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Community-based risk assessment of vulnerability of smallholder yam production to climate change and implications for adaptation planning

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ABSTRACT

Climate change places substantial pressure on the livelihoods of people living in sub-Saharan Africa, including Ghana. The cultivation of yam is a primary livelihood activity among smallholder farmers in north-western Ghana. However, yam production in north-western Ghana has not received adequate attention in vulnerability analysis and climate change literature, which creates a lacuna in vulnerability assessment and limiting the understanding of smallholder farmers' perspectives on how climate change affects yam production. Therefore, this study analysed the vulnerability of yam production to climate change, particularly the variability in rainfall and temperature in north-western Ghana. This study draws on a qualitative research design using in-depth interviews and focus group discussions for data collection and analysis in three purposively selected communities in the Sissala East Municipality. Participants and study communities were purposively selected and interview and focus group discussion guides were used to guide the conduct of interviews and focus group discussions. The results showed that yam production is exposed to significant risks of extreme rainfall variability. The overall effects of climate variability on yam production include poor and delayed germination, poor growth and tuber development, premature shedding of leaves, pest infestation of leaves and tubers, and high postharvest losses. The paper concludes that yam production is highly vulnerable to extreme changes in rainfall and temperatures and thus recommends that the Centre for Industrial and Scientific Research and Crop Research Department of the Ministry of Food and Agriculture should develop improved yam varieties that are friendly to droughts and high temperatures.

1. Introduction

Climate change continues to have devastating impacts on smallholder agriculture globally, with a disproportionate burden on the least developed regions, including Africa, where there are lower capacities for response and adaptation (Intergovernmental Panel on Climate Change-IPCC, 2014). Human livelihoods have been adversely impacted and are becoming increasingly threatened by climate change in such a manner that poverty reduction and food security efforts are becoming increasingly compromised (Kyei-Mensah et al., 2019; Menike & Arachchi, 2016). The agricultural sector in Africa continues to be the most sensitive and vulnerable to climate change because of its direct link and overly dependence on rainfall and the natural ecosystems (Okongor et al., 2021; Adifon et al., 2020).

In sub-Saharan Africa, the effects of climate change on smallholder agriculture are daunting and have become a major developmental concern (Akinola et al., 2019). Smallholder farmers continue to suffer a disproportionate burden of climate change adverse impacts due to their low adaptive capacities and overreliance on rainfall and natural ecosystem resources for their livelihoods (Adeleke et al., 2021; Adifon et al., 2020; Williams et al., 2018; Lindoso et al., 2012). Poverty levels among smallholder farmers in sub-Saharan Africa continue to remain relatively high because of the exposure and sensitivity of basic livelihood options (agriculture) to extreme climatic events such as floods, droughts, and climate-induced emergence of strange crop pests and diseases (Ayanlade et al., 2023). These mostly translate into poor crop yields, crop failure, and postharvest losses (File & Derbile, 2020; Ayalande et al., 2017; Harvey et al., 2014). Coupled with low levels of education, technology, and access to credit and extension services, the ability of smallholder farmers to effectively and sustainably adjust to the impacts of climate change is highly limited (File & Derbile, 2020; Holland et al 2017; Donatti et al., 2018). In this context, climate change is projected to pose significant threats to national and global efforts towards poverty reduction and enhancement of food security and sustainable development in sub-Saharan Africa (SSA) (Vermeulen et al., 2012; Lipper et al., 2014). In Ghana, climate change has been suggested to directly and indirectly affect food security (Derbile et al., 2022; Sullo et al., 2020).

The production of roots and tubers, including yam, is estimated to be adversely affected by climate change in SSA, particularly in the West African sub-region, where yam production is one of the predominant agricultural livelihood activities among smallholder farmers. Globally, it is suggested that the West African sub-region is the headquarters of yam production, which feeds the global market with different species of yam (Danquah et al., 2022). The quality and quantity of yams produced in the sub-region over the years has received commendations. It has further been indicated that Nigeria, Ivory Coast and Ghana are the leading countries in yam production in West Africa over the past and recent decades. Ghana ranks second after Nigeria in yam production and is the leading country in yam exports (Baffour-Ata et al., 2023). Although the position of Ghana in yam production has remained the same over the past few years, there have been concerns over decreasing levels of production as well as the quality of tubers produced by yams. This has been attributed to the impacts of climate change and variability typified by erratic rainfall, extreme temperatures, and increasing extreme climatic events (Danquah et al., 2022; Magna et al., 2018). Therefore, Ghana's position as a leading exporter of yam in the sub-region is continuously threatened by increasing climatic variability, which affects both production levels and the quality of tubers of yam produced in the global market.

Although there is growing evidence of the vulnerability of smallholder yam farmers to climate change (Cohn, 2017; Harvey et al., 2014), and the increasing need to ensure food security and sustainable food production under climate change (Vermeulen et al., 2012 and Lipper et al., 2014), there is limited research efforts and information on vulnerability assessment of yam production in north-western Ghana (Baffour-Ata et al., 2023). The impacts of climate change on smallholder agriculture, including yam production, are projected to intensify in the coming years due to projections of rising temperatures, erratic rainfall, and increasing frequency and intensity of extreme weather events (Kiba et al., 2020; Imbach et al., 2017). That is, vulnerability assessment at the local (community) level in north-western Ghana has mostly been generalized under the umbrella of vulnerability of smallholder agriculture to climate change, with little focus on specifically assessing the vulnerability of yam production to climate change. Therefore, vulnerability assessment of yam production, though critical, is highly limited in climate change discourse and climate change policy formulation and adaptation planning (Mignouna et al., 2020).

