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Farmers' maladaptation: Eroding sustainable development, rebounding and shifting vulnerability in smallholder agriculture system

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ABSTRACT

Adaptation has become crucial in developing economies due to climate change impact, especially on agriculture, which is the backbone of many economies and the main source of livelihoods and food security. Some adaptation strategies applied in the context of developing countries, however, produce maladaptive outcomes, which are usually ignored in the planning phase of adaptation policies and programmes. This mixed methods study therefore explores adaptation strategies and the associated maladaptation outcomes of smallholder farmers in rural Ghana. The study administered questionnaire survey to 378 farmers and 41 key informants were interviewed. The major adaptation strategies of farmers included crop and livelihood diversification, agrochemicals application, and reduction in the number and size of meals. However, farmers' adaptation strategies result in maladaptation outcomes through the release of greenhouse gases, environmental degradation, and contamination of water bodies as well as resource conflicts and increasing pressure on lands, among others, which affect their capacity to respond to future climate change. Adaptation policy makers and development practitioners should prioritize the minimization of maladaptation outcomes through intensive review and modification of programmes prior to their implementation and extensive education on best practices among smallholder farmers.

1. Introduction

Africa is highly vulnerable to climate change, particularly rising temperature, erratic rainfall, and the associated stressors and shocks such as floods, droughts, pest invasion and loss of crops. High vulnerability in the continent is largely due to overdependence on climate sensitive agricultural economy and low adaptive capacity (IPCC, 2018). Consequently, adaptation has been prioritized by African governments and their development partners to minimize climate change impact in the continent. This is evidenced in the Africa Common Position on Climate Change, which champions a collective African voice for the promotion of climate justice and adaptation. Similarly, Agenda 2063 of the African Union emphasizes the need to adapt to climate change. In smallholder agriculture systems, such as those in Ghana and many African countries, farmers must adapt to erratic rainfall and rising temperature, shocks

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including droughts, floods, pest invasion or risk losing agricultural yields and income (Asare-Nuamah, 2020; Asare-Nuamah and Amungwa, 2021).

Adaptation constitutes “an adjustment to current or anticipated climate change to reduce harm and/or exploit opportunities” (IPCC, 2014). The literature on adaptation categorizes adaptation typologies based on timing and spontaneity of implementation (Bryant et al., 2000; Smit et al., 2000). On the basis of timing of implementation, adaptation can be reactive or anticipatory. Similarly, there are also planned and autonomous adaptation based on spontaneity (Bryant et al., 2000; Smit and Skinner, 2002). Other adaptation categories also center on spatial scope (local or national), form of adaptation (eg. technological or institutional), degree of change (transformative or incremental), intent (planned or autonomous) and timing (reactive, concurrent or anticipatory) (see Biagini et al., 2014; Smit and Wandel, 2006).

Effective implementation of adaptation requires understanding what adaptation is, what is being adapted to, who implements adaptation, how adaptation occurs and the associated outcomes (Bryant et al., 2000). This is necessary to enhance farmers’ adaptive capacity by adopting emerging skills, knowledge and practices to reduce climate change impact (Asare-Nuamah et al., 2019). Effective adaptation recognizes different timeframes within which adaptation occurs: responding to long-term events (climate change), recurring anomalies (climate variability), and sudden, extreme or catastrophic events (drought or floods) (Smit et al., 2000). In sub-Saharan Africa, farmers, for instance, respond to changing rainfall patterns, pest invasion, droughts and floods through agro-chemical application, changing planting dates, and planting drought tolerant and improved crop varieties as well as irrigation farming (Asare-Nuamah, 2020; Shikuku et al., 2017; Sultan and Gaetani, 2016). Farmers also alleviate climate change impact on household food security through short term coping strategies such as reducing the number and size of meals as well as changing staple food consumption (Asare-Nuamah and Amungwa, 2021; Engle, 2011). Nevertheless, farmers also practice long-term adaptation strategies, such as tree planting and construction of irrigation facilities, to mitigate the emissions of greenhouse gases and strengthen resilient adaptation.

Recent literature calls for the need for transformative adaptation (innovation, reorganization, reorientation and expansion) strategies, which has the potential to minimize the root causes of vulnerability, thereby resulting in instrumental, radical and progressive outcomes (see Fedele et al., 2019; Few et al., 2017). In consonance with the Intergovernmental Panel on Climate Change (IPCC) (2014), transformative adaptation offers options to address maladaptive outcomes associated with some adaptation strategies, especially in vulnerable regions.

Barnett & O’Neill (2010) and Brown (2011) show that adaptation practices erode sustainable development options of farmers in smallholder agriculture system by increasing greenhouse gas emissions and environmental challenges. This stems from poorly conceived adaptation policies and programmes (Schipper, 2020; Schipper et al., 2021) and challenging socioeconomic conditions of farmers (Dankelman, 2010). Wilson (2014) contends that economic, political, and socio-psychological conditions and existing structural factors render adaptation strategies counterproductive by creating path dependence lock-in-effects, which eliminate future choices (UNEP, 2019).

Existing studies note that climate change adaptation strategies such as development of desalination plants and artificial snow are maladaptive, as they increase greenhouse gas emissions (Barnett et al., 2013; Hopkins, 2014). Similarly, Quezada et al. (2014) report that power grid investment financially burden the vulnerable poor, due to high poverty levels and their inability to pay. In addition, Glaas et al. (2015) argue that although tree planting is beneficial to the environment, it can in the long run destroy infrastructure, particularly during storms. Specific to smallholder agriculture system, Mateo-Sagasta (2020) denotes that uncontrolled and poor agricultural practices are the major causes of water pollution. For instance, agricultural intensification practices, such as agrochemical application, irrigation farming, change in land use and livestock keeping, intensify erosion and runoff, and increase water pollution, thereby affecting biodiversity and ecosystem services (Evans et al., 2019; Mateo-Sagasta, 2020; Mateo-Sagasta et al., 2018).

