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Farmers' adaptation strategies to combat the impacts of climate change on grapevine production in Dodoma, Tanzania

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Abstract

The grapevine is regarded as a drought-resistant crop, although in recent years it has been observed to be threatened by climate change (CC). This compelled an investigation into the adaptation strategies used by grapevine farmers to lessen the impacts of climate change in Dodoma, Tanzania. The impacts of CC on grapevine farming were explored, and the adopted adaptation strategies were examined. About 248 grapevine farmers, and 64 key informants and members of focus group discussions were involved in the study. Data were collected through surveys, discussions, interviews, observations, and reviews. Quantitative data were analysed through descriptive statistics while qualitative data were analysed using thematic analysis. Findings indicate that the major impacts of CC on grapevine production include the outbreak of grapevine diseases (76.2%), occurrence of pests and insects (67.6%), drought (26.9%), and extreme temperatures (10%). To moderate these impacts, grapevine farmers have adopted several adaptation strategies, such as applying pesticides (63.2%), implementing irrigation (21.3%), paroling to prevent birds (6.8%), and using manure (5.6%) to improve soil fertility. These findings inform that CC has a direct detrimental impact on grapevine production including uncertainties which affect grapevine markets, and the adaptation strategies for the CC impacts in the study areas are in place. It is recommended that the Tanzania government and other grapevine stakeholders should help grapevine farmers to improve and take on board existing adaptation strategies against CC through agricultural extension services, and enable farmers' access to financial capital. This could improve grapevine farmers' adaptive capacity to CC.

Keywords: *Grapevine; farmers; adaptation; climate; Dodoma; Tanzania*

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Introduction

Food security and economic growth in Africa is significantly threatened by climate change (Bocci and Thanos, 2019, Malhi *et al.*, 2021). These threats are particularly severe for countries dependent on a limited range of climate-sensitive economic activities, such as the export of climate-sensitive crops (FAO, 2019). The current pace of climate change has altered known variability patterns to such an extent that people are now facing unfamiliar situations. This urgent challenge requires immediate attention to anticipatory and planned adaptation strategies. For these strategies to be effective, they must build upon existing local adaptation methods, especially in arid and semi-arid regions (FAO, 2019, Singh, 2020, Issahaku and Abdulai, 2019).

Climate is the primary factor influencing grapevine yield and quality in a given region, as it directly and indirectly impacts vine physiology, growth, and developmental stages (Santos *et al.,* 2020, van Leeuwen *et al.,* 2024).

According to Droulia and Charalampopoulos (2021) and Arias et al. (2022), grapevines suffer significant damage from extremely high or low temperatures. Although grapevines have a relatively high tolerance for drought, extreme dry conditions can still negatively affect them (Droulia and Charalampopoulos, 2022). Optimal conditions for grapevine growth and high-quality wine production include mild to cool and wet winters, warm springs, and warm to hot summers with little precipitation (van Leeuwen *et al.,* 2024). A favourable seasonal climate regime greatly enhances the overall quality of a vintage (Gutierrez-Gamboa *et al.,* 2021).

As detailed by Santos *et al.* (2020), grapevines are demanding plant species that require a suitable climate for proper and economically sustainable development, despite all adaptation practices. Local and regional atmospheric conditions influence grapevine phenology, yield, and wine quality in various grape-producing regions worldwide (Gutierrez-Gamboa *et al.,* 2021, Grifoni *et al.,* 2008). Climate impacts grapevine growth and fruit and wine production in multiple ways. During winter, grapevines need some dormant chilling to effectively set the latent buds for the upcoming vintage (Santos *et al.,* 2020). During the growing season, grapevines require sustained average daily temperatures above 10°C to initiate growth, followed by sufficient heat accumulation to ripen the fruits. However, temperature extremes during berry growth induce stress, berry abscission, enzyme activation, and reduced flavour development (Yan *et al.,* 2020). Ideally, grapevines should begin the growing season with adequate soil moisture for initial growth and receive nominal amounts throughout the growing season. However, climate change has pushed, or will push, many of these climatic ideals to their limits in various regions (Tesli *et al.,* 2017, Fraga *et al.,* 2016).