This creates a gap in understanding the knowledge, experience, and perspectives of smallholder farmers on how climate change is impacting yam production. Hence, this study assessed the vulnerability of yam production by smallholder farmers in north-western Ghana, particularly those in the Sissala East Municipal area to climate change through community-based risk assessment approaches among smallholder farmers in Ghana. The objective of the study was to assess how rainfall and temperature variability affect yam farming in Sissala East area of north-western Ghana. This is important because yams are a major staple food crop in most traditional households in Ghana and West Africa. It also serves as a major source of household income for smallholder farmers and as a foreign exchange earner for Ghana in the global market (Acheampong et al., 2019). This study highlights the vulnerability of yam production through the perspectives of smallholder farmers and its implications for the livelihood of yam farmers and food security in the global south and markets across Europe. This will contribute to enhancing stakeholder dialogue to inform policy formulation and climate change adaptation planning at both the local and national levels. The section after the introduction is a review of literature, followed by the description of the study area, methodology, presentation of results and discussion and lastly, the conclusion and recommendations.

2. Literature review

2.1 Climate change and vulnerability assessment

Vulnerability is multidimensional and varies within the context of social, economic, cultural, environmental, geographical, demographic, institutional, and governance characteristics (Raza & Hatab, 2025). This makes vulnerability a complex concept to measure with a one-size-fits-all approach, considering the specific differences in various dimensions (Gitz & Meybeck, 2012). Therefore, the concept of vulnerability to climate change is defined within the context of specificity to its dimensions (Reed et al., 2013).

The IPCC (2022:5) defines vulnerability as the 'propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.' In this regard, it is a function of the exposure, sensitivity, and adaptive capacity of a system to climate change. Thus, vulnerability is measured within the context of a system's exposure to hazards, sensitivity to hazards, and adaptive capacity of the system to cope with, adapt, and/or recover from the effects of the hazard (IPCC, 2022; Reed et al., 2013). According to Chinwendu et al. (2017), vulnerability to climate change is the degree of risk and inability to resist climate deviations. Therefore, there are various approaches to assessing vulnerability at different levels, with varying emphasis on the social, economic, and environmental dimensions of vulnerability (Zarafshani et al., 2016). This is central to adaptation planning to mitigate adverse climatic effects (Corobov et al., 2013).

Sub-Saharan Africa's population is estimated to be more vulnerable to increases in dry conditions, with significant adverse effects on tropical regions (Lickley & Solomon, 2018). There have been considerable changes in climatic elements, such as rainfall and temperatures, across SSA, including the West African sub-region, which is projected to worsen. Rainfall continues to decrease, while temperatures continue to increase across the sub-region, with severe implications for smallholder agriculture. In SSA, changes in precipitation will vary widely, with countries in the north estimated to record significant decreases in annual precipitation leading to extreme droughts, while countries in the south will record possible increases in precipitation, which will expose their populations to frequent and severe floods (Chukwuone, 2015). This will worsen the levels of vulnerability to extreme climate events, which will adversely impact household livelihoods and food security in the sub-region due to their reliance on climate-dependent economic activities, such as agriculture (IPCC, 2023; FAO, 2021). Rain-fed agriculture, which is directly influenced by climate change, is a major livelihood activity in African countries. Smallholder farmers depend on weather patterns and natural ecosystems to plan their agricultural activities. Therefore, unpredictable weather patterns, such as rainfall, increase farmers' vulnerability to poor yields, crop failure, hunger, and poverty (Derbile et al., 2022; Chukwuone, 2015). Increasing and continuous deforestation in the sub-region is projected to aggravate the impacts of climate change in the form of increasing soil erosion, loss of soil nutrients, and other negative consequences. Activities such as firewood harvesting, charcoal production, and illegal logging are increasing deforestation and forest degradation, exacerbating the already increasing risks of climate change and variability among smallholder farmers (Appiah et al., 2018; Asare, 2014).

Local communities and smallholder farmers including yam farmers mostly assess climatic risks by the perceived impacts of climatic events on the growth and yields of crops (Derbile et al., 2016). These impacts are consequences of changes in rainfall and temperatures as well as other climatic variables. Changes in rainfall and temperatures result in erratic rainfall pattern, recurrent droughts and floods, extreme heat conditions which adversely impacts on the cultivation and yields of yam crops (Derbile & File, 2020; Dovie & Pabi, 2023). Thus, risk assessment of yam vulnerability to climate change is mostly based on local knowledge of smallholder yam farmers reflected in the several years of experience in changes in climatic variables and the impacts on yam production. Changes in climatic variables manifest in uncertain and unpredictable rainfall pattern, late onset of rainfall, early cessation of rainy season, extreme temperatures, frequent dry spells, and other adverse conditions present significant threats to food production (File & Nhamo, 2024; Akinola et al., 2019; Magna et al., 2018).