Studies further argue that gender inequality and poverty in poor and vulnerable farming communities, are further exacerbated by poor implementation of adaptation strategies (Mehtar et al., 2016), which according to Schipper et al. (2021), is due to poorly thought through and hasty policies and programmes aimed at remedying the effect of climate change in vulnerable economies. For instance, in Zimbabwe, Chazovachii et al., (2012) and Matarira et al. (2004) denote that the government’s promotion of maize commercialization is associated with a reduction in yields and income in some ecological zones, mainly due to unfavourable ecological conditions for maize. For Simelton et al. (2013), adaptation strategies backfire in smallholder agriculture system, due to the negligence of ecological conditions by policy framers and implementers. In São Tomé and Príncipe, agriculture intensification strategy that sought to increase yields through modernization, rather increased vulnerability, as only farmers with access to land benefited from the intervention, thereby creating inequality and marginalization among vulnerable farmers without access to land (Schipper et al., 2021).

Notwithstanding the growing concern on maladaptation outcomes and the implications on sustainable development, especially in smallholder agriculture system, there is a scarcity of information on smallholder farmers’ maladaptation in Ghana. This is problematic, as rain-fed agriculture is the backbone of the economy and being sensitive to climate change, multiple adaptation strategies have been implemented to mitigate the effect of climate variability and change on the sector. Although Antwi-Agyei et al. (2018) explored maladaptation outcomes in Northern Ghana, the findings from their study create the impression that each adaptation strategy is associated with a particular maladaptation outcome, when in reality an adaptation strategy can have multiple maladaptation outcomes. This study therefore builds on their study to provide a comprehensive understanding and classification of maladaptation outcomes associated with rural farmers’ adaptation strategies in Ghana, which is necessary for planning and implementation of sustainable adaptation policies and programmes. The study also classifies typologies of smallholder farmers’ adaptation strategies in rural Ghana, which has not been done in previous studies.

2. Conceptual framework

Adaptation strategies are implemented to mitigate climate change impact. Nevertheless, adaptation strategies could result in perverse outcomes. Maladaptation therefore constitutes adaptation strategies that increase climate change risk, vulnerability and impact (Barnett & O’Neill, 2010; Noble et al., 2014). Juhola, Glaas, Linnér and Neset (2016) also define maladaptation as “a result of an intentional adaptation policy or measure directly increasing vulnerability for the targeted and/or external actor(s), and/or eroding preconditions for sustainable development by indirectly increasing society’s vulnerability.” Barnett and O’Neill (2010) identify rising greenhouse gases emissions, path dependency and reduction in adaptation incentive as typologies of maladaptation outcomes emerging from the implementation of adaptation strategies to climate change.

IPCC (2014) emphasizes that maladaptation outcomes are not only as a result of poorly planned adaptation strategies but also from deliberate decisions that prioritize short-term outcomes at the expense of long-term threats. Thus, adaptation policies and programmes focus mainly on immediate benefits and neglect the associated future threats. Moreover, there is lack of information on both maladaptive outcomes and what can be done to prevent them (IPCC, 2007; Noble et al., 2014). This corroborates Granberg and Glover (2013) argument that there is no existing guide to aid in identifying maladaptation outcomes.

Notwithstanding, there is a rising and intense discussion in the literature on what constitutes maladaptation and the ways to avoid it (see Magnan et al., 2016; Schipper, 2020; Schipper et al., 2021). Juhola et al. (2016), for instance, developed a framework that categorizes maladaptation into eroding sustainable development, rebounding vulnerability and shifting vulnerability, as shown in Fig. 1. According to the framework, adaptation can erode sustainable development by increasing greenhouse gas emissions and creating socioeconomic and environmental problems. This mostly affect societies across a spatial scale. Adaptation can also increase vulnerability by increasing sensitivity and exposure, and decreasing adaptive capacity of the implementing actor. The authors referred to as rebounding vulnerability. Shifting vulnerability implies that adaptation can increase vulnerability of external communities/actors by reducing their adaptive capacity and increasing exposure and sensitivity. Thus, maladaptation constitutes the conscious and unconscious risks associated with the implementation of adaptation strategies.

Coping strategies, such as cutting down of trees, erode sustainable development efforts and gains by increasing greenhouse gas emissions, ozone layer depletion, and biodiversity loss as well as soil erosion and environmental pollution, thereby exerting grave negative impact on economies, livelihoods and food security of household as well as the environment (Juhola et al., 2016). Similarly, adaptation strategies, such as the application of fertilizer, weedicides and pesticides, can also rebound and shift vulnerability by exposing both implementing and external communities to health challenges (air and water borne diseases), depleting soil fertility, and reducing agricultural yields and income. Sales of productive and reproductive assets also rebound vulnerability by eroding the stock of household assets (example livestock and land), thereby increasing vulnerability and minimizing the capacity of communities to respond effectively to future climate shocks and stressors. It is therefore essential to examine the potential risks associated with current adaptation strategies of smallholder farmers. In view of this, this study adopted Juhola et al.’s (2016) typologies of maladaptation to answer the questions: what are the risks associated with existing adaptation strategies of smallholder farmers in rural Ghana? This framework was chosen as it advances the maladaptation literature and offers a better approach to identify and classify maladaptation outcomes.