As highlighted by Arslan *et al.,* (2017), agriculture in Tanzania is highly sensitive to climate change. Current climate fluctuations, such as droughts and floods, have already resulted in significant economic losses, particularly in the semi-arid regions of Central Tanzania (Matata *et al.,* 2019). Shemdoe *et al.* (2015) assert that most community members in Tanzania are not sufficiently adapted to the current climate and face adaptation deficits that require urgent attention.

Grapevine is one of Tanzania's most important cash crops and a significant source of employment, particularly in the Dodoma region, which is the main area for grapevine cultivation. The Tanzanian Ministry of Agriculture aims to produce 22,000 tonnes of grapes by 2024/2025 (Nalyoto and Ngaruko, 2022). According to Chacky and Pande (2022) and Mwamahonje *et al.,* (2015), Dodoma grows four grapevine varieties:

Chenin Blanc - A white grape known for its versatility in producing both dry and sweet wines.
Syrah/Shiraz – It is a red grape that yields rich, full-bodied wines with flavors of dark fruits, spices, and pepper.

Cabernet Sauvignon – It is another red grape renowned for its structured tannins and flavors of blackcurrant, plum, and cedar.

Makutupora – It is a local grape variety developed specifically for Dodoma, contributing to the unique character of Tanzanian wines.

A study by Lwelamira *et al.,* (2015) found that grapevine farming in Dodoma contributes more than one-third (35.6%) of total household income and plays a crucial role in household welfare. The study also revealed that the household consumption expenditure of grape farmers was twice that of non-grape farmers. However, research by Kalimang'asi *et al.,* (2014) identified major challenges faced by grapevine producers in Dodoma, including pests and diseases, inadequate storage facilities, and unreliable markets. They suggested that these challenges could be mitigated through extension services, increasing the number of processing firms, establishing farming contracts, and forming farmer-based organizations.

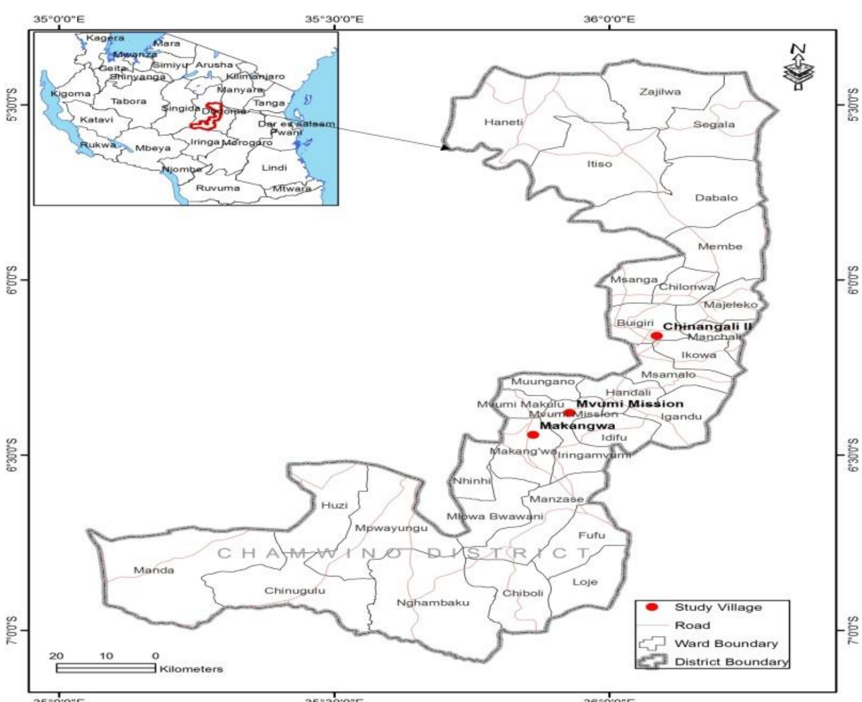
Although grapevine is considered among the drought-resistant crops, recent years have seen a decline in their productivity in Tanzania due to climate change. This situation prompted a study in Dodoma, Tanzania, an area considered suitable for grapevine cultivation. The study aimed to investigate the impact of climate change on grapevine production, and explore the adaptation strategies adopted by grapevine farmers.

