Navigating Complexities Towards Sustainable Food Crops Production: Local Practices For Climate Change Adaptation In Rural Ghana

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Abstract

Globally, food crops production has been challenged by the impacts of climate change. Climate change scholars have argued that rural dwellers, particularly smallholder farmers who engage in food crops production, suffer the most due to their low capacity to adapt. A growing body of knowledge also suggests that local practices serve as safeguards, that enable smallholder farmers to lessen their vulnerability in food crops productions. However, limited scholarly insight has been advanced about sustainable food production via the use of local practices. Through the mixed research approach, our study contributes to local practices and climate adaptation debates by examining the various local practices of smallholder farmers, the challenges they encounter with the use of such practices and the possibility for sustainable food crops production in the future. Our findings suggest that smallholders encounter multiple drawbacks in attempts to utilize local practices to adapt food crops production to climate change including the advent of modern farming inputs/practices. Even when multiple local practices (the planting of crops varieties, switching between crops and livestock rearing, reducing cultivatable land size) are utilized, only the increment in farm size, the use of income/remittances of rural-urban migrants to support food crops production, and early cultivation offered some possibilities of sustaining improvement in food crops production for the future. Therefore, we conclude that local practices are not necessarily panaceas for sustaining food crops production under climate change. We recommend further studies to pay attention to the sustainability of local practices under climate change.

1. Introduction

About two-thirds of the world's population dwell in rural areas and engage in subsistence agricultural production (Madsen, 2021). Estimates suggest that rural dwellers own, occupy and use about 22% of the global land resources (Nakashima et al., 2012). A growing body of knowledge also indicates that rural dwellers mainly rely on their local practices for food crops production, from which they irk a living (MFCS, 2014; Todaro & Madsen, 2021). About one-third of the farmers utilize more or less local practices for food crops production (Mofongoya & Ajayi, 2017). Unfortunately, food crops farming as a source of livelihood has over the years been vulnerable to changes in climate (Di Falco *et al.* 2011; ALP, 2013; Marrakesh, 2016; Nkegbe and Kuunibe, 2014). Studies in the global South reveal that drought, high temperature, erratic rainfall, flooding, soil erosion, insect infestations are key climatic events confronting smallholder farmers in irking a living through food crops production (Veihe 2000; Goswami, Saha, and Dasgupta 2017). These climatic events contribute to lowering food crops yields and increase the vulnerability especially of smallholder farmers who engage in subsistence food crops productions (Haščič, et al 2012; Mbow et al 2014; Adenle et al, 2017; Rusere et al. 2019). The reliance on rainfed agriculture, and climate-related effects on natural resources that augment smallholder farmers reinforce the vulnerability of smallholder farmers (Amoutchi et al. 2021; Yiridomoh, 2021). In Africa, smallholder farmers are characterized as farmers whose cultivable lands do not exceed 1.28 hectares (FAO, 2012).

Some scholars have also drawn the attention of climate change scholars' to the uneven geographies of climate change impacts, by showcasing the disparities in the vulnerability of farmers across geographies (ALP, 2013; Nyantakyi-Frimpong, 2013; Williams, Crespo, and Abu 2020; Fitton et al. 2021). In doing so, they brought to light the manifold climate-related factors that act as drawbacks to the food crops productions of smallholder farmers (Baruah, 2021). Climate change scholars have also showcased the insurgent and the diversity of measures that farmers undertake to limit the vulnerabilities that arise from climate change, including the Sustainable Intensification Agriculture and Ecological Intensification Agriculture (Marrakesh, 2016; Kpadonou et al., 2012; Adolph et al. 2020; Dakyaga et al. 2020). Moreover, how such practices sustain food crops production among smallholder farmers remain unknown.

Studies in particularly in the Africa context suggest that Sustainable Intensification Agriculture (SIA), Ecological Intensification and soil and water conservation practices are evolving as feasible alternatives for fostering food crops productions due to arable land scarcity and for enabling easier management of farms (Adolph et al. 2020; Dakyaga et al. 2020). Moreover, in many parts of Sub-Saharan, the adoption of these approaches have been low among smallholder farmers and more or less shaped by the socio-economic and ecological factors such as credit constraints, rainfall pattern, farmer households' income status, social capital and network, the availability and access to market (Teklewold, Kassie, and Shiferaw 2013; Jindo, Schut, and Langeveld 2020; Mutyasira 2020). Again, a growing body of knowledge has demonstrated the use of local practices and their potentials in fostering climate change adaptations, enabling natural resource management, biodiversity conservation, disaster risk reduction/disaster management and endogenous development (Nakashima et al., 2012; Mofongoya & Ajayi, 2017; Ajani, Mgbenka, and Okeke 2013; Dube & Munsaka, 2018; Dakyaga et al. 2020).

In the case of Ghana, the Ghana Statistical Service (2014), reveal that about 88.8% of households in Ghana rely on agricultural activities drawing on local practices. Moreover, research on local practices and climate change adaptation, have largely grown along with the

perceptions of smallholder farmers' about climate change, how smallholder farmers cope and adapt to climatic events (Dayour, Yendaw, and Jasaw 2014; Laube, Schraven, and Awo 2012), the vulnerability of smallholders to climate change (Williams et al., 2020), as well as the practices smallholder farmers engage in towards sustainable land management (Issahaku & Abdulai, 2020). These studies have demonstrated the multiple trade-offs that smallholders in Ghana make to adapt food crops production to climate change. They reveal that smallholder farmers sometimes compromise the production of certain food crops varieties for another in the given piece of land for an enhanced yield or may compromise the production of food crops, particularly, farming for poultry and livelihood rearing or utilizing tractors to fasten ploughing of farmlands to meet the short pattern of the rainfall, and in turn pay for the cost of the ploughing after harvesting (Adolph et al. 2020; Dakyaga et al. 2020). Any of these decisions taken by smallholder farmers hold certain consequences in their efforts towards adapting food crops production to climate change.

Moreover, in the sphere of local practices and climate change, few studies have explored the traditional ecological practices of smallholder farmers in adapting to climate change (Sullo et al. 2020; Baffour-Ata et al. 2021). These studies have shown that smallholder farmers utilize varieties of adaptive practices often including both on-farm and off-farm practices. These practices have been regarded as useful for lessening vulnerability among smallholder farmers (Sullo et al., 2020). Because of this, studies have advocated for the need to protect local practices for food crops production and also the need to integrate farmer-based practices and scientific-based evidence towards enabling smallholder farmers to adapt food crops production to climate (Sraku-Lartey 2014; Mugambiwa, 2018; File and Derbile 2020; Guodaar, Bardsley, and Suh 2021). These studies argue that whilst the adoption of technology may be influential for minimizing climate-related effects, the costs of modernized technologies are often beyond the financial capacities of smallholder farmers to enable their adoption (Maddison, 2006; Mburu et al., 2015; & Ngenwi, 2011; Basdew et al., 2017; Makondo, & Thomas, 2018).

Whilst scholarly debate on local practices has evolved steadily, limited scientific insight has so far existed about the extent to which local practices can sustain improvement in food crops production among smallholders to warrant their adoption and integration with modernized/scientific agricultural practices. Therefore, our study builds on the aforementioned debates on climate change and local practices concerning food crops production from the global South. We examine the multiple practices smallholder farmers utilize for food crop production, the challenges they face with the use of local practices, and how such practices can sustain food crops productions among smallholder farmers. Sustainable food crops production in this context entails farmers' perceived guarantee of improvement in food crops' yields presently and in the future with the use of local practices. This study is relevant to the global development agenda 2030 on sustainability (Sustainable Development Goals – SDGs) particularly SDG 1 and 2 "No poverty – eradicating extreme poverty among smallholder farmers" and "Zero Hunger – by achieving food security, increasing sustainable productivity and ensuring access to safe, nutritious and sufficient food all year round" respectively (de Andrade et al., 2021).