3. Materials and methods

3.1. Study design and participants

This study adopted a convergent parallel mixed methods design to explore smallholder farmers’ adaptation strategies and

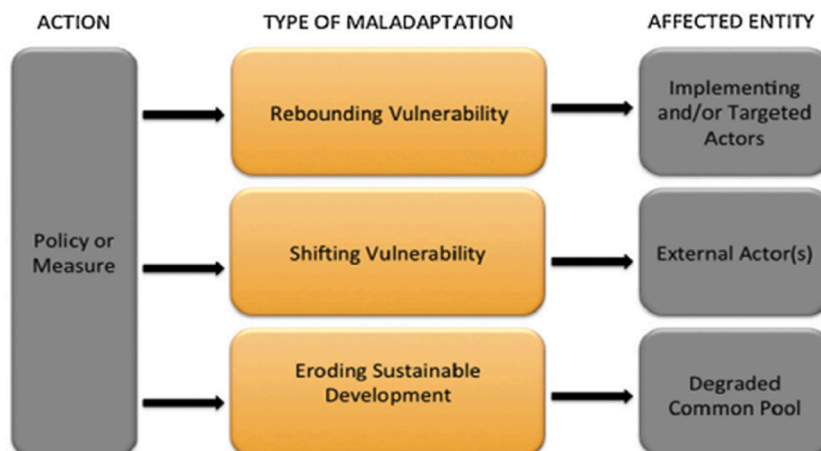


Fig. 1. Maladaptation framework Source: Juhola et al. (2016).

maladaptation outcomes. Simultaneous collection of quantitative and qualitative data enriched the study and minimized the weaknesses associated with either the quantitative or qualitative approaches (Creswell and Plano Clark, 2018; Kusi, 2012). The study was conducted in the rural Adansi North District in the Ashanti region of Ghana (see Fig. 2), which experiences 27 °C mean annual temperature, 1250–1750 mm rainfall, and a bimodal rainfall pattern (GSS, 2014). The major rainfall season spans April to July, while the minor rainfall season starts from September to November (MOFA, 2016). The district also experiences dry weather from November to March.

The dominant economic activity in the district is subsistence agriculture, which employs about 77% of the active population (GSS, 2014). Maize, cassava, plantain, yam, and cocoyam, in addition to cash crops, particularly cocoa and oil palm, are the major crops produced in the district. In addition, goats, sheep, fowls, and pigs, with an average household stock of about 20 livestock, are also raised by some households in the district (GSS, 2014). Smallholder farmers in the district use rudimentary farm tools and equipment and rely on the weather for their agricultural activities, which demonstrate their vulnerability. Also, poverty and low income weakens farmers' capacity to respond to climate change in the district.

Available data indicates that the district has experienced prolonged rising temperature, erratic rainfall, changing rainfall and planting season over the past 30 years, due to climate change (Asare-Nuamah and Botchway, 2019). It is therefore not surprising that farmers adapt to these changes (Asare-Nuamah and Amungwa, 2021). Similarly, the recent invasion of fall armyworm in the district has also triggered autonomous and planned adaptation among farmers with the support of the government over the last 3 years (Asare-Nuamah, 2020). Hence, the study explores how farmers in the study communities have adapted to multiple climate stressors and shocks.

Guided by the 2010 population census data and Krejcie and Morgan (1970) statistical table for sample size selection, 378 smallholder farmers in 15 communities, were randomly selected from 17,696 agricultural households. In addition, 41 key informants (15 district agriculture officers and 26 farmers) were purposively selected. The agriculture officers were comprised of four District Development Officers (DDOs) and 11 Agriculture Extension Agents (AEAs). The officers' selection criteria was the length of station in the district. Household heads who showed in-depth knowledge of the subject matter during the survey, were selected and interviewed. Twenty-six of them were interviewed after reaching a point of saturation based on the themes and views from the interviews.

3.2. Data collection instruments and procedure

Data was collected with the aid of questionnaire survey and semi-structured interviews. The questionnaire captured smallholder



Fig. 2. Map of Ghana demarcating the Ashanti Region and the Adansi North District Source: GSS, 2014.

farmers' adaptation strategies while the interviews collected in-depth information on the identified adaptation strategies and the associated maladaptation outcomes from participants' natural setting. The questionnaire asked farmers the adjustments made in their livelihood strategies (farming and non-farm activities) due to climate change, which also served as the basis for the interviews. The questionnaire also asked whether the adjustments in livelihood strategies substantially improve household livelihoods and food security. This was supported by the identification of risks and benefits associated with farmers' adaptation through key informant interviews.

The instruments were piloted, after which they were revised to get rid of ambiguous questions. For instance, the question 'what are the maladaptive outcomes in the community?' was rephrased as 'what risks and benefits are associated with your adaptation strategies?' Data was collected from April to September 2018. Five research assistants were recruited from the local communities and trained for data collection. The study adopted face-to-face questionnaire administration, which lasted for an average of 20 min. In the case of qualitative interviews, key informants were interviewed face-to-face and telephonically, per their preference and convenience. The interviews offered an in-depth understanding of the benefits and risk resulting from the deployment of a particular adaptation strategy. An interview lasted for an average of 1 h and all interviews were tape recorded, with participants' consent. All interviews were conducted in the local language (Twi). The participants' views are reported in verbatim quotes and the participants are identified using DDO1, AEAI and F1 as the first interviewed District Development Officer, Agriculture Extension Agent and Farmer, respectively. Prior to data collection, the study sought permission of entry and informed consent from gatekeepers and participants, respectively. In addition to the survey and interview guide, farm and community visits, and transect walks also helped to understand the environmental and physical characteristics of communities and how farmers implement adaptation strategies. This study forms part of larger study which was approved by the review committee of the Pan African University.

3.3. Data analysis

The study analyzed quantitative data in Statistical Package for Social Sciences (SPSS) using basic descriptive analysis that consisted of frequencies and percentages. Qualitative data was analyzed manually through thematic analysis, as described by Braun and Clarke (2014). Prior to data analysis, the recorded interviews were transcribed from local language to English, and the transcripts were perused consistently to identify themes and patterns. The study classified maladaptation outcomes of smallholder farmers in-line with the conceptual framework as indicated by Juhola et al. (2016), following the risk and benefits analysis outlined in Antwi-Agyei et al. (2018).

Data on risks and benefits of farmers' adaptation strategies was complemented with the literature to gain a comprehensive understanding from the study context. Farmers' adaptation strategies were categorized following Few et al.'s (2017) classification. The study then categorized the maladaptation outcomes associated with each adaptation strategy. Unlike Antwi-Agyei et al. (2018) who reported the overall outcomes of adaptation strategies, this study was premised on the assumption that adaptation strategies have overlapping risks, and therefore a single adaptation strategy could have multiple maladaptation outcomes and not necessarily a single (overall) outcome. This approach enabled the study to make significant contribution to maladaptation literature and enhanced clarity in the categorization of risks/maladaptation outcomes.