Materials and Methods

This study was conducted in Chamwino District and Dodoma Municipality, both located in the Dodoma region of Tanzania and Chamwino District has an estimated population of 330,543, comprising 5 divisions, 32 wards, 78 villages, and 732 hamlets (United Republic of Tanzania (URT, 2022). The district is characterized by several mountain chains running from the northwest to the southwest, with lower-lying, relatively flat areas around 1,200 meters above sea level situated between and around these mountains. These areas are prone to waterlogging during the rainy season, while the rest of the district experiences impeded drainage patterns. The main economic activities in Chamwino District include agriculture and livestock keeping, with a smaller portion of the population engaged in commercial and industrial sectors such as maize milling, carpentry, and tailoring. Food crops grown in the district include sorghum, maize, and cassava, while cash crops include grapevines, sunflower, sesame, groundnuts, bulrush millet, and paddy.

Figure 1

A map of Chamwino District in Dodoma, Tanzania

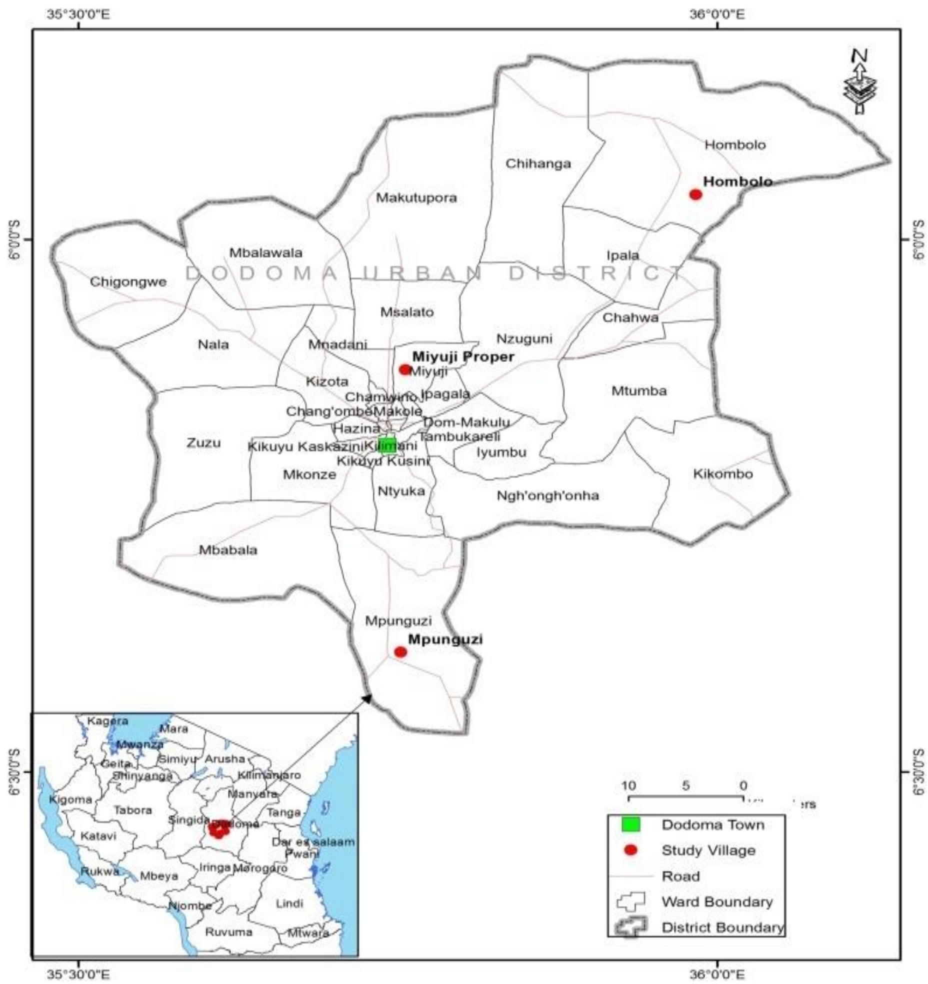


Dodoma Municipality is characterized by lowlands, hills, seasonal rivers, and both deep and shallow wells and dams, most of which dry up during severe dry periods. The municipality has an estimated population of 410,956 (Rugeiyamu, 2022). Administratively, it is divided into 4 divisions, 37 wards, 100 neighbourhoods, 39 villages, and 222 hamlets. Approximately 196,000 hectares, accounting for

71% of the total area, are suitable for agricultural production.

