement from spouses and children, indicating a collective effort in agricultural activities across the surveyed districts. These findings indicated that gender roles in food production are still existing in Zambia.

Table 4: Involvement of household members in maize and groundnut production

Crop	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Maize (%)										
Household head	37.3	58.5	58.6	62.8	52.8	62.1	47.2	60.6	47.1	53.1
Spouse	28.1	26.5	21.4	22.5	21.6	18.2	23.2	24.5	26.8	23.9
Head and spouse	50.3	33.3	29.7	30.2	40.8	30.3	40.1	35.1	42.0	37.5
Child	29.2	39.5	31.0	24.8	34.4	29.5	36.6	29.8	40.8	33.0
Other	7.0	10.2	12.4	12.4	7.2	18.2	12.7	8.5	12.1	11.1
Groundnuts (%)										
Household head	33.6	50.5	47.2	59.8	42.9	46.0	40.8	51.6	44.4	45.8
Spouse	37.8	40.9	30.3	23.7	33.0	23.0	35.7	32.8	25.0	31.6
Head and spouse	42.0	30.1	30.3	34.0	38.5	40.2	36.7	37.7	46.0	37.8
Child	28.0	44.1	34.8	27.8	36.3	24.1	39.8	26.2	40.3	33.3
Other	7.0	9.7	10.1	8.2	6.6	20.7	10.2	5.7	9.7	9.4

4.2.1.2. Crop Yields

In the surveyed districts, there was a considerable variation in yield per hectare for maize and groundnuts as shown in Table 5. Maize, a staple crop, had an overall mean yield of 1208.1 kg per hectare per household. The highest yields were reported in Mungwi (3160.3 kg) and Kasama (2364.7 kg), while the lowest were in Mumbwa (156.6 kg) and Chisamba (279.0 kg). For groundnuts, the mean yield was 481.1 kg per hectare per household. Mungwi again had high yield (943.3 kg), followed by Chama (702.5 kg) and Kasama (686.3 kg), whereas Chisamba (108.8 kg) and Nyimba (111.0 kg) had the lowest yields. The results indicated disparities in agricultural productivity, with northern districts such as Mungwi and Kasama achieving significantly higher yields for both crops compared to southern and central districts like Chisamba and Mumbwa. The disparity was a result of differences in soil fertility, climatic conditions, and farming practices. Normally northern districts receive better rains than southern and central districts.

Table 5: Maize and groundnut yield

Crop	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Maize yield in kgs(mean)	1280.4	287.8	279.0	2364.7	2300.0	1776.2	156.6	3160.3	289.1	1208.1
Groundnuts yield in kgs (mean)	702.5	246.6	108.8	686.3	639.0	505.7	291.3	943.3	111.0	481.1

4.2.2. Cash income sources

Various sources of cash income across the nine districts are outlined in Table 6, revealing livelihood strategies adopted by farming households in Zambia. Business activities, excluding farm products, were the most significant source of income, particularly in Chibombo (47.7%) and Nyimba (48.2%). This suggested the existence of a robust entrepreneurial environment in the two districts. Employment on someone else's farm was also a common source of income, with Chibombo again with 23.8% households engaged in the activity, while other paid employment remained relatively stable across all the districts, averaging around 10%. Remittances and gifts contributed modestly to household income, especially in Chibombo and Chisamba, where they accounted for 15.2% and 15.7%, respectively. Payments from projects or government assistance were notable in several districts, indicating reliance on external support for livelihood support for a considerable number of households. Additionally, informal loans were a significant income source in Mumbwa (27.4%), highlighting the role of informal financial networks in supporting households. Overall, the findings indicated a mixed income landscape, where entrepreneurial activities and informal support systems played crucial roles in household livelihoods across the surveyed districts.

Table 6: Cash income sources

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Employment on someone else's farm (%)	12.7	23.8	15.0	13.2	17.6	10.4	19.2	13.5	10.5	15.0
Other paid employment (e.g. salary) (%)	10.1	11.9	12.4	9.0	14.5	6.5	8.2	11.1	9.9	10.3
Business (other than farm products) (%)	32.3	47.7	40.5	37.5	42.0	38.3	32.2	33.3	48.2	39.1
Remittances or gifts (%)	6.4	15.2	15.7	8.3	8.4	10.4	11.6	13.5	11.1	11.1
Payments for environmental services (%)	0.0	2.7	1.3	0.7	0.0	0.7	0.0	0.0	1.9	0.8
Other payment from projects/ government including benefits in kind (e.g. aid, subsidies, etc.) (%)	7.9	15.2	22.9	21.5	19.9	15.6	9.6	17.5	21.6	16.6
Insurance for crops/livestock (%)	0.0	0.7	0.7	0.0	1.5	0.0	0.0	0.0	0.0	0.3
Loan/credit from a bank or other formal institution (microfinance, projects/programs, registered group) (%)	1.1	0.0	4.6	6.3	0.0	0.0	3.4	0.8	3.1	2.1
Loan/credit from an informal source (moneylender, Savings group, etc.) (%)	14.3	8.0	19.6	4.9	17.6	11.7	27.4	12.7	20.4	15.2
Renting out your own land (%)	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.7
Income from other sources (%)	24.3	21.2	9.2	12.5	11.5	7.8	18.5	6.4	20.4	15.1