4. Results

4.1. Adaptation strategies

Table 1 presents the responses of the participants on the changes they have made in their livelihoods and food security activities and strategies, due to unreliability of rainfall volume, patterns and seasons, rising temperature, pest invasion, floods and droughts, which result in continuous decline in agriculture yields and income in the district. Farmers noted that changes in farming activities are part of the agricultural system but climate change impact on smallholder agriculture has intensified their efforts to adjust their food security and livelihood strategies. About 68% and 89% of the respondents have made changes in crops and livestock, respectively, while 79% have diversified their sources of income, due to the incremental effect of climate change stressors and shocks on agriculture. Majority of farmers have made adjustments in their assets, as revealed by 90% of the respondents. The interviews revealed that

Table 1
General livelihood and food security adjustments.

Adjustments	Yes (%)	No (%)
Have you made any changes in your farming activities	74.3	25.7
Have you made any changes in time you performed these activities	70.6	29.4
Have you made any changes in the crops you grow	67.7	32.3
Have you made any change in livestock	89.2	10.8
Have you added any other sources of income generating activities	78.6	21.4
Have you made any changes in assets	89.9	10.1
Have you made any changes in eating pattern	86.2	13.8
Have you made changes in expenditure pattern	83.6	16.4
Are there any government adaptation programmes in your community	51.0	49.0

Source: Authors computation from fieldwork, 2018

farmers' adjustments in assets mainly involved sales and/or lease of both agricultural and residential lands (mostly by older farmers) as well as sales of livestock. Some, especially young farmers, have also acquired lands particularly for agricultural purposes.

Table 2 presents the perceived effectiveness of the adjustments in farmers' food security and livelihood strategies, due to climate change and its impact on subsistence agriculture, which is the main source of household income and livelihoods in rural communities. Although changes in farming activities (58%) and crops production (53%) seemed effective in enhancing food security and livelihoods of the respondents, farmers were ambivalent with respect to the effectiveness of the numerous changes in food security and livelihood strategies. For instance, while 45% of the respondents were neutral with the changes in assets, 30% were positive that changes in assets improve their livelihoods and food security. An agriculture extension agent noted that "while farmers in the district have responded to climate change by changing their food security and livelihood activities, the changes do not substantially improve farmers' livelihoods and food security, as erratic rainfall and the spread of pests and diseases, continue to reduce yields and income, coupled with high poverty in the district" (AEA4). This was confirmed by a farmer (F13) who echoed that "although changes in farming and livelihood strategies help farmers to alleviate grave and extreme impacts of climate change on agriculture and livelihoods, farmers do not see substantial improvement in their income, which is essential for improving household food security and/or livelihoods". Implicitly, farmers received low income from yields even after adjusting their livelihood strategies.

Table 3 presents the specific adaptation and coping strategies of smallholder farmers. It is indicative from the table that farmers employed different typologies of adaptation to mitigate climate change impact. The innovation typology refers to the application of a new activity or an old one in a new location, while the expansion typology constitutes intensification in the scale of an existing practice. Reorganization typology has to do with a major shift in the state institutional structure, policies and development agenda, while reorientation typology includes change in social values and relations. Majority of the farmers have adapted to climate change through crop diversification, use of multiple cropping seasons, and application of pesticides, weedicides and fertilizer. About 57% of farmers have diversified their livelihoods, while 64% have sold their assets. The farmers have also resorted to diet-based adaptation strategies to reduce climate change impact. For instance, 66% of the farmers have reduced the size of meals, while 57% and 52% of them have reduced the number of meals and changed staple food consumption, respectively.

The district agriculture officers assist smallholder farmers in adapting to climate change through government interventions. According to a district development officer, "through government interventions and programmes such as planting for food and job (PFJ), we provide improved seeds, fertilizer and pesticides to farmers to respond to climate change" (DDO1). An agriculture extension agent (AEA9) also expressed that "we educate and encourage farmers to adopt emerging practices, such as fertilizer application and the use of improved seeds."

4.2. Maladaptation outcomes of adaptation strategies

In Table 4, the benefits and risks (maladaptation outcomes) associated with smallholder farmers' adaptation strategies are reported using Juhola et al. (2016) typologies of maladaptation. Indeed, farmers adopted adaptation strategies due to the derived benefits, such as improving crop yields, increasing income, reducing the activities of pests and diseases, improving food security and livelihoods, and reducing poverty, especially in vulnerable communities. However, there are unintended and known risks associated with farmers' response strategies. It is indicative that farmers' adaptation strategies in the Adansi North District erode sustainable development, shift and rebound vulnerability. The farmers complained, which was also echoed by extension agents that agricultural intensification and extensification increase financial burden and agricultural expenditure among farmers, due to the expensiveness of agrochemicals. For instance, a farmer (F21) intimated that "we cannot increase yields without applying agrochemicals but the chemicals are expensive." Another farmer reported that "we receive low income from agriculture but we spend most of our income on agrochemicals." The situation has consequently intensified the use of chicken dropping as alternative to fertilizer, especially among cocoa farmers who perceived it to be less costly. The application of fertilizer, weedicides and pesticides has maladaptation outcomes on implementing actors and external communities by eroding sustainable development through greenhouse gas emissions, and disturbing the natural ecosystem and biodiversity. The practice also releases chemicals into water bodies, which affects sources of drinking water and health of communities, thereby increasing exposure and sensitivity of both implementing and external communities. Both farmers and extension agents agreed to the effect of chemicals on health and biodiversity. For instance, F6 reported that "we cover our nose and mouth with mask and wear protecting clothing when applying chemicals, due to the effect on our health but we cannot control the

Table 2

Perceived effectiveness of general adjustments towards farmers' livelihood and food security.

