Exploring tomato farmers' knowledge and adaptation practices to climate change: insights from Chinsali district, Zambia

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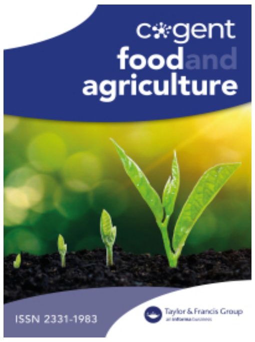

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Exploring tomato farmers' knowledge and adaptation practices to climate change: Insights from Chinsali district, Zambia

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ABSTRACT
Climate change poses a severe threat to agriculture in developing nations, with smallholder farmers in Zambia being particularly vulnerable. This study examined the knowledge and awareness of climate change among tomato farmers in Chinsali District, Zambia, and evaluated the adaptive practices used to mitigate its effects on tomato production. Using non-probability convenience sampling, structured questionnaires were administered to 40 farmers to collect quantitative data. The results revealed a gender imbalance, with 82.5% male participants, likely due to the high capital demands of tomato farming, which limit female and youth participation. While 64.9% of respondents were highly aware of climate change, mainly informed by radio, only 5.5% rated their knowledge as very good. Farmers reported noticeable shifts in temperature and rainfall patterns and relied on measures such as drought-resistant seeds and irrigation systems. These adaptations were constrained by limited financial resources and inadequate extension services. To strengthen resilience, there is a need to improve access to climate-resilient inputs, expand extension support, and provide financial assistance through subsidies or microloans. Enhanced climate change education and farmer cooperatives can further boost adaptive capacity. The study underscores the importance of targeted interventions to support sustainable tomato production amid climate-related challenges.

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1. Introduction

The global population is projected to approach 10 billion by 2050, with more than half of this growth expected to come from sub-Saharan Africa (Subacchi, 2019; FAO et al., 2022). Unfortunately, recent data indicates that the world is unlikely to achieve the goal of eradicating hunger and malnutrition by 2030 (FAO et al., 2022), highlighting the crucial role of the food production sector in ensuring food and nutrition security. One of the most significant challenges to global agriculture is climate change, defined as long-term alterations in meteorological factors such as precipitation and temperature (Malhi et al., 2021). Over the past few decades, human activities have accelerated these changes by altering the composition of the atmosphere (Sathaye et al., 2016). The concentrations of greenhouse gases like methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) have risen substantially since 1750, by 150%, 40%, and 20%, respectively (Pachauri et al., 2014).

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Agriculture is crucial in Africa, particularly in East Africa, where it contributes up to 40 percent of the region's Gross Domestic Product (GDP) and supports 80 percent of the population (Musayenka, 2023). The future of agriculture and food security on the continent is shaped by climate variability, global commodity trends, and local responses to these changes (Fonta et al., 2011). In agriculture, crops such as tomatoes *(Solanum lycopersicum)* are particularly vulnerable to these environmental shifts, especially during the reproductive phase, when low temperatures can cause, frost burn, flower abortion and limit fruit set, leading to significant yield loss (Thole et al., 2021). Agriculture is fundamental to human civilization, providing essential resources like food, fibre, and medicinal plants (Siankwilimba et al., 2025). Tomatoes are rich in vitamins, minerals, phenolic compounds, flavonoids, dietary fibres, and proteins, offering potent antioxidant, anti-inflammatory, and anticancer benefits (Tilahun et al., 2017). These health benefits are primarily due to their dietary antioxidants, which help combat diseases such as cancer, cardiovascular disease, cognitive decline, and osteoporosis, while also supporting weight management (Çelik et al., 2017). These antioxidants are effective in reducing the harmful effects of reactive oxygen species (ROS) generated during normal metabolic reactions and environmental stresses (Foyer, 2018).

Although tomatoes are grown in a wide range of climates, including temperate and tropical regions, climate-induced abiotic stresses severely affect production and productivity in many aspects. Among horticultural crops, tomatoes are especially significant, ranking third in global production by weight after potatoes and sweet potatoes (Tan et al., 2010). In 2012, Africa produced 17.938 million tons of tomatoes, with Egypt leading at 8.625 million tons. Currently, Africa produces 21 million tons from 1.3 million hectares, with East Africa contributing 1.9 million tons annually. Tanzania and Kenya are the top producers in the region, followed by Uganda (Ddamulira et al., 2021).