In northern Ghana, rain-fed agriculture is the primary livelihood activity. However, extreme climatic events, such as droughts, heavy precipitation, and floods, continue to have widespread damaging effects on food crop farming. To this end, smallholder food production and household food security in northern Ghana are continuously threatened by climate change and variability (File & Derbile, 2020). Recurrent droughts and floods have characterized the farming season in northern Ghana owing to the combined effect of torrential rainfall and the annual spillage of the Bagre and Kompienga Dams in neighbouring Burkina Faso. This has adversely affected thousands of farming households, as several acres of farmland are submerged in flood waters (Kankam-Yeboah et al., 2010). Smallholder farmers' vulnerability reflects their exposure to recurrent droughts and seasonal flooding, making smallholder agriculture significantly vulnerable to the double tragedy of climate variability (Derbile et al., 2016).

Climate change and variability significantly affect the quantity and quality of stored seeds, particularly when they are exposed to extreme conditions such as warming, flooding, and excessive humidity. Thus, the quality of stored seeds is negatively affected by changes in climatic conditions, where proper and adequate storage infrastructure is inadequate (Alliance for a Green Revolution in Africa-AGRA, 2021). Climate change continues to cause decreasing crop yields due to changes in rainfall and temperatures, which results in increasingly warm conditions, water stress and scarcity, and changes in pests and diseases. These conditions also affect seed germination due to erratic and unpredictable rainfall patterns. The cropping season has also shortened due to climate variability, which has significantly affected crop yields and food production in northern Ghana (United States Aid-USAID, 2017). Smallholder farmers' vulnerability to climate change is exacerbated by their limited access to agricultural mechanization, infrastructure, and markets (United Nations Development Programme-UNDP, 2017).

2.2 Climate change and yam farming in West Africa

The recurrence of droughts and floods, in addition to extreme temperatures, have severe consequences for root and tuber crop production. Yam, potatoes, cassava, and other tuber and root crops are the most vulnerable to extreme climatic conditions, such as variability in rainfall, extreme temperatures, and sunshine. Most tubers rot easily under high temperatures, leading to high postharvest losses. Droughts and extreme temperature conditions also affect germination and development of tuber crops (File, 2015; Codjoe & Owusu, 2011).

Yam crop production in Africa, particularly in West Africa, constitutes a major livelihood activity for many households (Cornet et al., 2023; Maroya et al., 2022; Acheampong et al., 2021; Kiba et al., 2020). West Africa accounts for much of yam production globally, where it supplies about 95% of yam to the world market (Moroya et al., 2022; Wumbei et al., 2022; Adewumi et al., 2021). It has been suggested that yam production could contribute significantly to the reduction of poverty and hunger in West Africa and Africa in general if given priority in national agricultural policies by governments (Mignouna et al., 2014). Yam is the third most consumed staple food in West Africa, after maize and rice (Mignouna et al., 2014; Omojola, 2014). It is also a traditional crop that is used for many purposes, including traditional rites such as festivals, funerals, and marriages, among other social events in many traditional African societies (File, 2015; Mignouna et al., 2014; Omojola, 2014; Magna et al., 2018).

However, climate change has constrained yam production in the West African sub-region. This is because yam cultivation is primarily rain-fed and significantly influenced by changes in rainfall and temperature patterns. Consequently, yam production has been declining in West Africa over the years due to poor rainfall patterns, increasing temperatures, and the emergence of pests and diseases that adversely affect yam productivity (Baffour-Ata et al., 2023; Okongor et al., 2021; Adifon et al., 2020; Adewuyi et al., 2014). Soil fertility and soil moisture continue to decline with increasing cases of water stress and scarcity and extreme heat due to high temperatures, which affect yam growth and development. High temperatures, pests, and diseases also account for the poor quality and postharvest losses of yam tubers (Wumbei et al., 2022; Sanginga & Mbabu, 2015). To this end, any marginal increase in yam production over the years has resulted in the expansion of land for yam cultivation through the conventional extension of land and forests (Danquah et al., 2022). This practice has accounted for deforestation and degradation of vegetation and land, which exacerbates the phenomenon of climate change in sub-regions, including Ghana.

2.3 Climate change and yam farming in Ghana

Ghana is ranked the second producer of yam after Nigeria and a leading exporter of yam for over a decade in the West African sub-region (Baffour-Ata et al., 2023; Danquah et al., 2022; Wumbei, 2022). According to Anaanumba (2013), about 94% of the total yam exports in West Africa come from Ghana, and many of these go to the United Kingdom, the United States of America, and the Netherlands. Yams from Ghana are known for their sweet taste and are usually preferred by many countries and consumers, especially Africans (Anaanumba, 2013; MiDA, 2010; Odinwa et al., 2011). Ghana overtook the Ivory Coast to become the second-largest yam production country in 2019 (Danquah et al., 2022; Neina, 2021). According to Danquah et al. (2022), yam production in Ghana over the period from to 2009-2019 increased to 11.06% and placed the country second to Nigeria (66.12%), with Ivory Coast coming third with 9.85% of total production over the period.