Adjustments	Effective (%)	Neutral (%)	Not effective (%)
Change in your farming activities	57.9	31.0	11.1
Change in time you performed these activities	52.6	36.5	10.9
Change in the crops you grow	51.6	39.7	8.7
Change in livestock	35.7	45.0	19.3
Change in other sources of income generating activities	35.4	43.9	20.7
Change in assets	30.4	44.7	24.9
Change eating pattern	42.3	42.9	14.8
Change in expenditure pattern	41.5	42.3	16.2
Government adaptation programmes in your community	31.0	33.3	35.7

Source: Authors computation from fieldwork, 2018

Table 3
Specific adaptation and coping strategies.

Indicators	(%)	N (378)	Typology of adaptation
Migration	8.3	33	Reorientation
Fertilizer application	68.0	257	Innovation
So Klin detergent application	44.4	168	Innovation
Planting early maturing crops	42.1	159	Innovation
Improved crops varieties	33.9	128	Innovation
Livelihood diversification	57.4	217	Reorientation
Help from family and friends	40.5	153	Reorientation
Crop diversification	93.4	353	Expansion
Delayed farming	70.1	265	Reorganization
Multiple cropping season	51.3	194	Reorganization
Pesticides application	34.7	131	Innovation
Weedicides application	43.2	164	Innovation
Cocoa pollination	34.7	131	Innovation
Cocoa spraying	42.1	159	Expansion
Reduce number of meals	57.4	217	Reorientation
Reduce size of meals	66.4	251	Reorientation
Change in meals/staple food	52.4	198	Reorientation
Irrigation (hand/machine)	26.7	101	Expansion
Extension services	51.1	193	Reorganization
Sales of assets (eg. land)	63.6	240	Reorientation
Change in livestock	35.4	134	Reorientation
Planting drought resistant crops	18.3	69	Innovation
Farm expansion	38.4	145	Expansion
Joining Farm Based Organizations	3.7	14	Reorganization
Chicken dropping application	17.5	66	Innovation

Source: Authors computation from fieldwork, 2018

harm on the environment.”

Planting early maturing and improved crops is a dominant adaptation strategy among smallholder farmers, as it increases crop yields and income and reduces the adverse climate change impact. Nevertheless, it equally strains land by increasing multiple or continuous cropping season on the same piece of land. It also reduces soil nutrients, which increases fertilizer application. Smart agriculture practices such as planting early maturing and improved crops, and irrigation are also capital intensive, which may affect the capacity of smallholder farmers to adapt to changes in climate. Irrigation for instance, also leads to water stress and can be a source of conflict.

5. Discussion

The results of the study and the associated implications are teased out under this section. The section first discusses the adaptation strategies employed by respondents in the study. This is followed with a discussion of the maladaptation outcomes associated with the identified adaptation strategies.

5.1. Adaptation strategies of smallholder farmers

The results from the study show that smallholder farmers in the Adansi North District have adjusted their livelihoods and food security activities to minimize climate change impact on households. Previous study in the district noted remarked changes in rainfall and temperature (Asare-Nuamah and Botchway, 2019), which are important climate variables for smallholder agriculture, thereby necessitating farmers' adaptation. Farmers' adjustments constitute innovation, expansion, reorganization and reorientation strategies, which are applied to diverse and complex climate shocks and stressors. Most of the adjustments occur in crop and animal production activities of the farmers, which are consistent with the existing literature (Shikuku et al., 2017; Sultan and Gaetani, 2016), thereby demonstrating the critical role of agriculture as the main source of income, livelihoods and food security in rural communities.

Findings from the study indicate that farmers have resorted to multiple adaptation strategies with the assistance of the district agriculture development institutions, to mitigate the impact of changing climate on agriculture. This is not surprising, as smallholder agriculture system across the world is battling with the impact of climate change. Hence, farmers in the rural district of Ghana implement adaptation strategies that are likely to mitigate climate change impact on household food security and livelihoods. For instance, innovation strategies, such as planting early maturing and improved crops varieties, result in improved crop yields, leading to a corresponding increase in agricultural income (Issahaku et al., 2016; Tambo, 2016).

The participants reorient their livelihoods and food security strategies through crop diversification, which is a dominant traditional agriculture strategy that enables smallholder farmers to be in business by planting multiple crops with different climatic and soil nutrient requirements. Hence, the practice increases access to food for households, even during hard times like floods and droughts. According to Sissoko et al. (2011), crop diversification enables farmers in Sahel Africa to spread and alleviate risk associated with climate change. Farmers in the study also practice delayed farming and multiple cropping seasons, due to changing rainfall and

Table 4
Risk (Maladaptation outcomes) and benefits of adaptation and coping strategies.