In Zambia, the demand for tomatoes is high due to their versatile use in culinary preparations and the country's rising population. As one of the most valuable horticultural crops, tomatoes hold significant economic importance, valued for their sensory qualities and nutritional content. They are consumed fresh or in processed forms such as sauces, soups, juices, ketchup, pickles, pastes, purees, powders, jams, and jellies, making them highly sought-after in both domestic and international markets (Chapoto et al., 2019; Mamun-Al-Munsur et al., 2019). This demand positions tomatoes as a valuable crop for farmers (Hichaambwa & Tschirley, 2006).

Chinsali District's economy remains predominantly agrarian, characterized by limited industrial development and heavy reliance on traditional smallholder farming (Mwansa, 2017). Primary food crops include maize, sorghum, cassava, and (Sathaye, 2016) millet (Musuka et al., 2023). Government support initiatives such as the Farmer Input Support Programme (FISP) aim to enhance agricultural productivity and livelihoods. However, the district contends with minimal private sector investment and constrained market access, undermining farmer incomes and regional economic ability to withstand climate changes impacts (Arah et al., 2015). Notably, tomato producers face acute profitability challenges, partly attributable to climate change impacts that exacerbate existing socioeconomic constraints.

Tomato farmers' knowledge and adaptation practices critically determine how well they withstand climate change impacts. Extensive Zambian research documents climate impacts on agriculture, particularly staple crops (Mulungu & Ng'ombe, 2019; Ngoma et al., 2024; Umar, 2021). These effects cascade into water security (Hamududu & Ngoma, 2020; Kunda & Phiri, 2024), food systems (Arndt et al., 2019; Mulenga et al., 2017; Nkomoki et al., 2018; Wineman, 2016), poverty reduction (Ngoma et al., 2024), and economic growth (Shula, 2022). However, studies focusing on climate knowledge and adaptive practices among tomato farmers in rural districts like Chinsali remain scarce, despite horticulture's socioeconomic importance. This study therefore assesses Chinsali tomato farmers' climate change awareness, adaptation strategies, and gendered vulnerability dimensions to guide context specific adaptation policies.

2. Materials and methods

2.1. Study area

This study was conducted in Chinsali District, Zambia (Figure 1), located in Region III of Zambia's agro-ecological zones. Chinsali lies between latitude 10°14′S and longitude 30°51′E and is characterized by