Figure 2

A map of Dodoma Municipality in Dodoma, Tanzania



The study focused on three villages/streets (Hombolo, Miyuji, and Mpunguzi) in the Dodoma municipality and three villages (Chinangali II, Makang'wa, and Mvumi-Mission) in the Chamwino district, selected for their prominence in grapevine production. A mixed research approach with a cross-sectional design was used to collect both qualitative and quantitative data. The sample size was determined using the Yamane (1967) formula, which considered the population of grapevine farmers in the study area. The Yamane formula is expressed as;

$N/1+N(e)^2$, where:

- n is the sample size
- N is the population of grapevine farmers
- e is the sampling error

Using this formula, the study estimated that 248 grapevine farmers would be involved, population proportionally distributed across the six villages as follows: Hombolo (58 farmers), Miyuji (8 farmers), Mpunguzi (71 farmers), Chinangali II (82 farmers), Makang'wa (13 farmers), and Mvumi-Mission (16 farmers). A simple random sampling technique (probability sampling) was employed to select the sample in each village. In contrast, purposive sampling (non-probability sampling) was used to select key informants based on their profession and experience with climate change issues; and members of focus group discussions considering sex and age.

Data were collected using multiple methods to triangulate information and enhance data validity and reliability. The data collection methods, along with the number of subjects involved, included a questionnaire survey (248), focus group discussions (58), key informant interviews (16), and a review of secondary data from various documents. In total, 312 subjects participated in the study.

The questionnaires were pre-tested to ensure their suitability and revised as necessary before use. Focus Group Discussions (FGDs) were conducted separately for elders and youths, with groups consisting of 7-8 people, a number deemed manageable and sufficient for obtaining the required data. According to Berg (2007), FGDs should include 6-12 participants. The FGDs also considered the sex of participants, with males and females not being mixed. The moderator of the FGD was also of the same sex as the FGD participants. The key informant interviews involved agricultural officers, agricultural research officers, non-governmental organization representatives, and village leaders, chosen for their knowledge and experience on the subject matter. These methods facilitated the exploration of grapevine farmers' insights, opinions, and views on grapevine production and climate change.

The collected data were both quantitative and qualitative, necessitating the use of corresponding analysis techniques. Quantitative data from questionnaires were edited, coded, cleaned and analysed using descriptive statistics that generate frequencies and percentage distribution via IBM-SPSS statistical software. The findings were presented through tables and figures. The qualitative data from key informant interviews and FGDs were analysed using thematic analysis where it involved transcribing data, familiarizing with data, identifying, analyzing and interpreting themes, and reporting the results by presenting each theme with supporting quotes.

Results

Impacts of climate change on grapevine production

The findings showed that the major impacts of climate change on grapevine production include outbreaks of diseases and pests (76.2% and 67.6 % respectively), drought (26.9 %), and high temperatures (11.6%). Other impacts were mentioned to be heavy rainfall (10%), grapevine fruit damage by birds (6.8%), and high wind speeds (1.2%)

Outbreaks of diseases such as powdery mildew, downy mildew, and anthracnose, and pests like mealybugs, termites, sting bars, soft scales, mosquitoes, butterflies, and birds were reported to be common across all villages. These outbreaks are likely due to weather and climate, which favour the reproduction of pests and disease-causing pathogens such as fungi, bacteria, and viruses. Some impacts were village-specific; for instance, farmers in Hombolo were primarily affected by birds, such as starlings, which caused fruit damage. It was reported that birds caused grapevine damage in several ways including pecking and eating grape fruits, cluster damage, spillage and waste, disease spread, bruising and crushing, and opening pathways for other pests.

As a result of these pest and diseases, farmers had to invest substantial financial resources in controlling them, thereby increasing the cost of grapevine production.