Adaptation/coping strategies	Benefits	Maladaptation outcomes (Risk)		
		Eroding sustainable development	Shifting vulnerability	Rebounding vulnerability
Change in meals/staple food consumption	Ensures household food accessibility; reduces hunger (Quaye, 2008)	N/A	N/A	Erodes cultural believes and practices associated with food
Chicken dropping application	Increase soil fertility and improves crop yields	N/A	Pollutes water bodies and decreases access to portable water	Pollutes water bodies and decreases access to portable water
Cocoa pollination	Increase yield and income from cocoa; improves household livelihoods, food security and adaptive capacity	N/A	N/A	N/A
Cocoa spraying	Reduces cocoa pests and diseases (eg. capsid and aphid); increases yield and income from cocoa; improves household livelihoods, food security and adaptive capacity	Application of agrochemicals increases greenhouse gases emissions; affects ecosystem and biodiversity leading to environmental problems	Creates common pool resource challenges (eg. access to drinkable water), increases water-borne disease, destroy aquatic ecosystem and biodiversity	Reduces access to portable water; increases water-borne diseases; affect aquatic ecosystem and biodiversity; exposes human health to respiratory disease due to inhalation of chemicals
Crop diversification	Increase household food availability, leguminous crops enhance soil fertility (Asare-Nuamah and Mandaza, 2020; Sissoko et al., 2011)	Slash and burning increases carbon emission and also affects ecosystem and biodiversity	N/A	Increases demand for certain seeds/crops and hence increases their price, reduces land capacity for agriculture
Delayed farming	Increases water availability for crops, enables crops to skip dry spells	N/A	N/A	Alters the farming seasons, leads to hunger and scarcity of food
Extension services	Promotes best farming practices through transfer of knowledge and skills; increases farmers' adaptive capacity through education and transfer of technology and innovation (Asare-Nuamah et al., 2019)	Leads to greenhouse gas emissions and environmental degradation through agriculture intensification and extensification	N/A	Adoption of best farming practice goes with rise in agriculture expenditure
Farm expansion	Increases agriculture productivity and income	Contributes to environmental degradation (Hosonuma et al., 2012) and greenhouse gas emissions through application of agrochemicals (Bouwman, 1996) and poor farming practices such as slash and burn	Application of agrochemicals creates common pool resource challenges eg. access to portable water	Increases agriculture expenditure; promotes application of agrochemicals which lead to water pollution (Antwi-Agyei et al., 2018); creates competing demand for limited farm land and portable water; leads to deforestation
Fertilizer application	Increase crop yields and income (Tambo, 2016)	Increases greenhouse gases emissions through nitrogen-based fertilizers (Stehfest et al., 2010)	Contaminates water bodies; affects ecosystem and biodiversity; increases water-borne diseases; creates social tension	Contaminates water bodies; affects ecosystem and biodiversity (Pittock, 2011); increase water-borne diseases; creates social tension; exposes human health to respiratory diseases due to chemicals inhalation (Nyantakyi-Frimpong et al., 2016)
Help from family and friends	Increases access to food and financial assistance; increases social bond	N/A	Puts pressure on family and friends; creates social conflict	Creates social conflict
Improved crops varieties	Increases crops yields through drought resistant and less water consumption (Mango et al., 2017) capacity of crops	N/A	N/A	Increases agriculture expenditure
Irrigation (hand/machine)	Increases agricultural intensification and extensification; improves livestock keeping particularly in arid regions; increases yields and income from crop and livestock (Requires huge capital and regular access to reliable sources of water	Creates competing demand for water which can lead to conflicts (Solh and Ginkel, 2014)	Increases financial burden and agriculture expenditure of farmers/communities (Lopez-Ridaura et al., 2018)

(continued on next page)

Table 4 (continued)

Adaptation/coping strategies	Benefits	Maladaptation outcomes (Risk)		
		Eroding sustainable development	Shifting vulnerability	Rebounding vulnerability
Joining Farm Based Organizations	Mango et al., 2017), improves access to water for consumption, farming and livestock (Sain et al., 2017) Increases access to finance, technology, innovation, knowledge and skills (Asare-Nuamah et al., 2019)	Leads to greenhouse gas emissions through agriculture intensification and extension	N/A	Increases financial burden of farmers through payment of dues, loans and agriculture intensification and extensification
Livelihood diversification (sales of forest product eg. firewood, charcoal, mushroom)	Increases income, supplements household food availability (Ofoegbu et al., 2015)	Creates environmental problem through deforestation	N/A	Creates common pool (forest) challenges (Ofoegbu et al., 2017), increases erosion, leads to soil infertility
Livelihood diversification (Sales of assets eg. land, livestock)	Increases adaptive capacity; improves household food security and livelihoods through increase in income (Scoones, 2007)	N/A	N/A	Reduces coping and adaptive capacity of household to future stressors and shocks (Haggblade et al., 2010); depletes household stock of assets; leads to long term poverty (Wilson, 2014)
Migration	Increases household income; reduces stress on household food security (Klepp, 2017)	N/A	Increases pressure on social amenities at destination; increases population at destination (Klepp, 2017)	Reduces farm labour, high cost of labour, puts pressure on household adaptive capacity
Multiple cropping season	Increases food availability; reduces food shortage and prices of food items; increases income from crops	Slash and burning and application of agrochemicals increase greenhouse gas emissions and also affects ecosystem and biodiversity	Creates common pool resource challenges (eg. access to drinkable water)	Puts pressure on fam land; creates common pool resource challenges
Pesticides application	Reduces the activities of crop pests; Improves crop yields (Andrieu et al., 2017)	Affects ecosystem and biodiversity leading to environmental problems; application of agrochemicals increases greenhouse gas emissions (Stehfest et al., 2010)	Creates common pool resource challenges (eg. access to drinkable water) (Obeng-Odoom and Gyampo, 2017), increase water-borne diseases, destroy aquatic ecosystem and biodiversity	Creates common pool resource challenges (eg. access to drinkable water) (Pittock, 2011), increases water-borne disease, destroy aquatic ecosystem and biodiversity; reduces soil fertility; exposes human health to respiratory diseases due to inhalation of chemicals (Obeng-Odoom and Gyampo, 2017)
Planting early maturing crops	Increases food availability through multiple cropping season; enables crops to skip dry spells (Sain et al., 2017)	N/A	N/A	Strains land and reduces soil fertility; leads to crop failure from long dry spells (Kihupi et al., 2015); increases agriculture expenditure
Reduce number of meals	Ensures household food availability (Quaye, 2008)	N/A	N/A	Creates health and nutrition deficiency especially in children and elderly; leads to starvation/hunger
Reduce size of meals	Ensures household food availability (Quaye, 2008)	N/A	N/A	Creates health and nutrition deficiency especially in children and elderly; leads to starvation/hunger
So Klin application	Reduces the activities of crop pests (eg. Fall armyworm)	N/A	Contaminates water bodies; affects ecosystem and biodiversity	Contaminates water bodies; affects ecosystem and biodiversity; affects soil fertility
Weedicides application	Reduces growth of weeds, improves crop yields (Andrieu et al., 2017)	Affects ecosystem and biodiversity leading to environmental problems (Antwi-Agyei et al., 2018); application of agrochemicals increases greenhouse gases emissions (Bouwman, 1996)	Creates common pool resource challenges (eg. access to drinkable water), increases water-borne disease (Nyantakyi-Frimpong et al., 2016), destroy aquatic ecosystem and biodiversity	Creates common pool resource challenges (eg. access to drinkable water) (Pittock, 2011), increases water-borne disease, destroy aquatic ecosystem and biodiversity; reduces soil fertility by killing microorganisms; exposes human health to respiratory disease due to inhalation of chemicals

N/A indicates Not Applicable.