4.2.3. Involvement of household members in cash income generating activities by gender

As shown in Table 7, in the surveyed districts, household heads were the primary participants in business activities, excluding farm products. The activities were the most significant source of income, with 51.5% of all surveyed households reporting their involvement. The highest involvement was seen in Mansa (66.1%) and Mungwi (64.3%), while Nyimba (33.3%) had the lowest. For spouses, about 20% of them on average participated in businesses activities, with notable high participation in Nyimba (34.6%) and Chibombo (23.6%), but much less in Kawambwa (7.3%). Joint participation by heads and spouses accounted for 25.7% of business involvement, peaking in Kawambwa (36.4%) and Nyimba (32.1%) and lowest in Chisamba (14.5%). This indicated that some household businesses were jointly managed by the household and the spouse. Children's participation was minimal at 2.1%, with slight peaks in Mumbwa (4.3%) and Kawambwa (5.5%), and none reported in Kasama or Nyimba. Other household members rarely participated (0.38% overall), with a small contribution in Kasama (1.9%). These results suggested that business activities were predominantly driven by household heads, with moderate contributions from spouses, and minimal involvement of children or other members.

Table 7: Involvement of household members in cash income generating activities by gender

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Business (other than farm products) (%)										
Household head	50.8	52.78	59.68	46.3	50.9	66.1	46.8	64.3	33.3	51.5
Spouse	19.7	23.6	21.0	18.5	7.3	15.3	19.3	16.7	34.6	20.4
Head and spouse	27.9	22.2	14.5	33.3	36.4	15.3	29.8	19.1	32.1	25.7
Child	1.6	1.4	3.2	0	5.5	3.4	4.3	0	0	2.1
Other	0	0	1.6	1.9	0	0	0	0	0	0.38

Besides agricultural activities, both rain-fed, petty trade, piece work that diversified diversify household income sources according to focus group discussions (FGDs), some households were involved in innovative activities like beer brewing and charcoal production, reflecting their adaptability in response to environmental and economic conditions. Generally, there was a multifaceted approach to food security and income generation, rooted in both agriculture and emerging local enterprises. Livestock rearing was also significant in income generation and food production especially in Kawambwa and Mungwi, according to FDGs

4.3. Climate information services

4.3.1. Access to climate information services

Households across the nine surveyed districts accessed different type of climate information services (CIS) as shown in Table 8. The most accessed CIS were the forecasts for the start of the rains (averaging 48.3% across all districts) and the forecasts for drought, flood, frost, cyclones, or other extreme events (averaging 42%). Seasonal weather forecast information was accessed by 38.5% of the surveyed households, while forecasts for pest or disease outbreaks was accessed by 29.1%. Access to short-term weather forecasts (today, 24 hours, and/or the next 2-3 days) was lower, averaging 15.4%. One focus group participant said.

"We receive weather focus, news about temperature and seasonal rain forecast to say the rains will be enough this year". Females FGD participant, Chisamba District.

However, a significant proportion of the households (27.3% overall) reported no access to any CIS, with Mungwi being a notable exception with only 16.7% lacking access. While forecasts related to rainfall and extreme events were widely accessed, there was a need to improve access to short-term forecasts and pest/disease outbreak information. Additionally, efforts should focus on reducing the proportion of the population without any access to CIS, particularly in districts like Chama, Chisamba, and Nyimba, where "no access" rates approached or exceeded 30%.

Table 8: Access to climate information services

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Forecast of drought, flood, frost, cyclone, or other extreme event	41.8	33.1	43.1	40.3	40.5	44.8	44.5	52.4	39.5	42.0
Forecast of pest or disease outbreak	28.0	23.2	27.5	29.9	35.9	35.7	29.5	31.0	22.8	29.1
Forecast of the start of the rains	44.4	42.4	47.1	52.1	51.9	51.3	48.6	53.2	46.3	48.3
Seasonal forecast of the weather	34.4	37.7	37.3	38.2	36.6	39.6	39.7	43.7	40.7	38.5
Forecast of the weather for today, 24 hours and/or next 2-3 days	9.0	13.9	18.3	17.4	16.0	16.2	17.8	15.9	16.0	15.4
No access	29.6	27.8	30.1	28.5	28.2	25.3	27.4	16.7	29.6	27.3

4.3.2. Climate information service medium and providers

The primary sources of climate information services regarding forecasts of droughts, floods, and other extreme events, pest or disease outbreak, start of rains, seasonal forecast of the weather, forecast of the weather for today, 24 hours and/or next 2-3 days were the same. CIS were transmitted predominantly through local and national radios, neighbours, friends, and other community members. Other sources included television, agricultural extension officers, social media, and family members. CIS providers were Zambia Disaster Management and Mitigation Unit (DMMU), Meteorological Department, NGOs e.g. One Acre fund, World Vision, Fath based organisation (Churches) and Conservation Farming Unit (CFU). Generally, CIS were disseminated through formal and informal networks, highlighting the value of interpersonal communication, media, and communal interactions for surveyed households to stay informed about climate-related risks. Since households with mobile phones were approximately 90%, while those with access to internet were approximately 20%, limited use of digital platforms compatible with smart mobile phones remained an unexplored opportunity to promote improved access to CIS.