Yam is cultivated in the forest and Guinea Savannah agro-ecological zones of Ghana, including the Northern, Bono East and West, Ahafo, Eastern, Upper West, Ashanti, parts of Volta, and Western Regions. The Bono East, Bono West, Ahafo, Northern and Eastern Regions are the major yam-producing regions, accounting for approximately 76% of total yam production in Ghana in 2010 (Anaanumba, 2013). Yam is a major staple food crop in Ghana and serves as a major source of dietary calories for many households. It is one of the most consumed food crops in Ghanaian households and is prepared in different forms of meals. Yam farming is also a major source of household income in Ghana, particularly in Northern Ghana. Yam production significantly contributes to the agricultural sector's GDP in Ghana (Baffour-Ata et al., 2023). To this end, there has been an increased demand for yams and their cultivation among households and individuals in Ghana, including north-western Ghana. However, this increased demand is met with decreasing supply because of the decreasing production of yams attributable to the impacts of climate change. The erratic patterns of rainfall, increasing temperatures, and sunshine among other factors pose significant challenges to yam production in Ghana (Baffour-Ata et al., 2023; Frimpong et al., 2020; Sanginga & Mbabu, 2015).

Yam is a long-gestation crop that takes at least 5-6 months to mature after germination (Yahaya et al., 2014). Other yam varieties can take up to 8-12 months to mature (Danquah et al., 2022). Therefore, the late start of rain and the erratic nature adversely affect the germination of yam seeds and tuber formation and development. Furthermore, early cessation of rain affects the redevelopment of seed yam after early harvesting. These are exacerbated by extreme temperatures, which lead to postharvest losses. Yam tubers are highly perishable under high temperatures and warm conditions, which is a major challenge for yam farmers.

According to Danquah et al. (2022), yam production in the West African sub-region increased from 44 Mt to 70 Mt from 2009 to 2019 due to population growth and the corresponding demand for yam. This also translated into an increase around land cultivated or harvested for yam from 4.22 million hectares (Mha) to 8.35 Mha. Consequently, yam production among the top three leading yam-producing countries increased from 29.09 Mt (Nigeria), 5.78 Mt (Ghana), and 5.31 Mt (Côte d'Ivoire) in 2009 to 50.05, 8.29, and 7.18 Mt, respectively, in 2019 (Danquah et al., 2022). This increase came at the back of expansion in land cultivated in Nigeria, Ghana, and Côte d'Ivoire from 2.78, 0.38, and 0.81 Mha in 2009 to 6.24, 0.46, and 1.29 Mha, respectively. Although yam production in Ghana has witnessed some increase from 15.26 t ha^{-1} in 2009 to 17.85 t ha^{-1} in 2019, translating in an increase of about 17%, this was still below the projected average yields of 50 t ha^{-1} (Danquah et al., 2022). This suggests that Ghana did not meet its full potential for yam production over this period. This observed general declining yield of yams is met with extensive clearing of land in attempts to increase production, which has adverse implications for sustainable forest and general biodiversity conservation.

3. Study area and methodology

3.1 Description of the study area

The Sissala East Municipality has a total population of 80,619, with 39,868 men and 40,751 women. The municipality is predominantly rural, accounting for a population of approximately 61,849, with 30,825 males and 31,024 females (Ghana Statistical Service-GSS, 2021). The Sissala East Municipality covers a total land area of 4,990 square kilometres with a population density of 16.2 per square kilometres and a total number of 18,262 households with an average household size of 4.0 (GSS, 2021). The major economic activity of the people is agriculture, which employs much of the working population (Sissala East Municipal Assembly, 2023. Farmers in the municipality usually engage in both crop production and animal husbandry (Ministry of Food and Agriculture-MoFA 2013). The municipality's topography is gently undulating. The soil type in the municipality is mainly savannah ochrosols and tropical brown earth. These soils are better suited for the cultivation of cereals, root tubers, and cotton (MoFA 2013). The municipality falls within the tropical continental zone of Ghana and thus experiences a long dry season followed by a short rainfall season, which begins in May and lasts until September and October (GSS, 2014). Sissala East Municipality is one of the major food baskets of the country and one of the major yam-producing areas (Sissala East Municipal Assembly, 2023), making it suitable for this study. The Challu, Nabugubelle, and Nmanduanu communities were purposively selected (as shown in Figure 1) for the study because they are major yam-producing communities in the Sissala East Municipality.