The aim of this study is to examine how smallholder farmers navigate the complexities arising from climate change through the use of local practices and how that sustains improvements in food crops production. To do so, the study draws a conceptual review from climate change and local practice as tools for adapting food crops productions to climate change to; (1) explore the local practices of smallholder farmers towards adapting food crops production to climate change; (2) the challenges smallholder farmers face with the use of local practices; (3) farmers' perceived sustainability in terms of improvement in food crops production through the use of local practices. The paper is organized into five sections, section 2, presents conceptual and empirical reviews on climate change, local practices and food crops adaptation. Section 3, presents the methods, and the study settings. Section 4, presents the results and discussions of the study, whilst the last section presents the conclusion of the study.

2. Climate Change Adaptation Of Smallholder Farmer's Food Crop Production In Sub-Saharan Africa

2.1 Climate change, local practices and sustainable food crops productions

As discussed earlier, whilst scholarly debates about climate change and local practices have evolved over decades, scholarly insight linking local practices and how they sustain improvement in food crops productions among smallholder farmers remains limited. Moreover, sustainability scholars have drawn our attention to the need for scholars to align research findings and perhaps map our progress towards the sustainable development agenda 2030 (de Andrade et al. 2021). The Sustainable development paradigm gained historical roots in the 1980s, defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Andrade et. al., 2021). Moreover, this study regards sustainable food crops productions, which refers to products that guarantee continuous improvement in food crops yields through the use of local practices by smallholder

farmers. Therefore, the study measures farmers perceived improvement of food crops yields through the use of local practices. According to Rankoana (2006), climate change refers to the variation in temperature and rainfall patterns over a long period. This definition centres on an observed variation in the elements of weather over time. A study by Theodory (2016) suggests that changes in the climate occur due to changes in the socio-economic activities of people, agricultural and environmental factors. MFCS (2014) observes that the concept of climate change in Ghana is associated with variations in the elements of weather for a long period that in turn result in persistent drought, and unpredictable rainfall.

The factors influencing climate change have been broadly categorized to include natural and human factors (Derbile et al. 2016; Manyani et al. 2017; Callo-Concha, 2018). Some studies have shown that climate change or its threats are a result of natural phenomena (MoSTE, 2015; ALP, 2017; Callo-Concha, 2018). The key natural climate stressors that adversely influence agricultural systems include erratic rainfall, high temperature and drought as well as flood (Antwi-Agyei et al. 2018). Empirical studies in the Upper West Region (the study location) such as Derbile et al. (2016) states that the "primary stressor of environmental change are drought " Whilst other reports such as Appiah et al., (2018) and Callo-Concha (2018) also suggest that climate change is a result of human activities. Moreover, Derbile et. al., (2016) and Appiah et. al., (2018) attribute the causes of climate change in Ghana to human activities such as deforestation and land degradation. They explain that bad farming practices and bush burning are specific activities that lead to deforestation and land degradation and hence climate change. However, in terms of perception, Callo-Concha (2018), notes that farmers associate supernatural forces such as curses from smaller gods/ancestors as factors propelling climate change.

However, available evidence also suggests that smallholder farmers may not understand climate change, especially regarding its causes, the same as researchers and policymakers (Magni, 2017), though they may feel its associated effects through changes in their livelihoods (Gyampoh et al., 2009). A study by Theodory (2016) supports this claim. He argues that smallholder farmers become aware of climate change because they exploit the natural capital for livelihood. What this implies is that farmers in the rural areas in most developing countries derive their livelihoods from primary production activities such as farming, hunting or lumbering which are vulnerable to climate change. Another school of thought Nzeadibe et al., (2011) and ALP (2013) maintains that smallholder farmers are not very ignorant about climate change issues as argued by some scholars. They contend that farmers have been forecasting the weather long before the emergence of climate change as a global concern. Through this, the mass media and Civil Society Organisations are now building on indigenous knowledge to enable farmers to observe and predict climate change.

Furthermore, Marrakesh (2016) explains that smallholder farmers can use their cultural practices (guided by indigenous knowledge) to forecast the weather and can guide their daily production decisions as a response strategy to climate change. Consistent with this position, Manyani et al., (2017) study in Zimbabwe show that local practices may be used to determine the timing of important agricultural activities such as ploughing and planting. These traditional practices may be based on conjecture and are not supported by statistical tests (Callo-Concha, 2018). Supportively, others argue that, all over Africa, local practices serve as a viable tool in food crop productions (Mofongoya & Ajayi, 2017). Primarily, farmers can observe and forecast the nature of the changing environment and take decisions towards managing their farms (MFCS, 2014; Saitabau, 2014). Marrakesh (2016) adds that it may occur through observation of the "biophysical entities including the stars, winds, livestock, insects, birds, trees and wildlife" In Malawi, South Africa, Tanzania, Uganda, Zambia and Zimbabwe, Mofongoya and Ajayi (2017) find that traditional methods such as tree phenology, animal behaviour and astronomical observation are the basis of a seasonal weather forecast. In Senegal, local practices have been proven to be critical in improving the quality of climate forecasting services for farmers (Vermeulen & Dinesh, 2006). As indicated earlier, the review of the aforementioned studies, suggest that the causes of climate change, awareness of smallholder farmers about the causes of the climate change, the challenges posed by climate change to food crops production as well as smallholder farmers' perceptions of causes of climate change are somehow known in the literature. Therefore, what remains less known is how smallholder farmers navigate the complexities posed by climate change towards food crops production through the use of local practices and how such practices sustain improvement in food crops production. The next section provides a further conceptual understanding of local practices as a tool for climate change adaptation.

2.2 Local knowledge and practices for adapting to climate change

Local knowledge is synonymous with the culture or indigenous practices of a group of people that have been handed down from generation to generation (Nahashima et al 2012; Otero, 2011; Ngenwi, 2011). This means that the cultures, values, norms and beliefs of farmers are tied to indigenous knowledge, which often manifests through practice. "Local knowledge refers to the knowledge and know-how that has been accumulated across generations, which guide human societies in their innumerable interactions within their surrounding environments" (Nahashima et al. 2012). Therefore, the term does not only connote current practices but also include those

that have been practised sometimes in the past. Theodory (2016) agrees with this perspective about local knowledge but maintains that the concept includes daily practices of indigenous people, learning and lessons regarding their lives. Such experiences shape water conservation and soil management practices in farming as well as knowledge in the systems of farming.

Kpadonou et al. (2012) indicate that climate discussions have assumed a global dimension and larger in context while the benefits associated with adaptation and mitigation efforts affect local communities and rural livelihoods. Farmers have noted the diversity of climate change impact and thereby develop their local response strategy in multifaceted ways (Callo-Concha, 2018). The main indigenous strategies/approaches developed fall under adaptation and or mitigation (Saitabau, 2014; Marrakesh, 2016; Mofongoya & Ajayi, 2017). According to Nzeadibe et al. (2011), adaptation is a proactive process because it envisages possible future changes in the climate. Adaptation is associated with ones' preparedness towards managing climate change-related risk on food crops production (Nzeadibe et al. 2011). Indigenous knowledge in practice contributes to the co-creation of farm-led knowledge on climate change adaptation (Mofongoya & Ajayi, 2017). It strengthens adaptation measures in multiple ways; by providing a wealth of observation and insight beyond the power of external experts, embedding solutions in local cultures and broadening the values and viewpoints of stakeholders (Vermeulen & Dinesh, 2006). Several empirical studies have acknowledged the potentials of indigenous practices in fostering farmers ability to adapt to climatic shocks and stressors (Audefroy and Sanchez 2017; Ajani et al. 2013; Kpadonou et al. 2012, Saitabau 2014; MoSTE 2015). This suggests that indigenous practices perhaps hold some potential for sustaining rural livelihoods even without the integration of scientific technologies.