4.3.3. Access to Climate Information Services and gender

CIS, that disseminated forecasts of extreme weather events (droughts, floods, frost, cyclones) were mostly (56.7%) accessed by household heads as shown in Table 9. Who were largely male. Spouses had significantly lower access, averaging 16.0%, with the lowest access in Kasama (10.3%). Both heads and spouses together had a moderate level of access (37.2%), while children and others had minimal access, averaging 7.7% and 1.2%, respectively. Similarly, for forecasts of the start of rains, household heads maintained the highest access (55.0%). Spouses again had limited access (15.4%), and the combined access of heads and spouses was slightly higher at 40.2%. Children had slightly more access (8.2%) compared to extreme event forecasts, but other household members remained largely uninformed (0.9%). The findings highlighted a gender gap in accessing climate information services, with spouses and children being underinformed. This underscored the need for inclusive approaches to disseminating critical climate-related information to ensure equitable access across all household members.

Table 9: Access to Climate Information Services and gender

Crop	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Forecast of drought, flood, frost, cyclone, or other extreme event										
Household head	51.9	54.0	48.5	58.6	58.5	63.8	52.3	69.7	53.1	56.7
Spouse	29.1	16.0	13.6	10.3	9.4	13.0	16.9	18.2	12.5	16.0
Head and spouse	32.9	40.0	42.4	41.4	39.6	31.9	41.5	27.3	40.6	37.2
Child	10.1	4.0	6.1	6.9	9.4	10.1	7.7	6.1	7.8	7.7
Other	0.0	0.0	1.5	1.7	0.0	2.9	0.0	4.5	0.0	1.2
Forecast of the start of the rains										
Household head	50.0	62.5	47.2	61.3	58.8	63.3	43.7	53.7	54.7	55.0
Spouse	16.7	15.6	15.3	9.3	11.8	15.2	15.5	22.4	17.3	15.4
Head and spouse	44.0	34.4	44.4	34.7	38.2	35.4	49.3	41.8	38.7	40.2
Child	10.7	10.9	8.3	6.7	8.8	5.1	8.5	6.0	9.3	8.2
Other	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.9

4.3.4. Advice inclusion in the climate information services provided

CIS were provided with advice in all surveyed districts as shown in Table 10. Overall, households received the highest level (averaging 86.0% overall) of advice inclusion on CIS focusing was on the forecasts of pest or disease outbreaks, with Chibombo recording the highest at 94.3%. This indicated that the surveyed household were provided pest management advice whenever there was an outbreak, and they noticed the advice that built their agricultural resilience. Forecasts related to extreme events such as droughts and floods also included advice, with an average of 75.1% surveyed households noticing it, indicated that communities were well-informed about potential disasters of extreme climate events. Additionally, the forecasts for the start of the rains and seasonal weather predictions also had high advice inclusion, with households that noted it averages 83.8% and 84.3%, respectively, reflecting efforts for timely weather information provision for agricultural planning purposes. Short-term weather forecasts, including those for the upcoming 24 hours, had slightly lower advice inclusion rates at 80.9%, and this suggested that households were not informed on what to do when weather changed promptly within days. Lack of such information made farming households especially during winter horticultural farming, vulnerable to sudden weather changes.

Table 10: Advice inclusion in the climate information services provided

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Forecast of drought, flood, frost, cyclone, or other extreme event	70.9	76	63.7	72.4	75.5	82.6	83.1	78.8	73.4	75.1
Forecast of pest or disease outbreak	84.9	94.3	76.2	88.4	76.6	89.1	95.4	82.1	89.2	86.0
Forecast of the start of the rains	84.5	85.9	72.2	76	75	88.6	93	88.1	90.7	83.8
Seasonal forecast of the weather	89.2	80.7	79.0	80.0	75.0	85.3	96.6	83.6	86.4	84.3
Forecast of the weather for today, 24 hours and/or next 2-3 days	76.5	66.7	71.4	80.0	76.2	88.0	92.3	80.0	92.3	80.9

4.3.5. Use of the advice provided with climate information services

Generally, there was low usage of advice derived from CIS in all districts as shown in Table 11 except for the advice from forecasts for the start of the rains and seasonal forecasts of the weather. These were used by over 50% of surveyed households in most districts, most likely for summer farming planning purposes. The least used climate information service (CIS) was short-term forecasts for today, 24 hours, or the next 2-3 days. This was used by less than 30% of households in most districts. These results suggested that while advice for longer-term forecasts was well-utilised, there was a notable gap in the uptake of advice for short-term weather forecasts. Moreover, the gap between information availability and practical application, pointed to the need for enhanced outreach and education to facilitate better utilisation of climate advice for agricultural decision-making in all districts. One focus group discussion said:

"We need to plant trees so that we can have enough rains and also the trees will break the winds from destroying our crops". Female, FGD participant, Mumbwa District.

Table 11: Use of the advice provided with climate information services

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Forecast of drought, flood, frost, cyclone, or other extreme event	24.1	34.0	34.9	36.2	35.9	46.4	41.5	59.1	31.3	38.1
Forecast of pest or disease outbreak	30.2	40.0	26.2	46.5	38.3	47.3	46.5	38.5	37.8	39.1
Forecast of the start of the rains	52.4	54.7	31.9	54.7	47.1	60.8	60.6	62.7	62.7	54.2
Seasonal forecast of the weather	56.9	54.4	35.1	50.9	39.6	45.9	53.5	50.9	56.1	49.6
Forecast of the weather for today, 24 hours and/or next 2-3 days	5.9	23.8	10.7	32.0	19.1	32.0	19.2	45.0	30.8	24.4

4.3.6. Farming changes after receiving climate information services

4.3.6.1. Forecast of drought, flood, frost, cyclone, or other extreme event

The surveyed households that acted on CIS provided adopted conservation agriculture practices, such as early planting, pot holing, residue retention, and using drought-tolerant or early maturing seed varieties to cope with forecasted extreme events such as drought. Additionally, diversification of crops, crop rotation, reducing planted area, reduced deforestation and planted more trees were also strategies that household used to cope with forecasted drought, flood, frost, cyclone, or other extreme event. However, a considerable number of respondents reported being unable to act on the advice given due to financial constraints, late delivery of information, or skepticism about its accuracy. For some, the advice arrived too late, as planting had already been completed. Based on these findings, there was need for timely, accurate climate information and access to resources for households to effectively insulate themselves against forecasted extreme climate events. One focus group discussion participant said;

"Drought led us to start pot holing because it holds water and pot holing gives us high yields". Female, FGD participant, Mumbwa District.