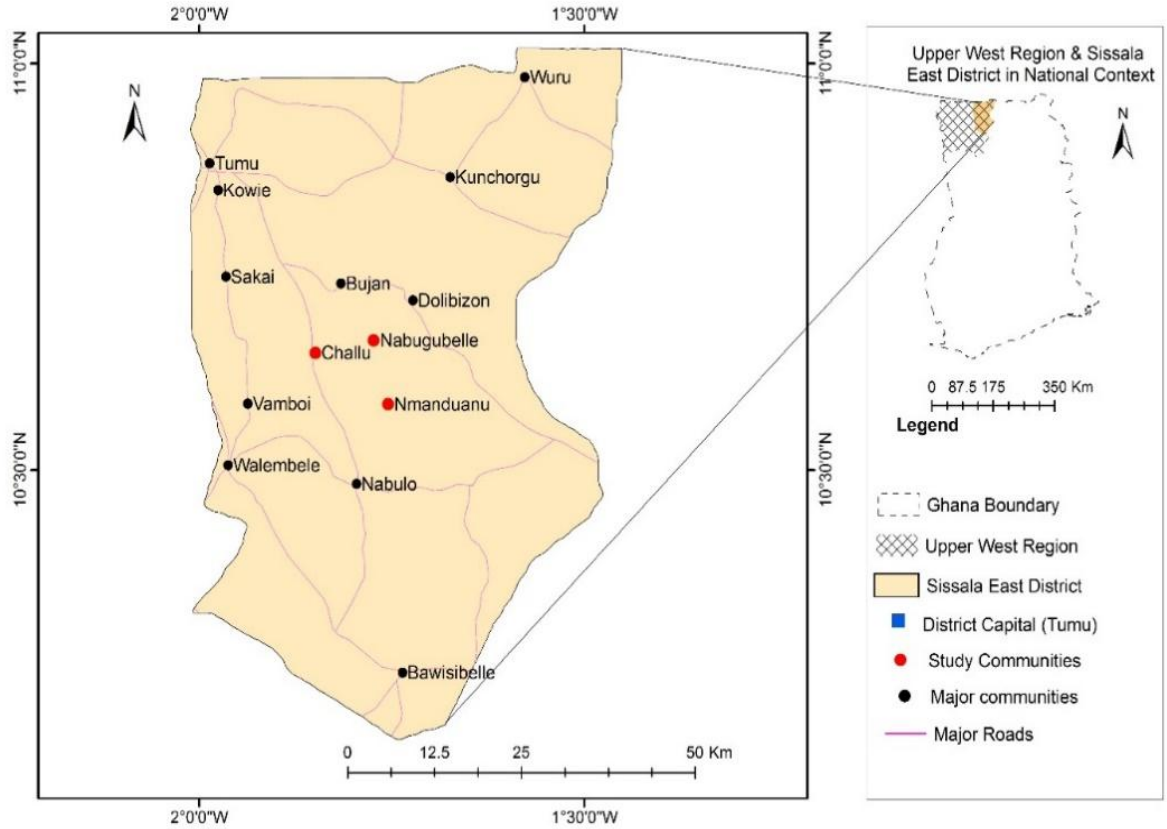

Figure 1: Study Communities
Source: Authors' Construct, 2022

3.2 Research design and methods of data collection

An exploratory research design was used for the study. This was helpful since the study sought to explore how changes in rainfall and temperature patterns over the years were affecting smallholder yam production in the study communities. A qualitative approach was also adopted for the data collection and analysis. This is because the qualitative approach helps to explore in-depth attitudes, practices, and experiences through such methods of data collection as interviews, focus group discussions and observations to deepen the understanding of how climate change affects yam production in Sissala East Municipality. It drew on diverse strategies of inquiry in gathering primary data (Creswell, 2009) to examine the impact of climate change on yam framing. It provides an opportunity to examine the lived experiences, perceptions, behaviour and actions of smallholder yam farmers in a simplified manner (Mohajan, 2018). To minimise the shortcoming of subjectivity in data interpretation associated with qualitative approach, the data collected were coded (Sarstedt & Mooi, 2019; Tyagi et al., 2013). To this end, the researcher coded all data collected through face-to-face interviews and groups discussions so they can easily to be identified accordingly during data interpretation.

Data were collected through in-depth interviews and focus group discussions. Participants' knowledge was sought on how changes in rainfall and temperature patterns over years have affected the production of yam as a staple food crop in the study communities. That is, how the effects of floods, drought, high temperatures, erratic rainfall. etc. have affected yam production. In-depth interviews were conducted with participants who had considerable knowledge and several years of experience in yam farming and related activities. These interviews were conducted with 30 household heads who were active yam farmers with at least 20 years of experience in yam farming and 15 former lead yam farmers who had over 25 years of experience as yam farmers. In each community, 15 in-depth interviews in a face-to-face manner were conducted and a saturation point reached. The interviews were mostly aimed to seek participants knowledge and experiences on how changes in rainfall in the form of droughts and floods as well as extreme temperatures and sunshine affect yam cultivation. The participants were purposively selected and interviewed until a saturation point was reached after interviewing 15 participants in each community. In all, 45 in-depth interviews were conducted among yam farmers across the three selected communities in the months of June and July 2024.

Focus group discussions (FGDs) were conducted among different groups of yam farmers, namely yam farmers who were youth, yam farmers who were in active yam farming and had over 20 years of experience, and elderly (retired) yam farmers who could not farm due to their old age. This was to help get new insights and cross check the data collected from interviews. The FGDs were also important for the researchers to unravel the issues that could not have been covered through the in-depth interviews as well as get further understanding and appreciation of some issues that emerged from the interviews. Participants were engaged to assess the extent of which changes in rainfall and temperatures have affected yam production over the years. The assessment of the adverse impact of changes in climatic variables on yam production was done using a Likert scale (1-Very High, 2-High, 3-Moderate, 4-Low, and 5-Very low). Overall, 15 focus group discussions were conducted across the study communities, with discussants ranging between 6 and 10 members per session (Kabir, 2016; Bhattacherjee, 2012). These were conducted in June and July 2024. An FGD guide was prepared and used to guide the discussions. The data collected were transcribed and presented through paraphrasing, direct quoting, general discourse analysis, and discussions on the subject matter as reported by participants.