Most studies have also pointed out how adaptation measures have manifested in resource management and subsistence agricultural practices (Saitabau, 2014; Antwi-Agyei, et al., 2018; ALP, 2013; Saah, 2015; Nyantakyi-Frimpong, 2013). Studies suggest that intercropping serves as the main indigenous adaptation strategy for food crops productions (Garutsa et al. 2018). In Mutoko (Zimbabwe), farmers substituted maize cultivation with millet and sorghum, which increased their farm yield, and reduce their level of vulnerability to climate change (Mugambiwa, 2018). Theodory (2016) notes that practices such as the cultivation of crops in wetlands facilitate food crops production in drought-prone regions and help farmers adapt to the short-term rainfall pattern. In Nigeria, regular weeding of cropped farmlands, early planting of crops such as maize and cassava, preservation and selection of seeds of next planting season are some of the adaptive measures identified by Nzeadibe et al. (2011). According to Gyampoh et al. (2009), farmers in Ghana cultivate food crops that thrive well under prevailing conditions. In Northern Ghana, farmers preferably cultivate traditional crop varieties as opposed to hybrid or synthetic ones because of perceived suitability to the local conditions (Nyantakyi-Frimpong, 2013). Consistent with these observations, Saitabau (2014) reports that farmers in Loita Maasai have maintained the indigenous strain of livestock which they believed can survive prolonged dry conditions. This implies that different ecological zones have specific indigenous practices that have been used as adaptation strategies.

Furthermore, local practices such as mulching, kraal manure, among others are measures adopted by some farmers against climatic events such as drought and shortening rainfall patterns (Mugambiwa, 2018; Nzeadibe et al., 2011; Rankoana, 2006; Dakyaga et al., 2020). The practice of agroforestry as both mitigation and adaptation strategy has been found essential in building food crops adaptation to climate change (Appiah et al. 2018; Mngumi, 2021). Most farmers recognize the importance of having trees on their farms to shade crops from intense sunshine (Dakyaga et al., 2020; Adolph et al., 2020). Some of the widely adapted measures identified in the Niger Delta Region of Nigeria include; the cultivation of cover crops like a melon for soil moisture conservation, zero tillage to limit the exposure of the soil (Nzeadibe et al., 2011).

With regards to water shortage, indigenous knowledge practices water management through the creation of temporary walls on riverbanks and stone bonds to conserve water (Mugambiwa, 2018; Dakyaga et al., 2020). The adoption of water conservation measures is in response to a reduction of soil fertility and the occurrence of erratic rainfall and drought (MFCS, 2014). In conclusion, the potentials of local knowledge and practices concerning food crops productions are somehow known in the literature from the Sub-Saharan African context. However, what remains less known in literature is how smallholder farmers navigate the complexities or challenges arising from climate change through the use of local practices and how such an attempt sustains improvements in food crops' productions.

3. Study Settings And Methods

3.1 Study area

The study was conducted in the Wa East District, located in the South-Eastern part of the Upper West Region of Ghana. The district shares boundaries with West Mamprusi to the northwest, West Gonja to the south-east and the Sissala East district to the north (Ghana

Statistical Service, 2014). The area has a landmass of about 4297.1 sq/ km², and it is located between latitudes 9° 55" N and 10° 25" N and longitude 1° 10" W and 2° 5" W. Fig. 1 shows a map of the district and the communities studied.

Similar to most communities in northern Ghana, the climate of the Wa East district is characterized by the guinea savannah, which experiences both hot and wet seasons within a year. The district is also characterized by high annual temperatures ranging between 22 °C and 42 °C. The single rainfall pattern occurs between May to October. This rainfall pattern limits all-year-round food crop production. The vegetation is made up of scattered trees, shrubs and grasses. The common tree species found included shea, baobab, kapok, Dawadawa, acacia, neem, ebony, mangoes, cashew and ache apple. The economy of the district has three major sectors (agriculture, industry and services). Agriculture engages (85%) of the workforce, industry (10%) and the services sector (5%). Food crop production is the major activity of the majority of inhabitants in the district. About (96%) of the farmers in the district are subsistence food crop producers and the major crops cultivated include sorghum, yam, millet, maize, cowpea, groundnuts, rice, soya beans, cowpea, cassava and vegetables (Ghana Statistical Service, 2014).

3.2 Material and methods

A mixed approach was used to examine how smallholder farmers navigate the complexities or challenges arising from climate change with the use of local practices and how such practices sustain food crop productions in their communities. Both quantitative and qualitative data were collected for the study through households' surveys, in-depth interviews, Focus Group Discussions (FGD). The mixed-method was useful for a descriptive and in-depth exploration of local practices. A three-stage multi-stage sampling procedure was used to select the study communities for the study. The first stage involved the selection of local government areas (district within the region). The aim was to select a district dominated by smallholder farmers and where residents are actively engaged in food crops farming. Therefore, the Wa East district was selected. The second stage involved the selection of communities more dominated by smallholder farmers in the selected district. Concerning this, six (6) communities were purposively selected including *Loggu, Bunaa, Bulenga, Tissaa, Baayiri and Kundugu* towards the households' sampling and the data collection.

A total of 196 smallholder farmer households were surveyed out of the district population of 89,194 (GSS, 2020. Projections), comprising 13,352 households. The six studied communities have a total farmer household of 1,401, with an average size of 6.6. Households were disproportionately sampled for the study (This is presented in Table 1).

Table 1
Basic characteristics of the study population

Study communities	Population	households	sampled households
Loggu	1,199	182	24
Bunaa	1,179	179	23
Bulenga	1,224	185	27
Tiisaa	1,749	265	32
Baayiri	1,550	235	40
Kundugu	2,344	355	50
Total	9,245	1,401	196
Source: Estimate data based on GSS (2014) report.			

The Ghana Statistical Service (2014) reports that 85% of households in the study communities- *Loggu, Bunaa, Bulenga, Tissaa, Baayiri and Kundugu* were engaged in food crops farming. The representativeness of the 196 households was determined using Panneerselvam (2007) sample size determination formula

$$n = \frac{Z^2 * P(1 - P)}{M^2}$$

Where;

n = required sample size

Z = confidence level at 95% (standard value of 1.96)

P = estimated prevalence of respondents in the population

M = margin of error at 5% (standard value of 0.05)

The value of P (percentage of households in agriculture in the Wa East District) is 85%. Hence the sample size is:

$$n = \frac{1.96^2 * 0.85(1 - 0.85)}{0.05^2}$$
$$n = \frac{3.8416 * 0.1275}{0.0025}$$
$$n = 196$$

Sample size = 196 farmer household.