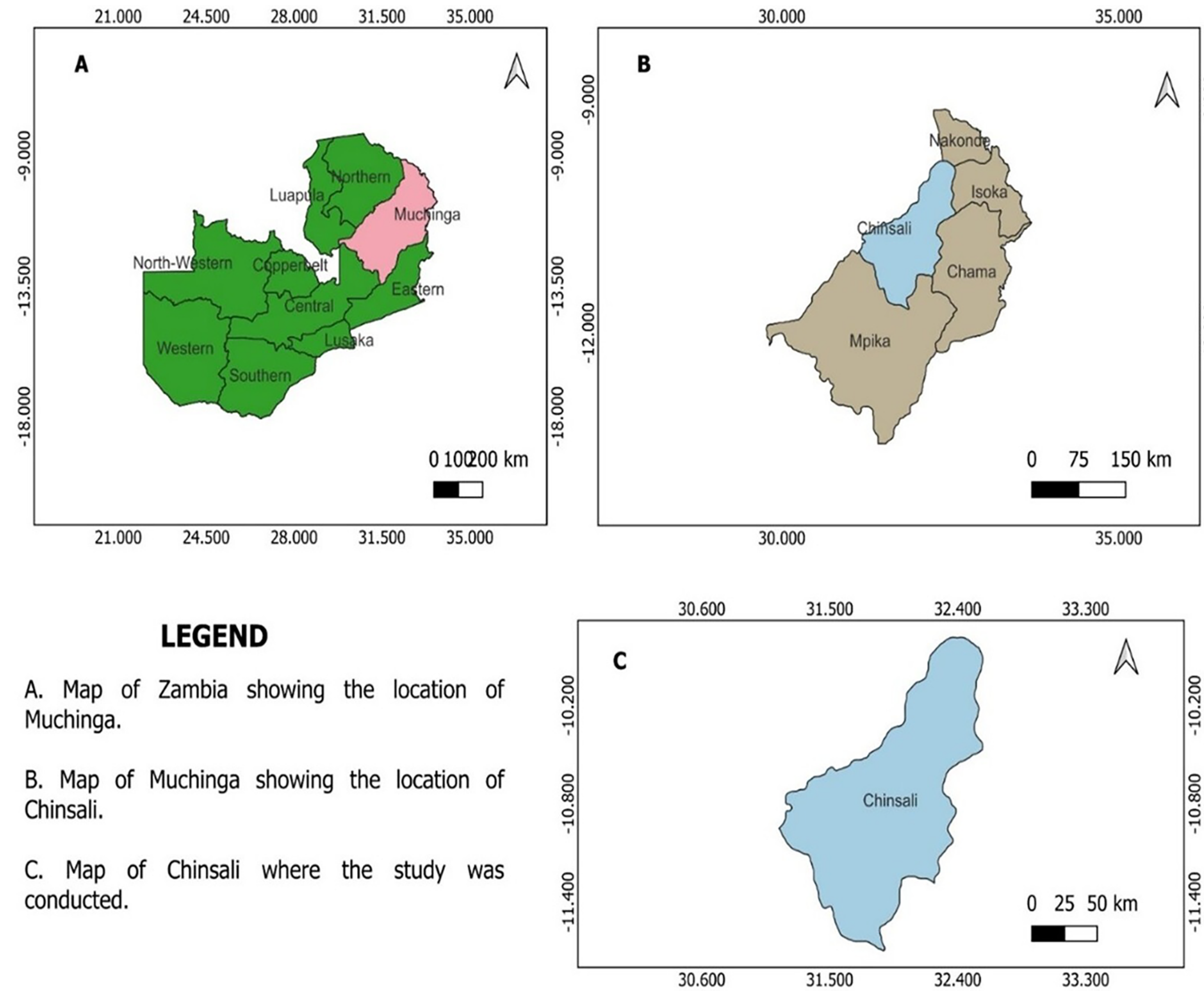

Figure 1. Map showing the location of Chinsali district.

favourable agroecological conditions, including high annual rainfall exceeding 1300 mm and mean temperatures ranging from 16 °C to 24 °C. The district is situated on the watershed between the Chambeshi River in the Congo Basin and the Luangwa River in the Zambezi Basin. Region III's climate, coupled with fertile soils, makes Chinsali ideal for cultivating a variety of crops. Farming is the primary economic activity in the area, with small-scale farmers growing maize, tomatoes, onion, vegetables, beans, and groundnuts. Chinsali District was chosen for this study due to its significant agricultural activity and its pivotal role in tomato production, which is increasingly influenced by climate change. The district's agroecological characteristics provide an ideal environment for exploring the impacts of climate change on crop farming and evaluating adaptation strategies. Additionally, its strategic location within the watershed areas offers unique insights into the intersection of agriculture, climate, and water resource management, making it a valuable case study for broader applications.

2.2. Ethical approval

This study received approval from the Kapasa Makasa University (KMU) Research and Ethics Board (REB) and was carried out in full adherence to their guidelines. The REB recommended verbal consent over written consent to encourage direct interaction between the researcher and participants while reducing any potential discomfort. Consequently, respondents who participated in face-to-face interviews provided informed verbal consent, which was documented by the interviewer marking the consent box on the physical questionnaires. All respondents were informed of their right to withdraw at any point without facing any repercussions.