3.3 Sampling procedure

This study draws on primary data collected from three purposively sampled study sites in Sissala East Municipality. The study communities were *Challu, Nabugubelle* and *Nmanduanu*. Purposive sampling allowed the researchers to select communities and study participants based on their judgment because of distinguished features, in-depth experiences, and knowledge. Participants for in-depth interviews were selected based on their in-depth knowledge and many years of experience in yam farming and related activities. These were smallholder yam farmers with at least 20 years of experience and could express themselves very well. Participants for FGDs were also selected based on their experience and knowledge in yam farming. Discussants were those willing to share their knowledge and experiences with the researchers on matters concerning the changing patterns of rainfall and temperatures and how these are affecting yam production in the study communities over the years. The opinions of discussants were sought on how changes in rainfall and temperature patterns were affecting yam production in their communities over the years. They were asked to indicate the extent to which erratic rainfall, floods, droughts, high temperatures and other changes were impacting yam production as a staple food crop.

3.4 Ethical considerations

The research was conducted under the guidelines and methodological processes and protocols outlined and approved by the research ethics review board of the Simon Diedong Dombo University of Business and Integrated Development Studies. The researchers adhered to ethical protocols by making participants understand the purpose of the research and maintaining a high level of confidentiality and anonymity of participants for their engagement. The consent of participants was sought before engagement. Permission was sought from participants before audio recordings, which were kept anonymous and confidential. Informed consent of the research participants was obtained verbally since the participants did not have formal education background to read and write on a written form. To this end, the purpose of the research was communicated in the local language (Sisaali) for the understanding of participants. All the interviews and discussions were conducted under the informed consent approval of the participants.

4. Results and discussions

4.1 Vulnerability of yam to rainfall variability

The impacts of climate change and variability on yam production in north-western Ghana have been typified in various forms, such as droughts, floods, pests, and diseases. These affect land preparation (field clearing and making mounds), planting, staking, early harvesting, harvesting, storage, processing of tubers and setts, and marketing.

The period for planting yam spans from December to May, with December to March being the early planting phase and April to May being the late planting phase. Smallholder yam farmers who make yam mounds before the end of the year (December) plant during the first phase, while second-phase planters are usually farmers who must wait for the early rains (locally called *duonpuso*) to make mounds for planting. In this case, farmers mostly plant yams a week after the mounds are raised. It has been suggested that this process enhances germination because the tubers are buried in wet (moisturized) soil. Germination is faster and more uniform than early planting because the yam setts germinate before they are planted on the mounds. However, the results showed that there have been shifts in the farming season over the years due to rainfall variability. The early cessation and late onset of the rainy season tend to affect activities on yam farms, as farmers must deal with other competing farm activities within a shorter season. In other words, the late onset of the rainy season delays the second phase of making mounds and planting yams, which adversely affects yam yields. In addition, the early cessation of rain makes it difficult for many farmers to make yam mounds for early planting. Results from FGD sessions suggest that many of the farmers get their yam fields dried shortly after clearing and are unable to make mounds for early planting during the December to March period. A yam farmer in Nmanduanu noted that a shift in the farming season due to rainfall variability adversely affected the farming calendar, including yam farming. According to the farmer:

> *"The early stop of the rains makes our fields to dry faster than we usually anticipate. By the time we finish clearing the fields, the land is dry up…and you cannot make mounds. One must wait until the rains start in March or April of the following year to make mounds. This takes time and coincides with other land preparatory works on the farm for other crops. In this case, one is forced to reduce the number of yams to plant so you can cultivate other food crops. With this situation, why would many people not stop cultivating yam?"* (Nmanduanu community, July 15, 2024).

Clearly, the early cessation of the rain culminates in the drying of fields, thereby pushing basic preparatory activities forward to compete with other activities. There are delayed planting and a contracted season for the maturation of yam plants. This results in poor growth and tuber formation. This agrees with the findings of Adifon et al. (2020) that rainfall anomalies significantly affect the growth and yield of yams negatively. Furthermore, Amikuzuno & Donkoh (2012) indicated that yam yields are predicted based on rainfall levels because there is a significant unidirectional causal relationship between rainfall and yields of most staple crops in northern Ghana.

In north-western Ghana, the major source of seed yam is early harvest between July and August to allow for the redevelopment of new tubers (mini setts) as seeds for the next planting season. However, it has been indicated that the delay in the onset of the rainy season caused a significant delay in tuber development for early harvest in July and August. This has negatively affected the availability of seed yams for many yam farmers in north-western Ghana. This is adverse because of the corresponding early cessation of the rainy season, which affects the redevelopment of seed tubers. Results from in-depth interviews and FGDs suggest that the rainy season ends abruptly in late August or mid-September, instead of October, as in the past. This leads to the early onset of drought, which adversely affects the redevelopment of seed yams for the next planting season. During the FGD session, the farmer noted that.

> *"…. because the rains cease abruptly, early harvested yam plants are unable to re-develop seed tubers. In this case, we often rely on tubers that are below the average size for the market for seed yam."* (Challu community, June 20, 2024).