4.3.6.2. Forecast of pest or disease outbreak

The household that received and used CIS advice on forecasted pest or disease outbreaks took proactive measures, such as purchasing and applying pesticides or herbicides, planting pest-resistant crop varieties, and reported outbreaks to agricultural extension officers for technical assistance. Additionally, early planting was another common strategy that was used by households to mitigate pest impact, as it allowed crops to mature before infestations became severe. Traditional methods, like using ashes, urea, or herbal treatments, were also used to limit the impact of infestation on both crops and livestock including chickens. However, a significant number of households also reported not changing their practices due to financial constraints, as they could not afford the recommended chemicals. Others expressed a lack of trust in the information provided or cited the absence of pests in the current season as a reason for inaction.

4.3.6.3. Forecast of the start of the rains

Households that acted after they received start of the rains forecasts made proactive measures in preparing for the summer farming season, such as purchasing early maturing and drought-resistant seeds, adjusting planting dates, and preparing land in advance to align with anticipated rainfall. One focus group discussion participant said;

"When it comes to crop production, if the rains come early, we do plant early through the information we received, when it comes to livestock we do build new houses fish farming we close the inlet and open the outlet of the fish pond", Females FGD participant, Kawambwa District

However, several households also noted that they did not change their practices due to late or unclear information, financial constraints, or a lack of trust in the provided advice. While early planting emerged as a common strategy, some farmers expressed frustration over inconsistent information and the feeling of being unprepared for the season's challenges. Overall, the findings revealed a mix of proactive adaptation and hesitation, highlighting the need for reliable and timely agricultural information to better equip farmers for climate variability.

4.3.6.4. Seasonal forecast of the weather

Just like in the previous CIS provided, households are receiving seasonal forecast of the weather they adapted strategies like early planting and the use of early-maturing or drought-tolerant crop varieties to enhance resilience against unpredictable weather patterns. Others adjusted their seed selection, choosing varieties suited to shorter or specific seasons. Some adopted conservation practices, including avoiding deforestation and switching to crop varieties suited to predicted conditions. In contrast, A notable number of households also indicated that they did not alter their practices due to financial constraints, late or unclear information or a lack of trust in the accuracy of the weather forecasts.

4.3.6.5. Forecast of the weather for today, 24 hours and/or next 2-3 days

Households that used the forecast of weather daily and/or next 2-3 days information, used it for guidance on when to apply fertiliser to avoid its application during unsuitable conditions, such as dry soil or during dry spells. Some incorporated provided advice, like applying fertiliser at the advised time and rate or performing weeding based on forecasts. Some households waited for instructions before applying fertilizers, reflecting a cautious attitude towards fertiliser use, especially in the context of uncertain weather conditions. However, a significant number of surveyed households acknowledged that they did not change their practices or apply fertilizers until prompted, highlighting a potential lack of proactive decision-making.

4.4. Climate related crisis

Climate-related crises prevalent is all nine districts as shown in Table 12. The majority of the households, 86.2% on average, reported experiencing such crises, with the highest incidents in Chibombo (97.4%) and Chisamba (98.0%). Drought emerged as the most faced climate event, particularly impacting Chibombo and Chisamba, where nearly 90% of households reported its occurrence. Erratic rainfall onset was notably less common, affecting only about 10.9% of households on average, with Chisamba reporting the lowest incidence. Prolonged dry spells and floods were also significant concerns, with varying impacts in all the districts. For instance, floods were particularly problematic in Chama (43.0%). Heat waves were less frequently reported overall, affecting only 3.3% of households. Additionally, pest infestations and diseases were prevalent, with over 30% of households in several districts indicating the challenge. Overall, the surveyed districts had diverse and significant climate-related stressors that impacted agricultural households, with drought and pest challenges being particularly acute.

Table 12: Climate related crisis

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Household faced climate related crisis	94.7	97.4	98.0	56.3	67.9	85.1	93.2	81.8	94.4	86.2
Climate event faced: Drought	35.8	89.1	94.7	43.2	30.3	57.3	83.1	54.4	92.8	67.2
Climate event faced: Erratic rainfall onset	17.9	9.5	6.7	0.0	10.1	5.3	16.2	5.8	17.6	10.9
Climate event faced: Prolonged dry spell	36.9	29.3	24.7	27.2	25.8	32.1	26.5	17.5	30.1	28.5
Climate event faced: Floods	43.0	10.2	2.7	23.5	33.7	16.8	8.1	30.1	7.8	18.9
Climate event faced: Early rainfall cessation	11.7	14.3	11.3	16.0	15.7	16.8	13.2	4.9	15.7	13.3
Climate event faced: Heat wave	2.2	3.4	0.7	4.9	10.1	3.8	0.7	4.9	2.6	3.3
Climate event faced: Pests	30.2	28.6	30.0	43.2	37.1	35.1	33.1	20.4	34.6	32.0
Climate event faced: Diseases	15.6	11.6	14.7	12.3	23.6	16.0	14.0	8.7	13.1	14.3
Climate event faced: Other	4.5	0.0	0.0	0.0	4.5	2.3	0.0	2.9	0.7	1.6