A household's survey was conducted with 196 randomly selected farmer households. Heads of households and persons directly engaged in food crops farming were targeted. In each of the selected communities, households were randomly approached for the survey. However, on occasions where no head of household or persons engaged in food crop productions was found, the next household was randomly approached for the survey. Throughout the survey, the semi-structured interview guide comprised closed and open-ended questions. These were used to unearth the practices of smallholder farmers and the associated navigations towards climate change adaptation, and for sustaining improvement in food crops production. Field data was gathered on the demographic characteristics of households, the various local practices of smallholder farmers, the challenges farmers encounter with the use of local practices towards adapting food crops' production to climate change. The study also questions smallholder farmers whether they are a possibility of the use of local practices to sustain improvement in food crops production now and in the future. The essence of this question was to draw smallholder farmers' experiences and understanding of the local practices concerning future food crops' production.

An in-depth interview was conducted with three (3) leaders of farmer groups. These elderly farmers were purposively selected based on their experiences and long-term engagement in food crop farming in the study communities. Data was collected on local practices they have utilized over the years, the challenges they have observed with the use of such practices for food crops production, and their perceived possibility of the existing practices to sustain improvement food crops production now and in the future.

In addition, Focused Group Discussions were also conducted with three (3) farmer groups in the selected communities to complement the household surveys and the data gathered through the in-depth interviews. The FGDs were conducted in Loggu, Bulenga and Kundugu due to the existence of farmer-based groups. The interviews validated the data collected from the households' surveys and that of the in-depth interviews collected from key informants. Data was collected on the various local practices of smallholders that enable adaptation to climate change, the challenges they face with the use of local practices towards adapting food crops production to climate change, and the possibility of local practices to sustain food crops production.

The data was collected between 10th February to 8th April 2018. The data collection process was assisted by three Research Assistants (RA), native speakers of Waala, Dagaare, and Sisaala (the dominant local languages spoken in the study communities). The qualitative data were analysed thematically. The quantitative data collected were edited, coded and processed with SPSS spreadsheet version 21. Descriptive and inferential statistics/cross-tabulation were used to differentiate the use of the local practices among the socio-economic groups of farmers studied. Chi-tests were conducted to determine the association between the use of the various local practices by smallholders' farmers and sustainable improvement in food crops' production. Cross-tabulation analyses were conducted to examine the differences among smallholder farmers in terms of practices undertaken and the complexities that smallholder farmers encounter with the use of local practices for food crops production. The two forms of data were integrated, to harness their synergies (Creswell, 2014). Ethical clearance for field study was obtained from Wa East District Assembly, and the University of Stuttgart, Germany in January 2018 for the conduct of field studies for a Master dissertation undertaken, at the University of Stuttgart, Germany.

4. Results And Discussion

4.1 Demographic characteristics of the respondents

From the household's surveys, the majority (75%, Table 2) of the respondents were males as presented in Table 2. Just a few females were found as household heads. This limited the study in obtaining perspectives from female-headed households' farmers. Besides, most of the respondents were married (85%), Table 2. In terms of ethnicity, most of the respondents were Waalas, who were affiliated with the Islamic religion. The gender distribution also implies that decisions making regarding the practice to adapt food crops production to climate change were taken mostly by males in the district. The results suggest that local practices towards food crops production in the district were shaped by the culture of the dominant ethnic group, the Waalas. Because local practices are more or less tied to the culture, values, norms and beliefs of smallholder farmers (Nahashima et al (2012; Theodory 2016; Otero 2011; Ngenwi (2011). In the study communities with diverse values, beliefs and norms, the beliefs, values and norms of the dominant ethnic group, in turn, shape the practices of the engaged group of farmers and manifest and utilize as a collective whole. Concerning finding this study, the Waalas who constituted the major ethnic group influenced the practices, values, norms that smallholder farmers applied towards adapting food crops productions to climate change. The findings also suggest that the beliefs and the practices of the few ethnic groups are in turn submerged by that of dominant groups of farmers.

Table 2
Demographic characteristics of the respondents

<i>Variable</i>	<i>Frequency</i>	<i>Per cent</i>
Gender		
<i>Female</i>	49	25.0
<i>Male</i>	147	75.0
Marital status		
<i>Single</i>	13	6.6
<i>Married</i>	167	85.2
<i>Divorced</i>	8	4.1
<i>Widowed/Widower</i>	8	4.1
Ethnicity		
<i>Waala</i>	137	69.9
<i>Dagaare</i>	49	25.0
<i>Sissala</i>	10	5.1
Religion		
<i>Christianity</i>	40	20.4
<i>Islam</i>	153	78.1
<i>Traditional African Religion (TAR)</i>	3	1.5
Total	196	100
<i>Source: Field Survey (2018)</i>		

In terms of age, the modal age of most of the respondents was 36 depicting the prevalence and the engagement of the younger and active labour in food crops production in the studied communities. On education, most of the respondents had basic level education with an average of 8.92 years of formal education experiences and training which perhaps informs their reliance on local practices due to less exposure to modern farming practices and technological innovations. Moreover, the study also realized that respondents obtained a greater proportion of their income from farming activities as their main livelihood activities, suggesting the relevance of food crops productions to the livelihood of residents in the study communities.

4.2 Local practices of smallholder farmers for adapting food crops' production to climate change

Farmers engaged in multiples and wide ranges of local practices towards adapting food crops production to climate change. These included changing the planting times of food crops, the cultivation of local/traditional crops varieties, maintaining a balance between food crop production and livestock and poultry rearing, reducing farm size amongst others. Whereas these practices have also been observed elsewhere in Sub-Saharan Africa (Mugambiwa, 2018; Nzeadibe et al., 2011; Rankoana, 2006; Dakyaga et. al., 2020), our findings suggest that variation often exists across the ages, sex and religious affiliations of smallholder farmers in terms of the adoption and usage of these practices towards adapting food crops production to climate change. Whilst most farmers (86.7%) utilized local practices towards adapting food crop production to climate change, particularly the short-term pattern of the rainfall by practising early cultivation of food crops, younger smallholder farmers particularly between the ages of 19 and 48 were the dominant group of farmers actively engaged in all the local practices towards adapting food crop productions to climate change. Elderly smallholder farmers though might have accumulated experiences were less actively involved in local practices. This implies that younger farmers might have acquired such knowledge and experiences from the elderly farmers over the years. Also, more males were engaged in local practices for climate change adaptation compared to females. This might have been shaped by the domination of males in terms of decision-making regarding food crop production in the rural communities (Nyantakyi-Frimpong, 2019). As indicated earlier, the dominant religious group such as the Muslims were the dominant group of smallholder farmers engaged in local practices. The findings suggest that, beyond the commonly reported utilization of local practices, there are usually remarkable variations in terms of socio-economic groups which has often been ignored in the climate change and local practices' reportage. As disclosed by a farmer, *"Because of the change in rainfall pattern, we now plant early maturing crops, change in the time of planting, planting of okra. We now rear a lot of livestock than before. We also sell cooked food to support the farm income"* (March 2018 an In-depth interview with the women group leader at Buffiama). This finding confirms Kom (2020) observations where smallholder farmers engage in the early planting of food crops to adapt to the changes in climate and for early harvesting. In effect, the finding demonstrates more or less the commonalities of these local practices across geographies, particularly, within the African continent (As shown in Table 3).