Droughts and dry spells are common hazards that can significantly affect yam production. These hazards have become frequent during the farming season because of their erratic patterns, which significantly affect yam farming. These intermittent dry spells affect yam crops in different ways at different stages of growth during the season. Yams require adequate and well-distributed rainfall or moisture to produce good tubers. During the FGD sessions, it was revealed that droughts and dry spells mostly cause delays in yam germination. In addition, the vines of yam plants become weak, tiny, and sometimes die off prematurely owing to excessive dry conditions and high temperatures. It was further indicated that dry spells result in poor development of the leaves and branches of yam plants, which delays the process of tuber development. It has emerged that yam crops require adequate and regular precipitation during the germination period (March and April) to the period when tubers are fully developed. This moisturizes the soil for germination and loosens it for easy penetration by tubers during tuber formation and development. Redevelopment of seed yam after early harvesting also requires good rainfall distribution through to the end of September. To this end, dry spells during tuber formation and redevelopment of seed yams adversely affect yam yields. Yams develop short and lean tubers that do not provide good market value for farmers. According to farmers, such tubers are easily broken during transportation to market centres, which further affects market prices. Therefore, erratic rainfall and dry conditions affect the length, shape, and size of yam tubers as suggested by Adifon et al. (2020). An early study by Ennin et al. (2009) indicated that the ability of yams to penetrate easily into the soil determines the shape and size of tubers. That is, yams require pulverized and loose soil for easy penetration and swelling of tubers.

Erratic rainfall patterns also expose yam plants and tubers to pest and insect infestations. Dry spells due to erratic rainfall tend to enhance the emergence of pests and insects to infest yam leaves and vines, especially between May and early July. These pests mostly eat off the vines and leave of yam plants to impede their growth, development and tuber formation, resulting in poor yield and harvest. Termite infestation of tubers has also been reported as a common incident associated with low and erratic rainfall patterns, which have become common in recent farming seasons. According to the participants, termite infestation of yam tubers was most prevalent during the period of less and intermittent rainfall patterns after July. Black termites (locally known as *churung*) mostly cause destruction of tubers during and after formation. Most infested tubers, which may be partially infested, lose the quality and normal sweet taste of the 'Ghana yam.' This indicates that farmers could experience significant losses and failure from their yam farms due to the incidence of termite infestation as opined by Wumbei et al. (2022).

The findings also show that limited rainfall coupled with abrupt cessation of the rainy season usually causes early shedding of yam leaves and the consequent inability of yams to fully develop or redevelop tubers. It was said to be worse if yams were harvested to allow the reformation of seed tubers. In such instances, yams are unable to redevelop tubers after shedding their leaves. A farmer noted the following during an in-depth interview.

> *"…low rainfall and early stop of the rains mostly cause yams to shed off leaves within a short period of time. The early harvested yams are most vulnerable because they shed off leaves within a week or two and cannot redevelop seed yams. The leaves turn yellow and fall off within a few days. But those that are not harvested usually shed off leaves gradually in two stages; first, they shed off their bottom leaves and secondly, shed off the top leaves."* (Nabugubelle community, June 24, 2024).

From the FGDs, the results show that the impacts of droughts on yam production were severer than the impacts of floods as shown in Figure 2. Majority (56.9%) of the participants believed that the incidence of droughts over the years have adversely affected yam production in their communities. Others believed that the impacts were 'very high' compared to those who thought the impacts were 'moderate.' On the other hand, floods were believed to pose moderate risk to yam production by many of the participants (51.2%) in the discussions; while about 30% of the participants believed the adverse impacts were 'high' and 'very high'. This may be attributed to the fact that there have been decreasing rainfall patterns which manifests in frequent dry conditions as indicated by File and Nhamo (2024).

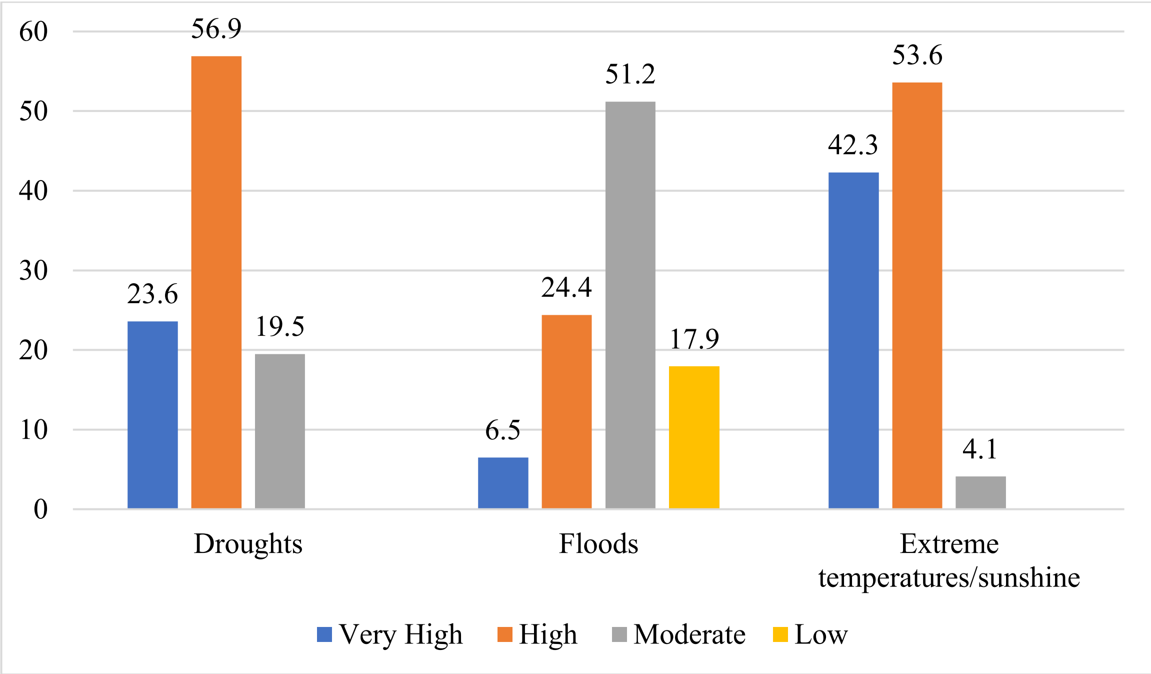

Figure 2: Adverse impacts of climatic variables on yam production
Source: Field Data, 2024