2.3. Sampling method and rationale

This study employed a non-probability sampling technique, specifically convenience sampling, due to the exploratory nature of the research and the challenges associated with accessing the target population of tomato farmers in the Chinsali District. The farmers in this area are dispersed across remote and isolated locations, making it difficult to establish a comprehensive sampling frame. As suggested by Ahmed (2024), non-probability sampling is particularly suited for exploratory studies where the population is difficult to access. The sample for this study was recruited from Chinsali District Main Market which was identified as the most practical location to meet the target population. Tomato farmers, despite being spread across the district, often bring their produce to this central market, making it an ideal site for recruitment. This approach aligns with the recommendations of Andrade (2021), who supports the use of convenience sampling when accessibility is a key challenge.

A total of 40 tomato farmers were recruited between June and August, 2024. Participant recruitment continued until saturation was reached, meaning that, during subsequent visits to the market, the number of new participants was significantly reduced, indicating that most of the farmers had already been interviewed. The decision to stop recruitment at 40 was based on the observation that no new information was being generated by interviews with additional participants, which aligns with the suggestion of Fontanella et al. (2011) who states that once data saturation is reached, sampling may be stopped. In addition, the sample size of 40 is almost twice the number of tomato farmers that were sampled by Mwansa (2017) who only sampled 21 farmers but is equal to the number of vegetable farmers that the said researcher sampled in the same district. While convenience sampling offers practical advantages, it is important to acknowledge its limitations, particularly in terms of external validity. As noted by Ahmed (2024), the findings of this study may not be generalizable to the broader population of tomato farmers across the entire district. However, the characteristics of the farmers sampled are expected to reflect those of the wider population due to similar characteristics, and the insights gained are still valuable and useful.

2.4. Data collection

To achieve the objectives of this study both primary and secondary data were collected from Chinsali districts. Primary data was collected using a structured questionnaire which comprised five major sections containing both open-ended and closed-ended questions. Section 1 comprising the demographic and social economic characteristics of the respondents, Section 2 comprised questions on the knowledge and understanding of climate change, Section 3 comprised questions on the source of information about climate change, and Sections 4 and 5 comprised questions on the adaptive practices and strategies and the challenges in adopting climate change adaptation, respectively.The stated data was collected through face-to-face using hard copy questionnaires between June and August 2024 after pre-testing and modifications to the questionnaire (Mphande et al., 2023; Muhala et al., 2021).

2.5. Data analysis

The collected data was initially entered into Microsoft Excel version 16.0 for cleaning, including identifying and correcting errors, handling missing values, and standardizing formats. The cleaned data was then exported to the IBM SPSS (Statistical Package for Social Sciences version 29.0) for analysis primarily through percentage calculations to summarize the responses. The results are presented in a table and figures to highlight the key trends.

3. Results

3.1. Demographic and social economic information

The demographic and social economic information is shown in Table 1. The majority (82.5%) of respondents were male, with females representing only 17.5% of the sample. The age distribution showed that the largest group (32.5%) was within the 31–40 age range, followed by those aged between 41–50 years

Table 1. Demographic and social economic information.

Variable	Category	N = 40	Percentage (%)
Gender	Male	33	82.5
	Female	7	17.5
Age	18–30 years	7	17.5
	31–40 years	13	32.5
	41–50 years	12	30.0
	Over 50 years	8	20.0
Level of education	No formal Education	15	37.5
	Primary Education	14	35.0
	Secondary Education	3	7.5
	Tertiary Education	8	20.0
Years in production	1–4 years	16	40.0
	5–9 years	8	20.0
	Less than a year	16	40.0
Farm size	1–4 hectares	13	32.5
	Less than a Hectare	27	67.5
Ownership of land	No	6	15
	Yes	34	85

(30%), with the least (17.5%) falling within the 18–30 age range. Almost half (37.5%) of the respondents had no formal education, followed by those with primary education (35%), and this was seconded (20%) by those having tertiary education, and the least (7.5%) represented those who had attained secondary education. Furthermore, a tie of 40% was obtained between the number of years involved in tomato production and those who had been in tomato farming for less than a year. While the least proportion (20.0%) of tomato producers had 5–9 years. Also, most (67.5%) of tomato farmers had farmland of less than a hectare, while the least (32.5%) had land of 1–4 hectares. Likewise, the majority (85.0%) of the respondents owned their land, with only a proportion (15.0%) not owning land.