Table 3
Local practices towards adapting food crops production to climate change

Local practices		Age of farmers				Sex		Religion		
		19-33	34-48	49-63	64-78	Male	Female	Christianity	Islam	TAR
Change in planting date	Count	76	83	10	1	126	44	38	129	3
	Expected	78.1	79.8	9.5	2.6	127.5	42.5	34.7	132.7	2.6
Cultivation of local crops varieties	Count	70	83	8	3	125	39	32	129	3
	Expected	75.3	77.0	9.2	2.5	123	41	33.5	128	2.5
Shifting cultivation	Count	35	28	2	1	49	17	16	50	0
	Expected	30.3	31.0	3.7	1.0	49.5	16.5	13.5	51.5	1.0
Balancing between food crop farming and livestock production	Count	6	9	6	0	18	3	2	17	2
	Expected	9.6	9.9	1.2	0.3	15.8	5.3	4.3	16.4	0.3
Reduction in farm size	Count	20	22	3	1	36	10	11	35	0
	Expected	21.1	21.6	2.6	0.7	34.5	11.5	9.4	35.9	0.7
Increasing cultivated areas	Count	9	4	0	0	9	4	0	13	0
	Expected	6.0	6.1	0.7	0.2	9.8	3.3	2.7	10.1	0.2
Use of irrigation	Count	16	20	4	0	37	3	2	38	0
	Expected	18.4	18.8	2.2	0.6	30.0	10	8.2	31.2	0.6
Use of shade and shelters	Count	22	33	4	0	37	12	11	38	0
	Expected	22.5	23.0	2.8	0.8	36.8	12.3	10.0	38.3	0.8
Rural-urban migration	Count	32	24	7	0	59	4	16	45	2
	Expected	28.9	29.6	3.5	1.0	47.3	15.8	12.9	49.2	1.0
Off-farm jobs	Count	56	52	11	0	108	11	21	98	0
	Expected	54.6	55.9	6.7	1.8	89.3	29.8	24.3	92.9	1.8
Increase in faith and Prayer	Count	27	33	3	0	47	16	15	46	2
	Expected	28.9	29.6	3.5	1.0	47.3	15.8	12.9	49.2	1.0
Use of manure	Count	56	52	2	0	86	24	19	89	2
	Expected	50.5	51.6	6.2	1.7	82.5	27.5	22.4	85.9	1.7
<i>Source: Field Survey (2018).</i>										

The findings also suggest that smallholder farmers rely on off-farm practice, particularly rural-urban migration through which they earn income to augment their farm produce (Sullo et al., 2020). Again, this practice was more engaged in by the young and active labour force. As disclosed in the course of the FGD, *"Some of the young ones now migrate to the city to find other jobs. We also shift the farms very often to different locations. We apply fertilizer to some of the crops too"* (March 2018 an In-depth interview with the women group leader at Jankore). In addition to these practices, farmers collected and developed stones bonds as soil water conservation practices which they acquired through experiences and as generational knowledge and local practices. In addition, collected stones were sold for income to augment food crops production. Discussants demonstrated the use of this practice as follows; *"We also collect stones during the dry season and sell to developers and building contractors to support our annual farm harvest"* (March 2018 an In-depth interview with the women group leader at Holomuni). These indigenous practices were applied by farmers in different places as confirmed by related past studies such as Odero (2011), Ngenwi (2011), Saitabau (2014), Antwi-Agyei, et al. (2018). The results of these studies are consistent with the empirical observation reported by this study.

4.3 Complexities with the use of local practices for adapting food crops production to climate change

Having revealed the varied local practices that smallholder farmers utilize towards adapting food crops productions to climate change, here we demonstrate the various complexities that smallholder farmers encounter with the use of local practices for adapting food crops production to climate change in their everyday engagement. The study revealed that whilst local practices have been useful for adapting food crops production to climate change the practices are not without challenges (As presented in Table 4). From the household's surveys, increasing incidences of bushfires, the depletion of water resources, limitations of arable lands as well as the diminishing in the adoption of local practices were found as drawbacks to the use of local practices for food crops production. Moreover, these challenges were socio-demographically associated among smallholder farmers studied. Specifically, rampant bushfires, limited arable land and the depletion of water resources were disclosed as major hindrances to the short-term pattern of rainfall, shifting cultivation and engaging in dry season gardening. Others included the extinction of indigenous practices due to the advent of modern farming practices and farm inputs and the reduction of livestock and poultry rearing, whose droppings usually serve as manure and input for the preparation of compost. As observed elsewhere, our study revealed that the extinction of local practices in the study communities is due to improper dissemination of local practices concerning food crops production, due to poor knowledge sharing culture among the present generation (Manyani et al. 2017; Mafongoya and Ajayi, 2017).

Table 4
Complexities with the application of local practices

Background		Rampant bushfires	Extinction of knowledge	Extreme farming practices	Limited arable land	Depletion of water resources	No idea	Total
Age								
19-33	Count	9	8	3	11	11	46	90
	Expected	6.4	9.6	3.7	11.0	11.5	46.4	90.0
	%	64.3	38.1	37.5	45.8	44.0	45.5	45.9
34-48	Count	5	11	4	11	14	47	92
	Expected	6.6	9.9	3.8	11.3	11.7	47.4	92.0
	%	35.7	52.4	50.0	45.8	56.0	46.5	46.9
49-63	Count	0	1	1	2	0	6	11
	Expected	0.8	1.2	0.4	1.3	1.4	5.7	11.0
	%	0.0	4.8	12.5	8.3	0.0	5.9	5.6
64-78	Count	0	1	0	0	0	2	3
	Expected	0.2	0.3	0.1	0.4	0.4	1.5	3.0
	%	0.0	4.8	0.0	0.0	0.0	2.0	15
Sex								
Male	Count	12	18	6	18	14	76	147
	Expected	10.5	15.8	6.0	18.0	18.8	75.8	147.0
	%	8.2	12.2	4.1	12.2	9.5	51.7	75.0
Female	Count	2	3	2	6	11	25	49
	Expected	3.5	5.3	2.0	6.0	6.3	25.3	49.0
	%	4.1	6.1	4.1	12.2	22.4	51.0	25.0
Marital Status								
Married	Count	10	18	7	24	21	84	167
	Expected	11.9	17.9	6.8	20.4	21.3	86.1	167.0
	%	6.0	10.8	4.2	14.4	12.6	50.3	85.2
Single	Count	2	0	0	0	2	9	13
	Expected	0.9	1.4	0.5	1.6	1.7	6.7	13.0
	%	15.4	0.0	0.0	0	15.4	69.2	6.6
Divorced	Count	2	2	0	0	0	4	8
	Expected	0.6	0.9	0.3	1.0	1.0	4.1	8.0
	%	25.0	25.0	0.0	0	0.0	50.0	4.1
Widowed	Count	0	1	1	0	2	4	8
	Expected	0.6	0.9	0.3	1.0	1.0	4.1	8.0
	%	0	12.5	12.5	0.0	25.0	50.0	4.1

Source: Field Survey, (2018).

As disclosed in the course of FGD; *"We use to have so much water flowing through our rivers, but it is now less because of the reduced rainfall pattern. There is now a lot of bush fires and overgrazing by the Trans-Nomadic farmers" (March 2018, leader of the women group at Jankore)"* (Table 5). The discussants further revealed that few farmers cultivated a local variety of guinea corn and millet due to their late maturity nature and the rising incidences of bush fires in their communities.

4.4 Farmers' perceived possibility of sustainable improvement in food crops productions

In this section, we present farmers' perceptions about the sustainability of food crops production via the use of local practices. Thus, the perceived guarantee of improving food crop yields over the years through the use of local practices. By analyzing the varied local practices of smallholder farmers that mediate food crops productions, our findings suggest that most smallholder farmers (70%) were optimistic about the possible sustainability of food crops production via the use of local practices in the future. However, about 30% of the smallholder had low confidence in the capability of local practices to sustain improvement in food crop productions.