Droughts prominently affected households during 2021, 2022, 2023, and most notably in 2024, causing widespread agricultural challenges. Similarly, pests were reported as a persistent issue, with notable peaks from 2019 through 2024. Prolonged dry spells also emerged as critical challenges in 2023 and 2024, exacerbating the adverse effects on crop yields. Other notable events included erratic rainfall onsets in 2023 and 2024, which disrupted traditional planting cycles, and early rainfall cessation reported prominently in 2024, further complicating farming activities. Floods were observed sporadically, with significant occurrences in 2019, 2020, and 2024, leading to extensive damage to crops and infrastructure. Additionally, diseases associated with climatic variability were recurrent, particularly in 2023 and 2024.

4.5. Agricultural enterprises greatly affected by climate related crisis

Climate-related crises affected various agricultural enterprises across all districts. However, crops were the most (86.5) significantly affected enterprise, with the highest percentage of households highlighting the impact in Chibombo (98.7%) and Chisamba (98.7%), while the lowest impact was in Kasama (63.2%) as shown in Table 13. This indicated the vulnerability of crop production to climatic variability, particularly droughts, floods, and erratic rainfall patterns. Livestock also suffered, but to a lesser extent, with the highest impact in Mumbwa (37.0%) and the lowest in Kasama (3.5%). Fisheries were minimally impact overall, with the highest recorded in Chama (5.3%), indicating a relatively stable sector compared to crops and livestock. Overall, the data highlights the overwhelming vulnerability of crop production to climate crises, while livestock and fisheries appear less affected, suggesting a need for targeted interventions to enhance resilience in the most impacted sectors.

Table 13: Agricultural enterprises greatly affected by climate related crisis

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Crops	93.7	98.7	98.7	63.2	66.4	84.4	92.5	79.4	94.4	86.5
Livestock	31.2	23.8	21.6	3.5	9.9	13.6	37.0	4.0	37.7	21.2
Fisheries	5.3	1.3	1.3	0.0	0.8	2.6	3.4	0.0	4.9	2.4
Other	11.1	1.3	0.7	37.5	32.8	14.9	6.8	22.2	4.9	14.0

4.6. Activities conducted to reduce the impact of climate crisis

Various activities were conducted by households across all districts to mitigate the impacts of climate crises on agriculture. Vegetable or horticultural production was the most (19.9) significantly practiced activity, especially in Chama (29.1%) and Nyimba (28.4%) as shown in Table 14. Savings and credit initiatives were notable in several districts, with the highest number of households participating in Nyimba (15.4%). Irrigation practices were particularly prominent in Chibombo (11.9%) and Mansa (11.7%), reflecting a focus on improving water management. Additionally, the establishment of women agricultural cooperatives was notable, especially in Nyimba (22.8%), indicating efforts to empower women in agribusiness. Programmes like the Food Security Pack (FSP) were prominent, with households notably (15.9% overall) participating, particularly in Mumbwa (30.1%) and Mansa (27.9%), indicating their role in enhancing resilience among vulnerable households. However, activities like tree planting and water catchment management were low across all districts, suggesting areas for potential improvement in all districts.

Table 14: Activities conducted to reduce the impact of climate crisis

	Chama	Chibombo	Chisamba	Kasama	Kawambwa	Mansa	Mumbwa	Mungwi	Nyimba	All
Tree nursery/tree planting	1.1	0.0	1.3	1.4	5.3	1.9	0.0	0.0	1.9	1.4
Fishponds	0.0	0.0	0.0	5.6	10.7	7.1	0.0	1.6	0.0	2.6
Fishing	0.0	0.0	0.0	1.4	1.5	3.2	0.0	4.0	1.9	1.3
Forest product collection	1.1	1.3	0.7	0.0	0.0	1.3	2.1	0.0	1.2	0.9
Water catchment management	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.1
Soil improvement activities	4.2	0.0	0.7	1.4	4.6	0.6	0.0	2.4	2.5	1.8
Crop introduction/substitution	1.1	0.0	0.0	0.7	1.5	3.2	0.0	3.2	1.2	1.2
Irrigation (specify the name of irrigation scheme)	4.2	11.9	7.2	2.1	8.4	11.7	11.6	3.2	3.1	7.0
Savings and/or credit	13.2	2.6	14.4	2.1	8.4	5.2	14.4	2.4	15.4	9.0
Women agricultural/ agribusiness cooperatives (i.e. livestock, crops, tree or fish)	1.6	12.6	8.5	3.5	4.6	3.9	7.5	7.1	22.8	8.0
Livestock & Poultry	5.8	2.6	0.7	0.7	1.5	0.6	8.2	0.8	3.7	2.9
Input cooperative (FISP)	0.0	0.7	1.3	2.1	0.8	0.0	0.0	0.8	3.1	1.0
Food Security Pack (FSP)	5.8	27.8	10.5	3.5	15.3	27.9	30.1	13.5	11.1	15.9
Seed production	7.4	7.3	0.7	0.0	0.8	0.0	5.5	0.0	8.0	3.5
Vegetable/ horticultural production	29.1	17.2	21.6	19.4	16.8	11.7	15.1	15.9	28.4	19.9
Nutritional Gardens/ groups	6.9	4.0	12.4	13.2	9.9	5.8	4.8	8.7	6.8	8.0
Other activities combined	55.6	48.3	57.5	70.1	58.8	54.5	46.6	64.3	45.7	55.4