3.2. Knowledge and understanding of climate change

The knowledge and understanding of climate change among tomato farmers in Chinsali district varied, with the majority (64.9%) aware of climate change, 18.9% uncertain, and 16.2% having never heard of it. Their self-assessed understanding ranged from poor to very good, with most farmers (45.9%) rating their understanding as fair, 24.3% as good, another 24.3% as poor, and a small proportion (5.5%) considering their understanding very good.

3.3. Farmers' perceptions of climate change causes and their sources of information

A majority of tomato farmers in Chinsali district (77.3%) perceived human activities as the primary cause of climate change, while a smaller proportion (22.7%) attributed it to natural processes. Regarding information sources on climate change, over half of the respondents (51.1%) reported receiving information through radio broadcasts, making it the most common source. Television followed as the second most cited medium at 24.4%. Additionally, 17.8% of farmers reported gaining knowledge from workshops, particularly those organized by NGOs and churches, while 6.7% mentioned church platforms directly.

3.4. Observed occurrence of climate change

The observed occurrence of climatic changes by tomato farmers included change in rainfall patterns, increased temperature, drought, and floods (Figure 2). Most of the farmers (42.2%) observed drought, and a substantial number of farmers (39.1%) reported a change in rainfall patterns. Additionally, a few farmers (17.2%) observed an increase in temperature and very paltry farmers (1.6%) indicated that they had noticed an increase in floods.

3.5. Climate change adaptation practices

Climate change adaptation practices were employed by the tomato producers included drought resistant seeds, irrigation practices, crop rotation, and Fertilizer (Figure 3). The results reveal that the majority

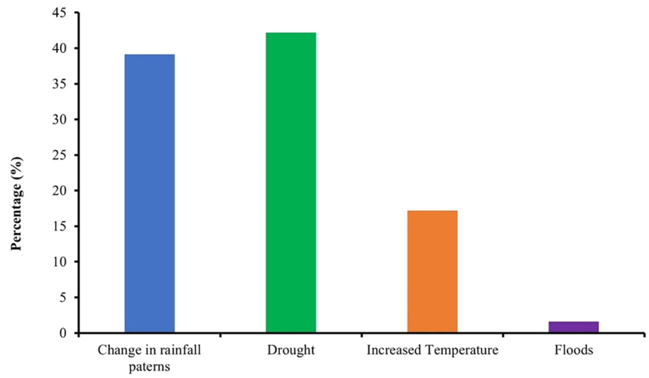

Figure 2. Observed occurrence of climate change.

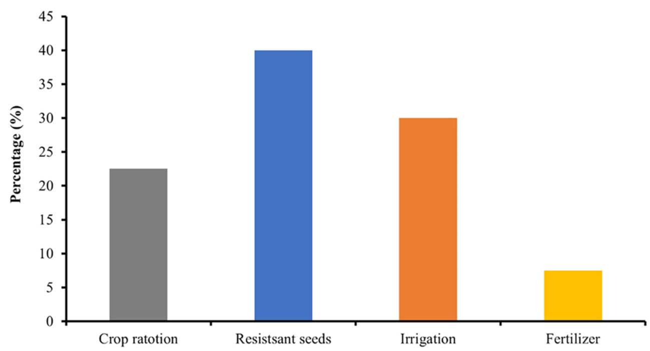

Figure 3. Climate change adaptation practices.