4.2 Vulnerability of yam production to sunshine and temperature variability

The results from the FGDs showed that extreme temperatures and sunshine negatively affected yam production (see Figure 2). Participants assessment suggested that the impact of extreme temperatures and sunshine on yam production were 'High' (53.6%) and 'Very high' (42.3%). This is because yam is a perishable crop, especially under extreme temperatures and sunshine, which creates extreme heat/warm conditions. These extreme conditions can significantly affect planting, germination, storage, and marketing. Yam seeds are planted in the morning when temperatures are low to reduce the risk of rot and poor germination. It was revealed that most farmers will not plant yam after 9.00am in the morning when ground temperatures begin to rise. It was indicated that when the seed tubers were buried in warm soil, they easily rot and could not germinate. A 62-year-old yam farmer noted that:

> *"Yams are planted mostly between the hours of 5:00 am to 8:00 am when soil temperatures are low. You do not need to plant when temperatures begin to rise or else you risk getting them rotten and will not germinate. You do not also need to expose the tubers to direct sunshine for more than 30 minutes before they are planted. Exposure to much sunshine will cause them to rot after planting."* (Nabugubelle community, June 27, 2024).

Yam farmers are particularly careful when planting during the warm season (locally known as *wulumung*), which occurs from February to April, as indicated by File and Derbile (2020). This is because of the extreme temperatures and sunshine that characterize the season across northern Ghana, resulting in high temperatures. Therefore, farmers are conscious of the risk of yam seeds getting rotten due to extreme temperature conditions and will consequently mulch them after planting to ensure low soil temperatures for good germination.

It was indicated that high temperatures and intensive sunshine could negatively affect vines, especially vines that are not staked or creeping on the ground. Yams that sprout during germination are also affected, particularly when they are not mulched. Therefore, mulching and early staking of yams have become important activities for yam farmers to avoid damage from extremely warm conditions due to increasing temperatures and intensive sunshine. Yam mounds are mulched with leaves and grasses to regulate soil temperature and to conserve moisture and low soil temperature to enhance germination. These materials also provide organic manure to crops during decomposition. In this regard, the FAO (2017) describes mulching as a multipurpose activity undertaken by smallholder farmers to conserve soil moisture, reduce runoff, increase water infiltration, control weeds, and increase soil fertility.

Extreme temperatures and sunshine can also adversely affect yam during harvesting and storage. As noted earlier, yam cultivation consists of several phases ranging from land clearing through planting to harvesting, storage, and marketing. During harvesting, tubers that are exposed to intense sunshine for more than 30 minutes before conveying them to the ban have a high risk of getting rotten. In most cases, tubers are not usually stored in yam bans up to the months of March and April but are sold out to reduce the risk of postharvest losses. This makes farmers vulnerable and thus exposes them to very poor prices offered by buyers at the farm gates. It was revealed that buyers were equally concerned about the yams getting rotten at their market stores after buying them from farmers. This was noted as a powerful bargaining power or tool among buyers at farm gates. Therefore, both farmers and buyers face the risk of perishability of tubers, either in the bans or at market stores, due to extreme warm conditions.

5. Conclusion

The study revealed that yams are a common staple food crop in traditional homes and are consumed by most households as yams are used in various forms of meals. Aside from consumption, tubers of yam are sold for household income as well as used for other traditional activities (rituals), thus revealing the multiple uses of yam for food, income, and social and religious purposes. The study further showed that although yam production has enormous benefits to farmers and contributes to the GDP of countries, particularly in sub-Saharan Africa, yam production is significantly compromised by the vicissitude of climate change in the form of erratic rainfall patterns and rising temperatures, which translate into frequent and prolonged dry spells, warm conditions, and pest and insect attacks on yam crops. These unfavourable conditions result in poor germination, late field preparation, poor yields, postharvest losses, and poor market prices for yam tubers. The nature of yams makes them particularly vulnerable to rainfall variability and extreme temperature. Hence, yam production has been declining because of changes in rainfall and temperature manifested in various climatic extremes. To this end, the paper recommends that the Centre for Industrial and Scientific Research (CSIR), the Crop Research Department of the Ministry of Food and Agriculture, and other related crop research bodies should develop improved yam varieties that are drought-friendly and friendly under high temperatures. The government should make funding available to these institutions to carry out extensive research to enhance the discovery and development of early maturing yam varieties that are conducive to extreme climatic conditions. There should be growing interest in mainstreaming climate change and vulnerability analysis into national, regional, and district development planning to enhance effective climate change adaptation planning for securing food security and livelihood sustainability.

Disclosure statement

The authors report that there are no competing interests to declare.

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