Figure 3 illustrates a grapevine farm in Hombolo village suspected to be affected by powdery mildew (*Blumeria graminis*) disease. As illustrated by Weixun *et al.,* (2020) and Santos and Figueiredo (2021), powdery mildew, caused by the fungus Erysiphe necator, affects all green grapevine tissues, leading to stunted fruit growth, necrotic leaves, and premature leaf abscission.

Table 1

Multiple response results on climatic challenges facing grapevine production in Chamwino District and Dodoma Municipality

Challenges	**Dodoma Municipality (%)**			**Chamwino District (%)**			**Total (%)**
	Hombolo (n = 58)	Miyuji (n = 8)	Mpunguzi (n = 71)	Chinangali II (n = 82)	Makang'wa (n=13)	Mvumi-Mission (n=16)	
Outbreak of diseases	15.3	1.6	19	31.5	4.8	4	**76.2**
Outbreak of pests and insects	14.1	1.6	14.9	29	4	4	**67.6**
Fruit damage by birds	4.4	0.4	1.2	0.8	0	0	**6.8**
Drought (Below 500mm)	4	1.6	5.6	12.1	0.8	2.8	**26.9**
Heavy rainfall (Above 600mm)	2.8	0.4	3.2	2	1.2	0.4	**10**
Extreme temperature (too low or too high)	4.0	0.4	2.4	4	0.8	0	**11.6**
High wind speed	0.4	0	0.8	0	0	0	**1.2**

Figure 3

*Grapevines suspected to be affected by a powdery mildew (*Blurmeria graminis*) disease in Hombolo, Dodoma Municipality (Photo by: Mahenge)*

High wind speeds significantly impact grapevine production, though farmers in the study area did not specify the exact speed they consider destructive. Secondary data from the Dodoma Meteorological Station indicates that the average maximum wind speed in the study area is 6.5 m/s.

Adaptation strategies to cope with the impact of climate change

The study investigated the strategies employed by grapevine farmers to mitigate the effects of climate change on grapevine production in the study area. These strategies were tailored to address specific impacts on grapevine cultivation. Two generic strategies identified were the application of pesticides (63.2%) to manage various pests and pathogens affecting grapevines and irrigation (21.3%) aimed at addressing drought conditions (

Table 2).

Table 2

Multiple response results on strategies adopted by the farmers to cope with climate change on grapevine production in Chamwino District and Dodoma Municipality

Impacts	Strategies	Dodoma Municipality (%)			Chamwino District (%)			
		Hombolo (n = 58)	Miyuji (n = 8)	Mpunguzi (n = 71)	Chinangali II (n = 82)	Makang'wa (n=13)	Mvumi-Mission (n=16)	**Total (%)**
Pests and diseases	Application of pesticides	15.7	1.6	15.3	26.6	4	0	**63.2**
	Timed pruning	0	0.4	1.2	2.8	0	0	**4.4**
Drought	Irrigation	4	1.2	5.2	9.3	0.4	1.2	**21.3**
	Application of p-fertilizers	0	0.4	0	0.8	0	0	**1.2**
Loss of soil fertility	Application of farm yard manure	0	0.4	1.2	2.8	1.2	0	**5.6**
Grapevine fruit damage by birds	Patrol	4.4	0.4	1.6	0	0.4	0	**6.8**
	Hanging nylon/garment materials	0	0	0	0.4	0	0	**0.4**

Grapevine farmers also employed additional strategies to manage the diverse impacts of climate change on grapevine production. These included timed pruning (4.4%) to mitigate pests and diseases, the use of phosphorus fertilizers (P-fertilizers) (1.2%) to enhance water absorption by grape roots, application of farmyard manure (5.6%) to enrich soil fertility, conducting patrols (6.8%) with scare devices (0.4%) to deter birds and other wildlife from damaging fruit. The findings from one of the FGDs showed that the farmers used mulching to reduce soil moisture loss during planting grapevine cultivars, and in case of high rain intensity the water drainage systems were improved to avoid water lodging. Likewise, findings from one of the Agricultural Extension Officers as a key informant revealed that farmers controlled the high wind speed through live fences.