Moreover, following the analysis, the local practices found included the changes in planting dates, planting of local crops varieties by smallholders to adapt to changes in the weather, and shifting cultivation amongst others. However, whilst most farmers were optimistic about future improvement in food crops production through the use of local practices, not all the local practices were found relevant in shaping sustainable improvement in food crops production. Instead, the variation in the planting date of food crops was found significant with farmers perceived sustainable improvement in food crops farming. *"We have noticed that when we plant early maturing crops, and as well delay in the planting date, we get improved yield" (Leader of the farmer group Kundugu, April 2018)*. About, 67.1% of the respondents adopted the variation of planting dates and disclosed to have observed some level of improvements in food crops yields and more optimistic of future improvements. The chi-square test reveals a test value of 4.910 which is significant at 5% (P-value < 0.05). The results also revealed that the planting of local crops by farmers has a significant influence on their farm outputs (see Table 5).

Table 5
Local practices and improvement in farming

Local knowledge/Practices	Possibility of sustaining improvement in food crop production for the future		Total (100%)	Chi-square	P-value
	Yes (%)	No (%)			
Change in planting date	23 (88.5)	3 (11.5)	26	4.910	0.018**
Planting of local crops	18 (56.2)	14 (43.8)	32	3.386	0.054*
Variations of plots	89 (68.5)	41 (31.5)	130	0.379	0.328
balancing between food crops farming and livestock	126 (72)	49 (28.0)	175	3.430	0.058*
Reduction in cultivated land	110(73.3)	40(26.7)	150	3.585	0.045**
Increase in cultivated land	124(67.8)	59(32.2)	183	5.996	0.008***
Use of irrigation	112(71.8)	44(28.2)	156	0.254	0.171
Use of shades and shelters	103(70.1)	44(29.9)	147	0.008	0.531
Rural-urban migration	104(78.2)	29(21.8)	133	13.540	0.000***
Off-farm jobs	59(76.6)	18(23.4)	77	2.726	0.067*
Increase in faith and prayer	94 (70.7)	39 (29.3)	133	0.119	0.426
Use of manure	54 (62.8)	32 (37.2)	86	3.679	0.039**
*, **, and ***, represent significance at 0.1, 0.05, and 0.001 level					

Source: Field Survey (2018).

Farmers engaged in both food crops' production and livestock and poultry rearing were optimistic of attaining sustainable improvement in food crops production also in the future. As disclosed by a key informant, "When we keep livestock in addition to the crop farming, we are better off than only farming, we can sustain ourselves and become sufficient" (March 2018, leader farmer group at Loggu). Other practices with the possibility of improving food crops production included a reduction in cultivation areas, that enables adequate management of the farm/plants and the application of the scarce manure, rural-urban migration through which income is obtained to purchase farm inputs (Table 4). Moreover, these local practices were never panaceas but rather requires the careful application to attain the desired output. However, local practices such as the use of shades and shelter, and rising faith and praying to God were not significant practices that can sustain improvement in food crops yields over the years.

5. Conclusions

This study examined how smallholder farmers navigate complexities that arise from climate change towards sustainable food crops production. We contribute to climate change and local knowledge debate by examining the various local practices smallholder farmers utilize, the challenges they encounter and the sustainability of such practices towards sustaining improvement in food crops production. By drawing a review on local practices and climate change, we contribute to existing scholarly debates on local knowledge and climate adaptation in Sub-Saharan Africa. Our findings suggest that smallholder farmers encounter multiple challenges that range from increasing incidences of bushfires, extinction of local practices to limited arable amongst others. These challenges limited smallholder farmers' ability to adapt food crops production to climate change through the use of local practices. Even where multiple practices are used, such as switching between food crops farming and livestock rearing, reducing cultivatable land size amongst others, only the increment in farm size, the use of remittances from rural-urban migrations to support food crops production, and early cultivation offer possibility of sustaining improvement in food crops production of farmers in the future. Therefore, we conclude that local practices are not necessarily panaceas for sustaining food crops production under climate change. The study recommends for policy-makers to pay attention to evolving alternatives that may enable smallholder farmers to adapt food crops productions in the future.

Declarations

Compliance and Ethical clearance

The study obtained ethical clearance prior to the field data collection from the Wa East District Assembly, and the University of Stuttgart, Germany in January 2018. In addition, informed consent was sought from each respondent and confidentiality assured before the conduct of interviews.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon request.

References

1. Ajani EN, Mgbenka RN, Okeke MN. (2013). *Use of Indigenous Knowledge as a Strategy for Climate Change Adaptation among Farmers in sub-Saharan Africa : Implications for Policy*. 2(1), 23–40.
2. Adolph B, Allen M, Beyuo E, Banuoku D, Barrett S, Bourgou T, Bwanausi N, et al. Supporting Smallholders' Decision Making: Managing Trade-Offs and Synergies for Sustainable Agricultural Intensification. *Int J Agric Sustain*. 2020;0(0):1–18. <https://doi.org/10.1080/14735903.2020.1786947>.
3. Alexander C, et al. (2011). Linking Indigenous and Scientific Knowledge of Climate Change. *American Institute of Biological Sciences, University of California Press's Rights and Permissions*; 61: 477–484. ISSN 0006-3568, electronic ISSN 1525-3244. . doi:10.1525/bio.2011.61.6.10.
4. ALP. (2013). Climate Change Vulnerability and Adaptive Capacity in Northern Ghana. Adaptation Learning Programme. CARE International, <http://www.careclimatechange.org/adaptation-initiatives/alp>.
5. Antwi-Agyei P, Dougill AJ, Stringer LC. (2013). Barriers to climate change adaptation in sub-Saharan Africa: evidence from northeast Ghana & systematic literature review. Sustainability Research Institute, Paper No. 52. *Centre for Climate Change Economics and Policy, Working Paper No. 154*. <http://www.see.leeds.ac.uk/sri>. <http://www.ccecp.ac.uk>.
6. Antwi-Agyeia P, Dougill AJ, Stringer LC, Codjoe SNA. (2017). Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. *Climate Risk Management*. ScienceDirect. Published by Elsevier B.V.