Source: Authors computation from fieldwork and literature, 2018

planting seasons, coupled with lack of irrigation. Less than 3% of arable lands in Ghana are under irrigation (MOFA, 2016), which forces smallholder farmers to rely on the weather for their agricultural activities. In arid environment, farmers rely on irrigation farming to compensate for the delays or changes in rainfall patterns and intermittent droughts (Andrieu et al., 2017; Mwongera et al., 2017).

The Government of Ghana climate change adaptation initiatives pay attention to climate smart agriculture strategies, in alleviating climate change impact on socioeconomic development (MESTI, 2012, 2013). It is therefore not surprising that many farmers apply fertilizer, weedicides and pesticides as well as use improved crop varieties. These agricultural practices have been reported to lessen climate change impact on agricultural activities of farmers in developing economies, such as Nigeria, Benin, Kenya and Ethiopia (Bryan et al., 2013; Fadina and Barjolle, 2018; Olayide et al., 2016; Shikuku et al., 2017). Nevertheless, high cost of agrochemicals compels cocoa farmers in the district to apply chicken droppings as a substitute for chemical fertilizer. According to GSS (2014), low income and high poverty in the district affect farmers' capacity to respond to climate change. This raises serious question on the ability of farmers to respond to future climate change and variability.

With the invasion of maize crop by fall armyworm in the district, smallholder farmers rely on their local environmental knowledge and network to respond to pest invasion by applying washing detergent (So-Klin) solution. Farmers' previous ecological experience in using detergents for the treatment of grasshopper invasion in Ghana in 1983 played a dominant role in the use of washing detergent for fall armyworm. Although this finding is unique to this study, previous studies have reported the critical role of local environmental knowledge in climate change adaptation (Boko et al., 2007). Ahmed, Hu, & Kumar (2016) and Krishna (2011) concur that smallholder farmers in India and Indonesia, respectively, rely extensively on their indigenous knowledge to respond to climate change.

In consonance with the literature, incremental adaptation strategies, such as the application of fertilizer and improved crops, are anticipatory, since farmers preconceive their use prior to the beginning of the planting season with the hope to boost production and income and mitigate climate change impact (see Fedele et al., 2019). Such strategies also transform smallholder agriculture system from physical labour to mechanized and innovative system (Few et al., 2017). For instance, outdated practices, such as weeding with physical energy, and the use of hoes and cutlasses, are gradually replaced with agrochemical products among the study participants. Similar tendencies also exist with respect to planting improved crop varieties instead of traditional varieties.

In addition to on-farm strategies, farmers also employ off-farm adaptation and coping strategies to minimize climate change impact on households. The dominant strategies include livelihood diversification, change in food consumption and sales of asset, which are consistent with previous studies (Abid et al., 2015). Livelihood diversification strategies, such as sales of livestock, firewood and other forest products as well as petty trading, constitute reorientation strategies that supplement household agricultural income and improve food security and livelihoods. Forest, in particular, helps rural communities to diversify their livelihoods to ameliorate the harm from climate change (Ofoegbu et al., 2015). This study also noted that farmers, particularly the aged, sell or lease their assets, especially farmlands, to energetic and youth farmers. The land tenure system in the Adansi North District comprises 'abunu' and 'abusa', where members who lease their lands to farmers for agricultural purpose, share produce or profit in two and three equal parts, respectively. Hence, leasing farmlands helps older farmers to gain income, while youth farmers expand their farms.

Furthermore, the study showed that smallholder farm households reduce the number and size of meals as well as change staple food consumption. Existing studies indicate that reducing the size and number of meals forms an important food security strategy among rural households (Quaye, 2008). According to Fedele et al. (2019), coping strategies, such in changes in meals, are applied when the intensity of climate change impact is low and vulnerable households are faced with limited financial and technical options to respond to climate change. The authors further argue that such changes do not really change the prevailing social characteristics and functions of society. However, change in staple food consumption has drastically impacted social and cultural values associated with the consumption of food in rural Ghana (Asare-Nuamah and Amungwa, 2021). The Food and Agriculture Organization (FAO) emphasizes that different social values and norms attached to the consumption of food in different communities, play crucial role in food security (FAO, 2008). The study participants also rely on their social networks, such as family and friends or membership of Farm Based Organizations, to respond to climate change, which corroborates previous studies that emphasized social networks as important capital for climate change adaptation (Scoones, 2009).

5.2. Maladaptation outcomes of adaptation strategies

Based on Juhola et al.'s (2016) typologies of maladaptation, it is evident that some of the adaptation strategies of smallholder farmers erode sustainable development, rebound and shift vulnerability. This has the potential to affect farmers' capacity to respond to future climate and environmental change. Maladaptation outcomes that erode sustainable development release greenhouse gases and create socioeconomic and environmental problems across a wider geographical scope. Farmers' adaptation strategies that erode sustainable development included application of agrochemicals, agriculture extensification/expansion and intensification as well as sales of assets.