In all villages, common adaptation strategies included the use of pesticides, as well as drip and traditional irrigation methods. Traditional methods were prevalent in Mpunguzi, Mvumi-Mission, and Makang'wa villages. Improved irrigation systems were common in Chinangali II, Hombolo, and Miyuji. Drip irrigation was observed in Chinangali II and Miyuji, while in Hombolo, improved irrigation canals with siphons to direct water from the main canal to the grapevine rows were common. During key informant (KI) interviews, the Chamwino District Agriculture and Livestock Development Officer mentioned that water shortages in the area were being addressed by digging trenches for planting grapevine cultivars 90 cm wide, 90 cm deep, and 80 m long to store sufficient water.

Other coping strategies were tailored to specific villages: for instance, Chinangali II employed bird control using scare tactics (such as hanging nylon or garment materials) (

Figure ***4***), while in Hombolo, Mpunguzi, and Miyuji, patrols were utilized for controlling both birds and theft of grapevine fruits. Nevertheless, researchers observed that the use of nylon and garment materials to deter birds was also practiced in other villages like Mpunguzi and Mvumi-Mission. Additionally, findings show that the application of farmyard manure for soil fertility enhancement was widespread in Chinangali II, Mpunguzi, and Miyuji. To mitigate soil moisture loss through evaporation, phosphorus fertilizers were applied to enhance grapevine root water uptake in Chinangali II and Miyuji.

Figure 4

Bird control through scares (plastic bags) at Mvumi-Mission grapevine farms (Photo by: Mahenge)

Discussion

Climate change impacts

The pests and insects affecting grapevines include mealybugs, termites, sting bars, soft scales, mosquitoes, butterflies, and birds. Mealybugs are particularly concerned in the spread of viral diseases such as leafroll, while termites directly damage grapevines by feeding on their rootstocks, leading to crop wilting. Ideally, insects impact grapevine production by damaging the vines, leaves, fruit, and roots, which affects grape yield and quality (Reineke and Thiéry, 2016). Various insects target different parts of the grapevine, causing issues that range from cosmetic damage to severe infestations that can threaten the entire vineyard. Insects can be influenced by climate change.

These findings corroborate various studies that document the detrimental impacts of pests and diseases (Boudon-Padieu and Maixner, 2007, Martinson *et al.,* 2008, Pietersen *et al.,* 2013, Habili *et al.,* 2023). According to Boudon-Padieu and Maixner (2007), climate change creates conditions favourable for insects that act as vectors for grapevine pathogens like viruses and phytoplasmas, including leafhoppers and planthoppers. Martinson *et al.* (2008), Pietersen *et al.* (2013) and Habili *et al.* (2023) have also highlighted that mealybugs and soft scales play a great role in spreading numerous viral diseases.

The fungal grapevine diseases such as powdery mildew (Blumeria graminis), downy mildew (*Peronospora farinosa*), and anthracnose (*Elsinoe ampelina*) are common worldwide (Modesto *et al.,* 2022). These fungi appear as an ash-grey to white powdery substance on the upper and lower surfaces of young leaves, shoots, or clusters of grapevines. Numerous studies (e.g., Amanda et al., 2017, Sastry and Zitter, 2014, Calonnec *et al.,* 2006, Thind *et al.,* 2004, Halleen and Holz, 2001) have noted that powdery mildew spores do not require free moisture to penetrate the host plant but are dispersed by wind.

The crown gall disease which impact grapevine production is caused by the bacterium *Agrobacterium tumefaciens*. This disease leads to poor shoot growth and fruit production by affecting the roots and trunks of grapevines. The main symptom of crown gall disease is the formation of galls on affected grapevines (Kawaguchi, 2022). The spreading risk of this disease may increase after grapevine pruning. Typically, farmers should prune their grapevines during periods of low rainfall, either from late March to early April or from late August to early September, as excessive moisture can exacerbate bacterial diseases.

Drought which is caused by short rainy seasons poses a significant challenge to grapevine production. It particularly affects grapevines during early development and fruiting stages, when adequate soil moisture is crucial. The findings conform to those of Khan *et al.* (2020) who note that drought significantly impacts the development of grapevine plants. Tesli *et al.* (2017) and Fraga *et al.* (2016) have also reported drought to inhibit photosynthesis in grapes and increases polyphenol content, resulting in imbalanced and bitter wine.