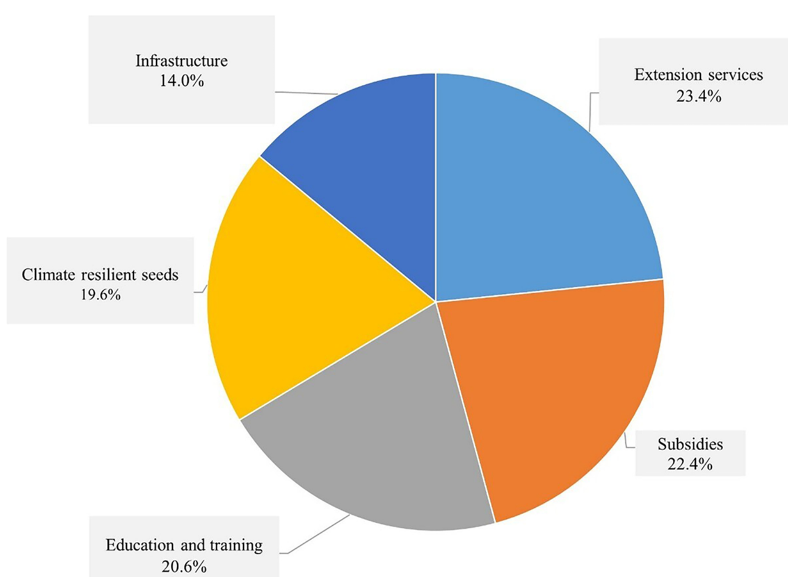

Figure 4. Ways in which Government can support tomato farmers.

(40.0%) employed drought-resistant seeds, while irrigation practices were the second most used (30.0%). Moreover, crop rotation accounted for 22.5%, with the least (7.5%) being fertilizer of the total sample.

3.6. Ways in which government can support tomato farmers

The different ways in which the government can support tomato farmers in Chinsali district varied from enhanced extension to improved infrastructure (Figure 4). Most (23.4%) of respondents chose enhanced extension services as support which was seconded by funding and subsidies with 22.4%. Furthermore, education and training represented 20.6%, while climate-resilient seeds accounted for 19.6%, with improvement of infrastructure coming last with only 14%.

4. Discussion

This study assessed tomato farmers' knowledge and practices related to climate change in Chinsali District, Zambia. The majority of respondents were male, reflecting a gender disparity consistent with Moranga et al. (2016), who reported male dominance in tomato farming in the region. This imbalance may be due to the high initial capital required, often less accessible to women, and the physical demands of labour-intensive tasks such as pruning and spraying, which Wachira et al. (2014) also linked to male predominance in Nakuru, Kenya. Additionally, most farmers were aged 31 to 40, aligning with Siyao and Sanga (2023), who identified this group as the most financially capable and productive segment of the labour force. The majority owned customary land, consistent with findings from Nara et al. (2021) in northwest Ghana and Kosa in South Africa, where farmers commonly own small plots either customarily or through purchase.

Farmers largely attributed climate change to human activities, supporting Maulu et al. (2024), Jang (2013), and Hoogendoorn et al. (2020), who emphasized anthropogenic causes over natural processes. While respondents rated their understanding of climate change as fair, this may reflect lower education levels, as noted by Muhala et al. (2021), who found high general awareness but limited depth of understanding among less educated individuals. Hasan and Kumar (2019) similarly reported moderate perception and vulnerability to climate change among farmers. Moreover, consistent with Ddamulira et al. (2021), most tomato producers demonstrated significant climate awareness, likely linked to increased access to information via radio and television. However, our findings diverge from Maulu et al. (2024), who reported limited understanding among a minority of farmers due to lower education levels, whereas our respondents' high literacy correlated strongly with climate knowledge.

Our study revealed that most farmers accessed climate change information primarily through radios, likely due to affordability and accessibility, consistent with Oyekale (2015), who linked radio access to low cost and wide coverage. Similarly, Maulu et al. (2024) noted that aquaculture producers owned radios and televisions, facilitating climate knowledge acquisition. Tomato farmers' preference for radio aligns with Singh et al. (2016) and Muema et al. (2018), while Mburu (2013) also highlighted the role of radios and televisions in disseminating climate-related information. However, few farmers relied on extension services, potentially due to a shortage of extension officers amid rising farmer populations, as reported by Mubamba et al. (2018), Maulu et al. (2021), Chavula and Yali (2022), and Siankwilimba et al. (2023). This contrasts with Jones (2003), Singh (2020), and Kumar et al. (2020), who emphasized extension services and reliable weather information as critical for informed decision-making and reducing vulnerability to weather variability (Siankwilimba et al., 2023). Likewise, most farmers reported changes in rainfall patterns causing droughts and floods, reflecting findings by Benabderrazik et al. (2022), Manzoor et al. (2024), and Koza (2022), who documented similar climate impacts affecting water management for crops. The predominant adaptation strategy was the use of drought-resistant seeds, consistent with Guodaar et al. (2020). Adoption of other practices, such as crop rotation, was low, aligning with Afele et al. (2024), likely due to resource and knowledge constraints. Comparable adaptation strategies have been observed in South Africa's Western Cape (Talanow et al., 2021) and northern Ethiopia (Tesfahunegn & Gebru, 2021), highlighting the importance of water management for sustaining tomato production under climate stress. Moreover, limited access to drought-resistant seeds, primarily due to financial constraints, was the main challenge faced by farmers, echoing Mudzonga (2012) in Zimbabwe.