4.7. Impact of access to climate information services on maize yield

The impact of access to climate information services on maize yields per hectare was assessed through a log-linear maize production model to capture climatic and non-climatic impacts on the maize yield. Independent variables included various production costs, such as land preparation, weeding, harvesting, seed, basal fertilizer, and urea fertilizer, which reflected economic inputs necessary for maize cultivation. Additionally, the model incorporated a dummy variable related to adaptive management practices, such as the adoption of soil and water conservation methods. Other dummy variables were related to access to climate to information services. Access to CIS was essential for farmers to make informed decisions, mitigate climate risks and achieve higher yields. The model was specified as in equation (1), while Table 15 describes the model variables. The model was chosen because, maize yield was assuming to increase exponential in the face of a linear relationship with CIS and other production factors.

$$In(Maize\_yield) = \beta_0 + \beta_1 Land_{prep} + \beta_2\text{Weeding} + \beta_3\text{Harvesting} + \beta_4\text{Seed} + \beta_5\text{Basal} + \beta_6\text{Urea} + \beta_7 Soil_{water} + \beta_8\text{Drought} + \beta_9\text{Pest} + \beta_{10}\text{Rain} + \beta_{11}\text{Weather} + \beta_{12}\text{Weather24} + \varepsilon \dots \dots \dots (1)$$

Where;

β – coeficient of of variables (or percentage changes); ε – Error term; Maize_yield – Maize yield per hecture (ha) In (Maize_yield) – Natural logarithms of maize yield per hecture (ha); Land_prep – Cost (ZMK) of land preperation per hectare per season ; Weeding – Cost (ZMK) of weeding per hectare per season ; Harvesting – Cost (ZMK) of harvesting per hectare per season ; Seed – Cost (ZMK) of seed per hectare per season; Basal – Cost (ZMK) of basal fertiliser per hectare per season'Urea – Cost (ZMK) of Urea fertilised per hectare per season; Soil_water – Soil and water conservation methods adoption (Dummy); Drought – Forecast of drought, flood, frost, cyclone, or other extreme event (Dummy); Pest – Forecast of pest or disease outbreak (Dummy); Rain – Forecast of the seasonal start of the rains (Dummy); Weather – Seasonal forecast of weather (Dummy); Weather24 – Forecast of the weather for today, 24 hours and /or next 2-3 days (Dummy)

Table 15: Maize Log-linear regression - dependent and independent variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent variable					
Maize yield per hecture (kg/ha)	1218	1208.1	1924.7	0	25000
Independent variables					
Cost (ZMK) of land preperation per hectare per season	1218	482.6	695.1	0	7142.9
Cost (ZMK) of weeding per hectare per season	1218	330.0	523.8	0	3840
Cost (ZMK) of harvesting per hectare per season	1218	252.8	523.1	0	7200
Cost (ZMK) of seed per hectare per season	1218	675.9	940.5	0	20800
Cost (ZMK) of basal fertiliser per hectare per season	1218	1264.2	1548.0	0	13200
Cost (ZMK) of Urea fertilised per hectare per season	1218	1272.6	1632.9	0	17142.9
Soil and water conservation methods adoption, where 1=Household adopted	1218	0.8	0.4	0	1
Forecast of drought, flood, frost, cyclone, or other extreme event, where 1=Household received the forecast	1218	0.4	0.5	0	1
Forecast of pest or disease outbreak, where 1=Household received the forecast	1218	0.3	0.5	0	1
Forecast of the seasonal start of the rains, where 1=Household received the forecast	1218	0.5	0.5	0	1
Seasonal forecast of weather, where 1=Household received the forecast	1218	0.4	0.5	0	1
Forecast of the weather for today, 24 hours and /or next 2-3 days, where 1=Household received the forecast	1218	0.2	0.4	0	1

The log-linear maize production model regression results are shown in Table 16. The results indicated that access to climate information services (CIS) significantly ($p < 0.05$) influenced maize yields. For example, household access to forecast of drought, flood, frost, cyclone, or other extreme event information increased maize yield per hectare by 28.8%, while controlling for agronomic and economic factors that affected maize production. Such CIS enabled beneficial households to make informed decisions and mitigate risks. Although other CIS-related variables, such as pest forecasts and seasonal weather predictions, did not show significant effects, the positive impact of extreme weather forecasts highlights the critical role of CIS in enhancing agricultural resilience and productivity, suggesting that their utilisation might be limited or their influence less direct. Additionally, significant coefficients for costs related to land preparation and harvesting, suggesting that informed decision-making, facilitated by CIS, can lead to better economic investments and improved yields in maize production. Higher investments in these activities were associated with increased productivity.