Bird species like starlings and finches significantly impact both the quantity and quality of grapevine fruits during ripening. These findings align with those of Rivadeneira *et al.* (2018), who emphasize that birds such as starlings, robins, blackbirds, and finches are attracted to ripening grapes, resulting in crop loss and bunch rot. Similarly, Somers and Morris (2002) identified bird damage, particularly by starlings, as an economic concern in Canadian grapevine agricultural regions.

The extreme temperatures, whether excessively high or low, have a significant impact on grapevine production. High temperatures favour late grapevine harvests by compressing the season with early harvests; while low temperatures can cause chilling of grapevines. However, grapevine chilling is uncommon in the study area due to its semi-arid nature, which is characterized by generally high temperatures. Accorging to Venios *et al.,* (2020), high temperatures exceeding 31°C negatively impact grapevine production by compromising soil physical and chemical properties, which reduces soil fertility. This situation also increases irrigation requirements due to elevated evaporation and evapotranspiration rates, and it heightens berry acidity (malic acid). These combined effects result in reduced grapevine yields and wine quality, thereby increasing production costs due to the strategies farmers implement to mitigate these effects.

According to Retallack (2012), optimal wind speeds for grapevine production should ideally be below 3 m/s, as speeds above this threshold lead to increased evaporation and closure of stomata. Wind speeds exceeding 3 m/s, common from May to September in the study area, can cause fruit and flower drop, thereby hindering grapevine reproduction by reducing the number of flowers that mature into fruit. These winds also result in increased vine water loss due to higher evaporation rates. These findings align with Ribereau-Gayon (2000), who confirms that severe winds contribute to smaller berries with thicker skins and drying out clusters, thereby limiting mold growth on grape leaves and berries. However, Bois *et al.,* (2017) have observed that higher wind speeds reduce the development of pathogens.

Adaptation strategies

The primary method of pest control, such as termites and mosquitoes is through pesticide application. Termite control commonly utilizes *Atakan* S5 (trade name), while insecticides like imidacloprid, spinosad, or pyrethrin are employed for other pests, except birds which are deterred using scare tactics. The prevalence of birds is influenced by climate (Cooper *et al.*, 2014). Many bird species breed during the rainy season, and some birds migrate in response to changing weather conditions (Fiedler, 2021).

Fungal diseases such as powdery mildew and downy mildew are managed with fungicides like blue copper combined with *ridomil* (trade name), which is also effective against anthracnose during grapevine flowering. These strategies imply a targeted approach to pest and disease management in grapevine production, employing specific chemical treatments for different threats.

Another strategy used by grapevine farmers to combat diseases and pests is timed pruning. Pruning, done during or just after the short rainy seasons to avoid high humidity, prepares the vineyard for new shoot growth susceptible to pests, fungi, and bacteria. The study finding is in line with that of Santos and Figueiredo (2021) who recommend pruning to enhance air circulation and minimize moisture accumulation in grape clusters. However, Elfar *et al.,* (2020) stress the importance of chemical control for effectively reducing bunch rot incidence. In contrast, Amanda *et al.* (2017) emphasize the need for hedging and fruit zone leaf removal from early to mid-season to mitigate the severity of powdery mildew and Botrytis bunch rot. Pietersen *et al.* (2013) and Habili *et al.* (2023) outline an integrated approach for managing grapevine viral diseases, advocating certified virus-free planting material, insecticide and herbicide application, removal of infected vine material, fallow periods, sanitation practices, and specific horticultural techniques to limit viruliferous mealybugs spread.

Grapevine farmers deploy irrigation and phosphorus fertilizers against drought incidences. Soil moisture is crucial when planting new rootstock cultivars, which require additional water through irrigation during dry seasons. In the study area, both traditional and improved irrigation systems are used. In other places of the study areas, the drip irrigation system includes a tank for mixing water and phosphorus fertilizer, which promotes root development and enhances soil water uptake, countering evaporation rates. The study findings corroborate to those of Fox and Rockstrom (2000), who report that adaptation strategies combining water stress management with soil fertility management help farmers mitigate the effects of climate change and variability. Likewise, Ciotta *et al.* (2018), affirm that applying modest amounts of phosphorus fertilizer to nutrient-deficient soils increases crop water use efficiency and accelerates grapevines development.