- <https://doi.org/10.1016/j.crm.2017.11.003>. . <http://creativecommons.org/licenses/by-nc-nd/4.0/>.
7. Appiah DO, Akondoh ACK, Tabiri RK, Donkor AA. Smallholder farmers' insight on climate change in rural Ghana. Food Science & Technology | Research Article. Cogent Food Agriculture. 2018;4:1436211. <https://doi.org/10.1080/23311932.2018.1436211>.
 8. Audefroy JF, Sánchez BNC. (2017). Integrating Local Knowledge for Climate Change Adaptation in Yucatan, Mexico, International Journal of Sustainable Built Environment, doi: [http:// dx.doi.org/10.1016/j.ijsbe.2017.03.007](http://dx.doi.org/10.1016/j.ijsbe.2017.03.007).
 9. Adenle AA, Manning DT, Arbiol J. Mitigating climate change in Africa: Barriers to financing low-carbon development. World Dev. 2017;100:123–32. <https://www.sciencedirect.com/science/article/abs/pii/S0305750X17302620>.
 10. Amoutchi AI, Mehner T, Ugbor ON, Kargbo A, Paul KE. (2021). Fishermen's perceptions and experiences toward the impact of climate change and anthropogenic activities on freshwater fish biodiversity in Côte d'Ivoire. Discover Sustainability, 2(1). <https://doi.org/10.1007/s43621-021-00062-7>.
 11. Baffour-Ata F, Antwi-Agyei P, Apawu GO, Nkiaka E, Amoah EA, Akorli R, Antwi K. Using traditional agroecological knowledge to adapt to climate change and variability in the Upper East Region of Ghana. Environmental Challenges. 2021;4(May):100205. <https://doi.org/10.1016/j.envc.2021.100205>.
 12. Basdew M, Jiri O, Mafongoya PL. Integration of indigenous and scientific knowledge in climate adaptation in KwaZulu-Natal, South Africa. Change Adaptation in Socio-Ecological Systems. 2017;3(1):56–67. <https://www.degruyter.com/view/journals/cass/3/1/article-p56.xml>.
 13. Baruah UD, Saikia A, Robeson SM, et al. Perceptions and adaptation behavior of farmers to climate change in the upper Brahmaputra Valley, India. Environ Dev Sustain. 2021;23:15529–49. <https://doi.org/10.1007/s10668-021-01309-z>.
 14. Callo-Concha D. (2018). Farmer Perceptions and Climate Change Adaptation in the West Africa Sudan Savannah: Reality Check in Dassari, Benin, and Dano, Burkina Faso Climate, 6(44); doi:10.3390/cli6020044. .
 15. Creswell JW. (2014). Qualitative, Quantitative and Mixed Method Approach to research Design. Fourth edition. Sage Publication.
 16. Dakyaga F, Derbile EK, Naazie GK, Tampulu SF, Banuoku DF, Beyuo E, ... Gubbels P. (2020). *Trade-offs in sustainable intensification Ghana country report About the authors*.
 17. Dayour F, Yendaw E, Jasaw G. (2014). *Local Residents' Perception and Adaptation/Coping Strategies To Climate Induced Disasters in Bankpama, Wa West District, Ghana*. (FEBRUARY).
 18. de Andrade LC, Borges-Pedro JP, Gomes MCRL, Tregidgo DJ, do Nascimento ACS, Paim FP, ... do Amaral JV. (2021). The sustainable development goals in two sustainable development reserves in central amazon: achievements and challenges. *Discover Sustainability*, 2(1). <https://doi.org/10.1007/s43621-021-00065-4>.
 19. Derbile EK, Adams M, Yakubu I. Local Knowledge and Community–Based Assessment of Environmental Change in Ghana. J Geogr. 2016;8(2):pp.; 59–83.
 20. Di Falco S, Veronesi M, Yesuf M. 'Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia'. Am J Agr Econ. 2011;93:829–46.
 21. Dillon A, Mueller V, Salau S. 'Migratory Response to Agricultural Risk in Northern Nigeria'. Am J Agr Econ. 2011;93:1048–61.
 22. Dube E, Munsaka E. The contribution of indigenous knowledge to disaster risk reduction activities in Zimbabwe: A big call to practitioners. Jambá: Journal of Disaster Risk Studies. 2018;10(1):1–8. http://www.scielo.org.za/scielo. .php?script=sci_arttext&pid=S1996-14212018000100007.
 23. Eugene Climate and Energy Action Plan Glossary. Climate Variability. Oregon: City of Eugene; 2016.
 24. File DJM, Derbile EK. Sunshine, temperature and wind: Community risk assessment of climate change, indigenous knowledge and climate change adaptation planning in Ghana. Int J Clim Change Strateg Manag. 2020;12(1):22–38. <https://doi.org/10.1108/IJCCSM-04-2019-0023>.
 25. Fitton JM, Addo KA, Jayson-Quashigah PN, Nagy GJ, Gutiérrez O, Panario D, ... Stempel P. (2021). Challenges to climate change adaptation in coastal small towns: Examples from Ghana, Uruguay, Finland, Denmark, and Alaska. Ocean Coast Manag, 212(March). <https://doi.org/10.1016/j.ocecoaman.2021.105787>.
 26. Food and Agricultural Organization. (2012). Smallholders and Family Farmers. Sustainabilitypathways.http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_SMALLHOLDERS.pdf last access 27th June 2018.
 27. Garutsa TC, Mubaya CP, Zhou L. Gendered differentials in climate change adaptation amongst the Shona ethnic group in Marondera Rural District, Zimbabwe: A social inclusions lens. [Version 1; referees: 1 approved with reservations]. AAS Open

- Research. 2018;1:14. (doi: 10.12688/aasopenres.12826.1).
28. Gyampoh BA, Amisah S, Idinoba M, Nkem J. (2009). Using traditional knowledge to cope with climate change in rural Ghana. *Unasylva* 231/232, Vol. 60, 2009 DOI: https://www.researchgate.net/publication/242072480_Using_traditional_knowledge_to_cope_with_climate_change_in_rural_Ghana.
 29. Goswami R, Saha S, Dasgupta P. Sustainability assessment of smallholder farms in developing countries. *Agroecology Sustainable Food Systems*. 2017;41(5):546–69. <https://doi.org/10.1080/21683565.2017.1290730>.
 30. Guodaar L, Bardsley DK, Suh J. Integrating local perceptions with scientific evidence to understand climate change variability in northern Ghana: A mixed-methods approach. *Appl Geogr*. 2021;130(March):102440. <https://doi.org/10.1016/j.apgeog.2021.102440>.
 31. Haščič I, Silva J, Johnstone N. (2012). Climate mitigation and adaptation in Africa: evidence from patent data. https://www.oecd-ilibrary.org/environment/climate-mitigation-and-adaptation-in-africa_5k8zng5smxjg-en.
 32. Institute of Green Growth Solutions. Climate Change Learning Strategy in Ghana: Background Report. MESTI; 2015.
 33. Issahaku G, Abdulai A. Sustainable Land Management Practices and Technical and Environmental Efficiency among Smallholder Farmers in Ghana. *J Agric Appl Econ*. 2020;52(1):96–116. <https://doi.org/10.1017/aae.2019.34>.
 34. Jindo K, Schut AGT, Langeveld JWA. (2020). *Sustainable intensification in Western Kenya : Who will benefit ?* 182(March). <https://doi.org/10.1016/j.agry.2020.102831>.
 35. Kom Z, Nethengwe NS, Mpandeli NS. (2020). Determinants of small-scale farmers' choice and adaptive strategies in response to climatic shocks in Vhembi District, South Africa. *GeoJournal*. <https://link.springer.com/article/10.1007/s10708-020-10272-7>.
 36. Kpadonou RAB, Adégbola PY, & Tovignan SD. Local Knowledge and Adaptation to Climate Change in Ouémé Valley, Benin. *African Crop Science Journal African Crop Science Society*. 2012;20(2):181. – 192. ISSN 1021-9730/2012 \$4.00.
 37. Laube W, Schraven B, Awo M. Smallholder adaptation to climate change: Dynamics and limits in Northern Ghana. *Clim Change*. 2012;111(3):753–74. <https://doi.org/10.1007/s10584-011-0199-1>.
 38. Maddison D. (2006). *The perception of and adaptation to climate change in Africa*. CEEPA Discussion Paper No. 10. *Centre for Environmental Economics and Policy in Africa*, University of Pretoria, South Africa.
 39. Madsen S, Bezner Kerr R, LaDue N, et al (2021). Explaining the impact of agroecology on farm-level transitions to food security in Malawi. *Food Sec*. 13, 933-954 (2021). <https://doi.org/10.1007/s12571-021-01165-9>.
 40. Mafongoya PL, Ajayi OC. (2017). *Indigenous Knowledge Systems and Climate Change Management in Africa*, CTA, Wageningen, the Netherlands, 316pp. ISBN 978-92-9081-619-5. .
 41. Manyani A, Chagweda K, Muzenda-Mudavanhu C, Chanza N. (2017). Indigenous-Based Practices of Adapting to Climate Change: Reflections from Chirumhanzu, Zimbabwe. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*. e-ISSN: 2319-2402, p- ISSN: 2319-2399. 11(12); PP 54-66, . DOI: 10.9790/2402-1112015466.
 42. Marrakesh M. (2016). *Indigenous Knowledge and Climate Change*. United Nations Educational, Scientific and Cultural Organization. Local and Indigenous Knowledge Systems programme. www.indigenous2016.org.
 43. Mburu BK, Kung'u JB, Muriuki JN. (2015). Climate change adaptation strategies by small-scale farmers in Yatta District, Kenya. *African Journal of Environmental Science and Technology*. 9(9), pp. 712-722, DOI: 10.5897/AJEST2015.1926, 5BD992948228, ISSN 1996-0786. <http://www.academicjournals.org/AJEST>.
 44. MFCS. Multi-features and capacity-enhancing services ltd. In: Climate change and agricultural adaptation measures in the transition zone of mid-Ghana. Final research report. *U.S. Agency for International Development*; 2014.
 45. MoSTE. Indigenous and Local Knowledge and Practices for Climate Resilience in Nepal, Mainstreaming Climate Change Risk Management in Development. In: Ministry of Science, Technology and Environment. Kathmandu, Nepal: MoSTE); 2015.
 46. Mugambiwa SS. (2018). Adaptation measures to sustain indigenous practices and the use of indigenous knowledge systems to adapt to climate change in Mutoko rural district of Zimbabwe, Jambá: *Journal of Disaster Risk Studies* 10(1), a388. <https://doi.org/10.4102/jamba.v10i1.388>.
 47. Mbow C, Smith P, Skole D, Duguma L, Bustamante M. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*. 2014;6:8–14. <https://www.sciencedirect.com/science/article/pii/S1877343513001255>.
 48. Makondo CC, Thomas DS. Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. *Environ Sci Policy*. 2018;88:83–91. <https://www.sciencedirect.com/science/article/abs/pii/S1462901118300418>.