Table 16: Maize - Log-linear regression model results

Variables	Log (Maize_yield)
Cost (ZMK) of land preparation per hectare per season (ha)	0.000282**
	(3.02)
Cost (ZMK) of weeding per hectare per season (ha)Weed	0.0000660
	(0.52)
Cost (ZMK) of harvesting per hectare per season (ha)	0.000762***
	(6.30)
Cost (ZMK) of seed per hectare per season(ha)	-0.000112
	(-1.92)
Cost (ZMK) of basal fertiliser per hectare per season (ha)	0.0000587
	(0.80)
Cost (ZMK) of Urea fertilised per hectare per season(ha)	0.000206**
	(2.96)
Soil and water conservation methods adoption	-0.239
	(-1.65)
Forecast of drought, flood, frost, cyclone, or other extreme event	0.288*
	(2.13)
Forecast of pest or disease outbreak	0.187
	(1.09)
Forecast of the seasonal start of the rains	0.00452
	(0.04)
Seasonal forecast of weather	0.0829
	(0.66)
Forecast of the weather for today, 24 hours and /or next 2-3 days	-0.239
	(-1.35)
_cons	5.550***
	(37.10)
N	1029

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

4.8. Impact of access to climate information services on maize groundnut

The impact of access to climate information services on groundnut yields per hectare was assessed through a log-linear groundnut production model to capture climatic and non-climatic impacts on the ground yield. Independent variables included various production costs, such as harvesting, and total production cost, which reflected economic inputs necessary for groundnut cultivation. Additionally, the model incorporated a dummy variable related to adaptive management practices, such as the adoption of soil and water conservation methods. Other dummy variables where related to access to climate to information services. Access to CIS was essential for farmers to make informed decisions, mitigate climate risks and achieve higher yields. The model was specified as in equation (2), while

Table 17 describes the model variables. The model was chosen because groundnut yield was assumed to increase exponential in the face of a linear relationship with CIS and other production factors.

$$In(Gnut\_yield) = \beta_0 + \beta_1\text{Harvesting} + \beta_2\text{Total}_{\text{cost}} + \beta_3 Soil_{water} + \beta_4\text{Drought} + \beta_5\text{Pest} + \beta_6\text{Rain} + \beta_7\text{Weather} + \beta_8\text{Weather24} + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots. (2)$$

Where;

β – coeficient of of variables (or percentage changes)

ε – Error term

Gnut_yield – Groundnut yield per hecture (ha)

In (Gnut_yield) – Natural logarithms of groundnut yield per hecture (ha)

Harvesting – Cost (ZMK) of harvesting per hectare (ha)

Total_cost – Toral cost (ZMK) of production per hectare per season

Soil_water – Soil and water conservation methods adoption

Drought – Forecast of drought, flood, frost, cyclone, or other extreme event

Pest – Forecast of pest or disease outbreak

Rain – Forecast of the seasonal start of the rains

Weather – Seasonal forecast of weather

Weather24 – Forecast of the weather for today, 24 hours and /or next 2-3 days

Table 17: Groundnut Log-linear regression - dependent and independent variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent variable					
Ground nut yield per hectare (ha)	830	481.1	886.5	0.0	9071.4
Independent variables					
Cost (ZMK) of harvesting per hectare per season	830	39.0	89.40	0	1260
Toral cost (ZMK) of production per hectare per season	830	851.9	1848.21	0	19166.7
Soil and water conservation methods adoption	830	0.8	0.38	0	1
Forecast of drought, flood, frost, cyclone, or other extreme event	830	0.5	0.50	0	1
Forecast of pest or disease outbreak	830	0.3	0.47	0	1
Forecast of the seasonal start of the rains	830	0.53	0.50	0	1
Seasonal forecast of weather	830	0.43	0.50	0	1
Forecast of the weather for today, 24 hours and /or next 2-3 days	830	0.17	0.38	0	1

The log-linear groundnut production model regression results are shown in Table 18. Just like in the case of maize production, the results indicated that access to climate information services (CIS) significantly influenced groundnut yields. For example, household access to forecast of drought, flood, frost, cyclone, or other extreme event information increased groundnut yield per hectare by 58.9%, while controlling for agronomic and economic factors that affected groundnut production. Additionally, the adoption of soil and water conservation methods had a positive significant effect on yield ($p < 0.05$), reinforcing the importance of integrating adaptive management practices with CIS. Conversely, forecast of the seasonal start of rains was significantly ($p<0.05$) associated with negative effect, potentially indicating challenges in timing, accuracy, or integration of these forecasts into decision-making processes.

Table 18: Groundnut - Log-linear regression model results

Variables	Log_ground nut
Cost (ZMK) of harvesting per hectare per season (ha)	0.00127*
	(0.000526)
Toral cost (ZMK) of production per hectare per season	0.000186***
	(0.0000269)
Soil and water conservation methods adoption	0.352*
	(0.137)
Forecast of drought, flood, frost, cyclone, or other extreme event	0.589***
	(0.133)
Forecast of pest or disease outbreak	0.162
	(0.166)
Forecast of the seasonal start of the rains	-0.202
	(-0.129)
Seasonal forecast of weather	0.0199
	(0.123)
Forecast of the weather for today, 24 hours and /or next 2-3 days	-0.409*
	(-0.175)
_cons	5.243***
	(0.102)
N	618

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

4.9. Best ways climate related information could be disseminated

The focus group discussions across seven out of the nine surveyed districts highlighted several key improvements for disseminating climate-related information effectively. Participants emphasized the need for diverse communication channels, including direct engagement through extension officers (most mentioned) and non-governmental organisations, radio, and social media. They expressed a strong preference for information to be delivered in local languages, particularly Bemba, Tonga, and Nyanja, to ensure comprehension and relevance. Timeliness was another critical factor, with community members wanting to receive information before the onset of rains and pest outbreaks, ideally through weekly or monthly updates. There was also a demand for geographical specificity in the information provided, allowing farmers to make informed decisions based on local conditions. Additionally, participants valued interactive learning opportunities, such as meetings and educational programmes led by agricultural officers and NGOs, which would enhance understanding and engagement with climate-related topics. Overall, the discussions highlighted the need for a community-driven approach for CIS to be effective, focusing on timely, localized, and accessible information to empower farmers in adapting to climate challenges. Additionally, during the discussions it was highlighted that most communities do not have disaster management plans at local level except in Mungwi district. In Mumbwa district, the male only focus group discuss noted the existence of a committee of 11 members, initiated by office of the District Commissioner that oversaw disaster issues and had a disaster management plan which the female only FGD was not aware of, indicating exclusion of women in disaster management issues in the district.