Farmyard manure is employed by grapevine farmers as the primary strategy for improving soil fertility in grapevine yards. The study finding aligns to those of Ngigi (2009), who noted that African farmers adapt to climate change through soil fertility management, including the use of fertilizers. Tadesse (2010) further emphasized that sustainable land management can significantly impact marketing by helping mitigate the effects of rising global food prices on impoverished populations in Africa. Additionally, Lema and Majule (2009) reported that farmers in Manyoni District, Tanzania, enhance soil fertility by burying crop residues in the field to replenish nutrients and burning the residues for quicker nutrient release.

Grapevine farmers use local scaring methods to control bird damage to grapevine fruits, such as hanging plastic bags or garment materials and conducting patrols. However, some areas in this study were observed to have poorly managed farmyard environments, which contradict Somers and Morris (2002), who recommend managing habitat features surrounding grape farms—such as power lines, trees, hedges, and orchards—to control bird damage. Although not ecologically sound, Tracey *et al.,* (2007) also suggested population reduction techniques such as shooting, trapping, netting, and poisoning to control bird damage to grapevines. Additionally, Rivadeneira *et al.,* (2018) recommend using noise and decoy methods such as reflective tape, plastic bags, electric fencing, recorded distress calls, programmable electronic bird deterrents, and propane cannons. In Australia, bird trapping remains the primary method for controlling crop damage from birds (Tracey and Saunders, 2003).

Grapevine farmers use mulching, especially during the planting of cultivars, to lessen excessive evaporation and prevent increased water loss caused by high temperatures. The findings corroborate to those of Goodall *et al.,* (2023) which pinpoints that mulching helps conserve soil moisture by reducing soil water evaporation. This practice demonstrates the farmers' proactive approach to water management aiming at enhancing the resilience and health of their crops under challenging climatic conditions.

Grapevine farmers use live fencing against high wind speeds, indicating their adoption of a natural and sustainable method to protect their crops. The finding is in line to those of Mariani and Ferrante (2017) who note that live fencing can serve as a windbreak, reducing the impact of strong winds, which helps minimize fruit and flower drop, decrease vine water loss through evaporation, and enhance overall grapevine stability and productivity. Goodall (2020) also supports that live fencing of vineyards represents a long-term investment in farm infrastructure, offering ongoing benefits with relatively low maintenance costs once established.

Conclusion

The study highlights the significant impacts of climate change on grapevine production in Dodoma, Tanzania, identifying key issues such as disease and pest outbreaks, drought, bird damage, extreme temperatures, and high wind speeds. These challenges have prompted farmers to adopt various adaptation strategies tailored to specific threats. For example: Pest and disease management involves the use of pesticides such as *Atakan S5*, imidacloprid, spinosad, and pyrethrin to control pests, fungal diseases are managed with fungicides like blue copper combined with *Ridomil*, and timed pruning during or after short rainy seasons reduces humidity-related issues, preparing vineyards for new growth less susceptible to pests and pathogens, and enhancing air circulation to minimise moisture accumulation and disease spread; drought is controlled through the use of traditional and improved irrigation systems to maintain soil moisture and the application of phosphorus fertilizers to promote root development and enhance water uptake; soil fertility is improved through the application of farmyard manure and practices such as burying and burning crop residues to replenish soil nutrients; bird damage is controlled through scaring methods and patrols; and extreme weather, such as high temperatures, is managed through mulching to reduce water loss, while high wind speeds exceeding 3 m/s are controlled through live fencing. All of these adaptation strategies have cost implications for the farmers, and some may lack the necessary resources to implement them.

Recommendation

The findings indicate that the Tanzanian government and other stakeholders should assist grapevine farmers in enhancing and implementing existing adaptation strategies. This support can be provided through improved agricultural extension services; better access to financial, human, social, physical, and natural resources; and ongoing research and development of sustainable farming practices. Addressing these needs within the agriculture policy framework will enable grapevine farmers to more effectively manage the adverse effects of climate change, ensuring the sustainability and productivity of grapevine farming in Dodoma.

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