Furthermore, farmers expressed a need for enhanced extension services, supporting Lipper et al. (2014), who advocated for government subsidies, improved infrastructure, and extension support to bolster farmers' capacity to manage climate risks. Our findings also align with Abdul-Razak and Kruse (2017), who identified financial resources and training as critical for enhancing farmers' ability to adjust to climate change. Education and training significantly improve farmers' adoption of new technologies (Yang et al., 2020). While financial support was ranked lower by respondents, it remains essential when combined with training to ensure sustainable adaptation a balanced approach addressing both resource provision and capacity building is crucial for long-term ability to withstand climate changes impact in farming systems as was suggested by van Zonneveld et al. (2020).

5. Conclusion

This study demonstrates high climate change awareness among tomato farmers in Chinsali District, Zambia, primarily disseminated through radio and television. However, this awareness does not readily translate into effective adaptation due to significant barriers: pronounced gender disparities limiting participation, low formal education levels, and the inherent constraints of small-scale farming. Farmers actively employ strategies such as drought-resistant seeds and irrigation to counter increasing droughts and erratic rainfall. Yet, the effectiveness of these measures is critically undermined by financial limitations, weak extension services, and inadequate infrastructure. These inequities result in uneven adoption of adaptive practices, exacerbating vulnerability among resource-poor households and threatening the sustainability of local tomato production systems crucial for food security. To strengthen resilience, we recommend the immediate scaling of accessible climate information via community radio and participatory workshops. Crucially, policy interventions must prioritize improving access to affordable drought-resistant seeds, establishing community-managed irrigation schemes, and revitalizing extension support. Furthermore, long-term investments in farmer cooperatives and targeted input subsidies or microloans are essential to overcome persistent financial barriers. Our findings provide direct pathways for policymakers, underscoring the urgent need to address gender equity, ensure equitable access to seeds, water, and finance, and upgrade critical infrastructure to bolster smallholder adaptive capacity within this vital horticultural sector. Future research should quantitatively evaluate the impact of the specific drought-coping practices identified here (e.g. particular seed varieties, irrigation methods) on farm productivity and resilience.

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Authors' contribution

CRediT: **Francis Kabwe Mwamba**: Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft; **Lawrencia Taimolo**: Investigation, Methodology, Writing – original draft; **Shadreck Chinyanta**: Methodology, Writing – original draft, Writing – review & editing; **Joseph Mphande**: Conceptualization, Data curation, Formal analysis, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Enock Siankwilimba**: Visualization, Writing – original draft, Writing – review & editing; **Pharoah Collins Sianangama**: Validation, Writing – original draft, Writing – review & editing; **Oliver Jolezya Hasimuna**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. All the authors reviewed the final version of the manuscript and approved its submission to the journal for publication.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Shadreck Chinyanta is an agroforestry technician and researcher holding a Bachelor of Science degree in Agroforestry from the Copperbelt University, Zambia. He specializes in sustainable land use, climate-resilient agriculture, and integrated agroforestry systems. Shadreck has extensive experience in designing and implementing practices that enhance soil fertility, conserve water, and improve food security among smallholder farming communities.

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Data availability statement

The data used to support the findings of this study are available and can be requested from the corresponding author.

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