5. Discussion

This study aimed to evaluate the effectiveness of Climate Information Services (CIS) in enhancing the preparedness of smallholder farmers in Zambia, focusing on their knowledge, access, usage, gender-specific needs, characteristics of services demanded, influencing factors for adoption, and the impact on crop yields. The findings revealed that smallholder farmers possessed a varying degree of knowledge about CIS, primarily relying on local and national radio broadcasts, community networks, and agricultural extension officers as their main sources of climate-related information. This reliance highlighted the importance of accessible and relatable communication channels that resonate with the farming communities in Zambia. However, while farmers were aware of CIS, the extent to which the information they received was integrated into their decision-making processes remained inconsistent. Many respondents indicated using CIS for planning agricultural activities, yet barriers such as delayed information and a lack of trust in forecasts hindered practical application of CIS. Moreso, male household heads predominantly accessed climate information, while female producers often faced barriers due to limited access and lower levels of engagement with climate services. This gender gap in access to information is crucial, as it may exacerbate existing inequalities in agricultural productivity and resilience. Tailored interventions that focus on enhancing female access to CIS through community workshops and targeted outreach could bridge this gap and empower women in agricultural decision-making.

Additionally, smallholder farmers expressed a demand for CIS that were timely, specific, and actionable. They required forecasts not only regarding rainfall but also about extreme weather events, pest outbreaks, and seasonal trends. The characteristics of desired CIS highlighted the need for localized and context-sensitive information that aligned with the unique challenges faced by different farming communities. Moreover, integrating local knowledge with scientific data could enhance the relevance and usability of CIS for farmers.

Several factors influence the choice and use of CIS among farmers. Resource availability, knowledge of climate variability, and trust in the information provided emerged as significant determinants. Farmers with better access to resources, such as mobile phones, radio and internet connectivity, had higher engagement with CIS. Conversely, skepticism regarding the accuracy of forecasts and the perceived complexity of using CIS deterred adoption of advice provided through CIS. Building trust through consistent and reliable information delivery, as well as training farmers on how to interpret and apply CIS, was essential for improving uptake of CIS. Moreover, the study demonstrated a positive correlation between the use of CIS and crop yields, particularly for staple crops like maize and groundnuts. Farmers who actively engaged with climate information tended to adopt more effective agricultural practices, such as early planting and the use of drought-resistant seeds, leading to improved productivity. However, the impact of CIS on yields varied significantly across districts, indicating that local climatic conditions, soil fertility, and farming practices also played a crucial role. Therefore, while CIS can enhance resilience and productivity, it should be complemented with broader agricultural support systems that address these underlying factors. Overall, CIS have the potential to mitigate climate-related risks, but there is need to for holistic interventions that address socio-economic barriers and promote equitable access to information across all demographic groups. This is because the uptake of CIS remained uneven across districts, with disparities linked to socio-economic factors, access to infrastructure, and literacy levels.

6. Conclusion

In summary, the effectiveness of CIS in Zambia was influenced by knowledge, access, gender dynamics, characteristics of the services demanded, and various socio-economic factors. To enhance the impact of CIS required targeted interventions that improved access, addressed gender inequalities, built trust, and ensured the information was tailored to meet the specific needs of smallholder farmers. Continued research and investment in climate information systems will be vital for equipping farmers to better cope with the challenges posed by climate change and variability.

7. Recommendations

Based on the findings of this study on Climate Information Services (CIS) and their effectiveness for smallholder farmers in Zambia, the following recommendations are proposed:
Implementation of training workshops for smallholder farmers to improve their understanding of CIS. The workshops should cover how to access, interpret, and utilise climate information effectively in decision-making.

- Facilitation of community meetings and discussions to raise awareness about the importance of CIS. This should include involvement of local leaders and successful farmers to demonstrate the benefits of using climate information.
- Investment in communication infrastructure, especially in underserved districts, to ensure reliable access to CIS. This includes expanding mobile network coverage and internet access.
- Utilisation of multiple channels for disseminating CIS, such as radio broadcasts, SMS alerts, community meetings, and social media platforms, to reach a broader audience, especially in rural areas.
- Designing outreach programmes that specifically target women farmers, ensuring they received tailored information and support. This can include women-led focus groups or workshops that address their unique challenges and needs.
- Encouraging the participation of women in decision-making processes related to agricultural practices and climate information. This could involve training female extension workers to better serve women farmers
- Customisation of CIS to local contexts, considering regional climatic patterns, agricultural practices, and community-specific needs. This could include collaboration with local farmers to gather insights on relevant information.
- Provision of resources and tools that enable farmers to act on CIS recommendations. This could include subsidised inputs, such as drought-resistant seeds or irrigation technologies.
- Initiation of pilot projects that showcased the benefits of using CIS in agricultural practices. This hands-on approach can help farmers visualise the practical applications of climate information.
- Documentation and dissemination of success stories of farmers who have benefited from using CIS. Highlighting tangible results can motivate others to engage with climate information.

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