49. Mugambiwa SS. Adaptation measures to sustain indigenous practices and the use of indigenous knowledge systems to adapt to climate change in Mutoko rural district of Zimbabwe. *Jàmábá: Journal of Disaster Risk Studies*. 2018;10(1):1–9. http://www.scielo.org.za/scielo.php?script=sci_arttext. &pid=S1996-14212018000100014.
50. Magni G. (2017). Indigenous knowledge and implications for the sustainable development agenda. *European Journal of Education*, 52(4), 437–47. <https://onlinelibrary.wiley.com/doi/abs/10.1111/ejed.12238>.
51. Mngumi LE. (2021). Socio-ecological resilience to climate change effects in peri-urban areas: Insights from the Pugu and kazimzumbwi forest reserves of Dar es Salaam, Tanzania. *GeoJournal*. <https://link.springer.com/article/10.1007/s10708-019-10071-9>.
52. Nakashima DJ, McLean KG, Thulstrup HD, Castillo AR, Rubis JT (2012). *Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation*. Paris. *UNESCO, and Darwin, UNU*, 120 pp..
53. Mutyasira V. Prospects of sustainable intensification of smallholder farming systems : A farmer typology approach. *African Journal of Science Technology Innovation Development*. 2020;0(0):1–8. <https://doi.org/10.1080/20421338.2019.1711319>.
54. Nyantakyi-Frimpong H. Unmasking difference: intersectionality and smallholder farmers' vulnerability to climate extremes in Northern Ghana. *Gender Place Culture*. 2019;0(0):1–19. <https://doi.org/10.1080/0966369X.2019.1693344>.
55. Ngenwi AA. Climate change and adaptation strategies. lessons from women's indigenous knowledge practices; 2011.
56. Nyantakyi-Frimpong H. (2013). Indigenous Knowledge and Climate Adaptation Policy in Northern Ghana. *Africaportal a project of the Africa initiative*. www.africaportal.org. No. 48.
57. Nzeadibe TC, Egbule CL, Chukwuone NA, Agu VC. (2011). Climate Change Awareness and Adaptation in the Niger Delta Region of Nigeria. African Technology Policy Studies Network; Working Paper Series | No. 57. *African Technology Policy Studies Network. Nairobi Kenya*. ISBN: 978-9966-1552-6-9. <http://www.atpsnet.org>.
58. Odero K. (2011). The role of indigenous knowledge in responding to climate change: local-global Perspectives.
59. Rankoana SA. (2016). Perceptions of Climate Change and the Potential for Adaptation in a Rural Community in Limpopo Province, South Africa Sustainability. 8(672); doi:10.3390/su8080672. .
60. Rusere F, Crespo O, Dicks L, Mkuhlani S, Francis J, Zhou L. Enabling acceptance and use of ecological intensification options through engaging smallholder farmers in semi-arid rural Limpopo and Eastern Cape, South Africa. *Agroecology Sustainable Food Systems*. 2019;0(00):1–30. <https://doi.org/10.1080/21683565.2019.1638336>.
61. Saah DS. Indigenous Knowledge and Adaptations to Climate Change: A Case Study of Agriculture in Selected Communities in the Bosomtwe District. *Kwame Nkrumah University of Science and Technology*; 2015.
62. Saitabau H. Impacts of Climate Change on the Livelihoods of Loita Maasai Pastoral Community and Related Indigenous Knowledge on Adaptation and Mitigation. Nairobi-Kenya: National Museums of Kenya; 2014.
63. Sraku-Lartey M. Harnessing indigenous knowledge for sustainable forest management in Ghana. *International Journal on Food System Dynamics*. 2014;5(4):182–9. <https://doi.org/10.18461/ijfsd.v5i4.543>.
64. Sullo C, King RS, Yiridomoh GY, Doghle K. Indigenous knowledge indicators in determining climate variability in rural Ghana. *Rural Society*. 2020;29(1):59–74. <https://doi.org/10.1080/10371656.2020.1758434>.
65. Shahzad A, Ullah S, Dar AA, et al. Nexus on climate change: agriculture and possible solution to cope future climate change stresses. *Environ Sci Pollut Res*. 2021;28:14211–32. <https://doi.org/10.1007/s11356-021-12649-8>.
66. Tessema I, Simane B. (2020). Smallholder Farmers' perception and adaptation to climate variability and change in Fincha sub-basin of the Upper Blue Nile River Basin of Ethiopia. *GeoJournal*, <https://link.springer.com/article/10.1007/s10708-020-10159-7>.
67. Teklewold H, Kassie M, Shiferaw B. (2013). *Adoption of Multiple Sustainable Agricultural Practices in Rural Ethiopia*. 64(3), 597–623. <https://doi.org/10.1111/1477-9552.12011>.
68. Theodory TF. Dealing with Change: Indigenous Knowledge and Adaptation to Climate Change in the Ngono River Basin, Tanzania. Rheinische Friedrich-Wilhelms-University of Bonn; 2016.
69. Yiridomoh GY, Bonye SZ, Derbile EK, et al. Women farmers 'perceived indices of occurrence and severity of observed climate extremes in rural Savannah, Ghana. *Environ Dev Sustain*. 2021. <https://doi.org/10.1007/s10668-021-01471-4>.
70. Vermeulen S, Dinesh D. (2016). Measures for climate change adaptation in agriculture, Opportunities for climate action in agricultural systems. <http://hdl.handle.net/10568/71051>.
71. Veihe A. Sustainable farming practices: Ghanaian farmers' perception of erosion and their use of conservation measures. *Environ Manage*. 2000;25(4):393–402. <https://doi.org/10.1007/s002679910031>.

Figures

Figure 1

Map of study Areas

Source: Digitized and modified from GSS, 2014.