Agriculture intensification, for instance, increases the use of agrochemicals, such as fertilizers, weedicides, and pesticides among the farmers, which affects sources of drinking water for communities and increases greenhouse gas emissions. In addition, the cost associated with agrochemicals increases the financial burden of smallholder farmers in the study area and reduces their ability to respond to future shocks and stressors. This findings corroborate Antwi-Agyei et al. (2018) who noted that the high cost of agrochemicals affects vulnerability of farmers in Northern Ghana. Agrochemicals with nitrogen content also contribute to global warming

and climate change by releasing greenhouse gases (Stehfest et al., 2010). Thus the contribution of agrochemicals to global warming negatively affects exposure and sensitivity to climate shocks in smallholder agriculture systems. Agrochemicals have health implications, disrupt freshwater ecosystem services and create common pool resource challenges in the farming community, which is consistent with previous studies (Nyantakyi-Frimpong et al., 2016; Obeng-Odoom and Gyampo, 2017; Pittock, 2011). Intuitively, adaptation strategies, such as agrochemical application, have the propensity to result in multiple maladaptation outcomes, which supports the study's argument that an adaptation strategy may not necessarily lead to a single/overall maladaptation outcome but can result in multiple counterproductive outcomes.

Farm expansion among the farmers also encourages deforestation, slashing and burning and agrochemicals application as well as strains common pool resources, such as forest. The practice also puts stress on water for agriculture and domestic purposes and increases greenhouse gases emissions from agriculture. Slash and burning is associated with the release of carbon dioxide in the atmosphere, which intensifies global warming and climate change (IPCC, 2014, 2018). Similarly, the quest to expand farmlands among the farmers also contributes to deforestation through the removal of trees and land covers, thereby exposing farmlands to erosion. This confirms Hosonuma et al.'s (2012) argument that agriculture extensification contributes significantly to deforestation, particularly in dry land farming systems.

Livelihood diversification, such as sales of livestock and land, reduces the stock of assets of smallholder farmers, thereby increasing their vulnerability to future climate shocks and stressors. Thus, there is a high tendency that sales of asset may aggravate poverty of vulnerable communities during severe climate hazards (Haggblade et al., 2010; Wilson, 2014). Furthermore, irrigation shifts vulnerability by creating social tension and conflict among farmers, due to competing demand for limited water resources. Solh & Ginkel (2014) contend that irrigation in dry land areas has been a major source of conflict, particularly between herders and crop farmers. Consistent with Lopez-Ridaura et al. (2018), irrigation is capital intensive, which financially burdens farmers in the district, thereby affecting their capacity to respond to climate change.

Adaptation strategies also rebound vulnerability by decreasing adaptive capacity and increasing exposure and vulnerability of implementing actors. For instance, coping strategies, such as reduction in size and number of meals, affect health and nutritional status of households, particularly children and the elderly. This corroborates studies that associated nutritional and health challenges of children to inadequate meals intake (FAO, IFAD, UNICEF, WFP, & WHO, 2017; Jaffee et al., 2019). Indeed, the risks associated with farmers adaptation strategies concur with Mateo-Sagasta (2020) that farmers' current agricultural practices have grave negative impact on sustainable development efforts.

The discussion above shows that farmers' response strategies to climate change are highly associated with risks that have the potential to erode sustainable development gains, increase the root causes of vulnerability and erode capacity of communities to respond to future climate shocks and stressors. Most of the adaptation strategies are implemented by the farmers with the support of the government and extension agents of the Ministry of Food and Agriculture (MOFA). Implicitly, both the government and the farmers focus excessively on the benefits associated with adaptation strategies without careful consideration of their counterproductive outcomes. In essence, adaptation policies and programmes are hastily implemented to remedy climate change impact in communities battling with the adverse effect of shocks and stressors, (Schipper et al., 2021), which erodes the chances of evaluating their efficacy. However, in some cases, the environmental and health challenges associated with adaptation strategies, such as fertilizers, weedicides and pesticides application, are known but ignored since there are no alternative measures available to vulnerable farmers to combat climate change impact. Hence, policies and programmes for climate change should strengthen farmers' capacity to address the root causes of vulnerability and inequality, and improve sustainable response to climate shocks and stressors. Coherent and inclusive policy formulation process should therefore be adopted by engaging all stakeholders, especially farmers, and understanding their needs and socioecological context. It is also essential for government extension and advisory services to incorporate maladaptation into their extension and support programmes, and provide alternative strategies to farmers. Without that, vulnerable farmers will continue to resort to strategies that entrap them in poverty and vulnerability.

6. Conclusion

This study adopted mixed methods design to explore smallholder farmers' adaptation strategies and the associated maladaptation outcomes in the rural Adansi North District of Ghana. The findings showed that smallholder farmers have responded to climate change through on- and off-farm adaptation strategies. The study also showed that some of the farmers' adaptation strategies are associated with negative outcomes and risks that have the tendency to erode gains in sustainable development, worsen vulnerability, reduce adaptive capacity and entrap farmers in their constrained socioeconomic conditions. Thus, some adaptation strategies adopted or implemented by the farmers and the government have maladaptation outcomes in the short and long run that can negatively affect efforts toward mitigating climate change impact in vulnerable communities.

There is therefore an urgent need to critically review and modify existing climate change adaptation policies, programmes, and interventions that support smallholder farmers, to ensure that they are sustainable in reducing vulnerability and risk, and enhancing adaptive capacity. Adaptation policies and strategies should have long-term perspective to enable a critical examination of their associated threats. Most importantly, the Government of Ghana and its development partners should be keenly interested in maladaptation outcomes by developing yardsticks to aid in determining the risks associated with current and future adaptation strategies. Furthermore, intensive education that promotes attitudinal change and enhances the adoption of sustainable agricultural practices among smallholder farmers, should be prioritized, particularly by extension services and the associated programmes and policies. Such a strategy should be accompanied with incentives to farmers to boost the adoption of sustainable agricultural practices. Further field and experimental studies should be carried out to test and ascertain the risks associated with adaptation strategies in rain-fed

agriculture system and offer verifiable and in-depth knowledge. Studies should also investigate climate change adaptation policy processes and extension services in Ghana to understand the principles and frameworks that guide their design and implementation, to minimize the risks associated with current and future adaptation strategies.

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Authors' contribution

PAN designed the study and instruments, collected and analyzed data and wrote the first draft; CD and RA perused the first draft. All authors critically perused the manuscript for important intellectual content.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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