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How do climate change adaptation strategies result in unintended maladaptive outcomes? Perspectives of tomato farmers

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ABSTRACT

Most studies on farmers' adaptation strategies do not adequately treat the downside of such practices, and how practitioners can survive with the strategies in the wake of climate variability and change. Emphasis has always been on benefits of adaptation which includes showing resilience to increase food production, enhancing livelihood outcomes with less vulnerability, and reducing poverty. This project was undertaken to determine unintended maladaptive outcomes resulting from farmers' adaptive strategies to climate variability. The project took place in rural southern Ghana with input from tomato (*Solanum lycopersicum* L.) growers from the Offinso North District. To mitigate adverse effects of climate variability on tomato productivity, adaptive strategies resulted in reduction in agro-biodiversity, release of greenhouse gas, pollution of nearby water, increasing soil acidity above the optimum requirement of tomato, adverse effects of household farm labor, increasing vulnerability of dependents, increasing pressure on social facilities, competition of crops for nutrients, moisture and sun light, and increase in spread of pests and diseases. Age, gender, formal education, farming experience, and access to extension services influenced farmers' perceived maladaptive outcomes of adaptation strategies. Adaptation strategies to climate variability, if unchecked, can increase vulnerability, or erode, sustainable development opportunities for farmers in rural agroecological settings.

KEYWORDS
Solanum lycopersicum; climate variability; mixed-methods; Offinso North District; southern Ghana

Food security is under threat to global climate variability and change, particularly in developing countries (Field, 2014; Kotir, 2011). Food crop production is climate sensitive and change in plant requirements may result in productive capacities and yield reduction of crops (Lobell et al., 2011; Odewumi et al., 2013).

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Climate variability is likely the probable leading cause of food crop production declines in most agricultural areas in sub-Saharan Africa (Guodaar, 2015; Guodaar et al., 2017c; Yaro, 2010). Sensitivity of agriculture to climatic change is because crop growth and yield are temperature and rainfall related (Easterling et al., 2007). Populations that depend on agricultural activities for their livelihood will be affected by oscillations and dynamics of climatic elements. Climate variability is a major threat to agriculture and food security especially among smallholders of developing countries.

Adverse effects of climate variability on vegetable production include high incidence of pests and disease, inadequate water supply causing production loss, and extreme events such as floods which affect top soil (Deuter, 2008) all of which are detrimental to sustainability of food crop production, and consequently on human nutrition. Climate variability directly affects vegetables, and industrial sectors that depend on raw materials from agriculture are indirectly affected. Tomato (*Solanum lycopersicum* L.) is a crop that is sensitive to temperature and rainfall variability. Smallholder tomato producers in Ghana continue to experience reductions in production due to high temperature and unpredictable rainfall patterns (Guodaar et al., 2017a). Heavy rainfall with poor drainage induces waterlogged conditions that reduce soil oxygen availability causing wilting, chlorosis, leaf epinasty, and ultimately death (de la Pena and Hughes, 2007). High temperatures modify vegetative and reproductive processes in tomatoes and affect photosynthetic functions which affect productivity (Hazra et al., 2007). The impact of drivers of variability on tomato production and consumption and subsequent importation of tomatoes from other countries are issues which need to be addressed.

The magnitude of climate variability impact has shifted the debate from mitigating strategies to adaptive measures, e.g., mixed cropping, irrigation, crop rotation, and crop diversification, aimed at moderating harm or exploiting beneficial opportunities (de Pinto et al., 2012; Lobell et al., 2011). Employment of adaptive measures may help farmers be resilient and reduce the vulnerability associated with climate variability. Sound adaptive measures may potentially enhance sustainability of food crop production and improve social and economic livelihoods of households. However, some adaptive strategies of farmers could perpetrate greater pressures on their households' ability to cope with pressures and future vulnerabilities (Barnett and O'Neill, 2010; Brown, 2011; Fazey et al., 2011) leading to unintended outcomes termed maladaptation. Maladaptation explains ostensible actions, or inactions, that may lead to increased vulnerabilities and adverse outcome (Noble et al., 2014). Maladaptation results from an unintentional adaptation policy or measure directly increasing vulnerability for targeted and/or external actor(s), and/or eroding preconditions for sustainable development by indirectly increasing society's vulnerability (Juhola et al., 2016). Three broad typologies of maladaptation were defined as rebounding vulnerability (where adaptation strategies return unintended vulnerability outcomes to the farmer), shifting vulnerability (where adaptation strategies make nearby communities vulnerable), and eroding sustainable development (where adaptation strategies inhibit achievement of sustainable development [Juhola et al., 2016]). Adaptive strategies can culminate in unintended outcomes (Banette and O'Neill, 2010; Brown, 2011; Fazey et al., 2011). These studies placed emphasis on theoretical and conceptual aspects neglecting empirical aspects which could inform policy on the practical need to strengthen adaptive capacities of smallholders. Agricultural crop producers require adequate support systems through appropriate programs and strategies to substantially reduce, or remove, potential maladaptive outcomes associated with adaptive practices (Brown, 2011; Davis, 2012).

There has been recent studies on climate variability adaptation and crop production (de Pinto et al., 2012; Guodaar, 2015; Guodaar et al., 2017c; Masahumi et al., 2011; Yaro, 2010). While these studies document evidence of strategies employed by smallholder farmers in adapting to climate variability across spatial locations, studies relating to how adaptation strategies of farmers can produce maladaptive outcomes are limited (Rodriguez-Solorzano, 2014), particularly in sub-Saharan Africa. There is also an absence in literature on the predictors of maladaptive outcomes of adaptation strategies. This study was undertaken to document the outcomes associated with adaptive measures of tomato farmers using Ghana as a case study. This study was undertaken to find answers to the following questions: (1) how do tomato farmers perceive climate variability effects on tomato yield, (2) what socioeconomic factors influence tomato farmers' perceived effects of climate variability on tomato yield, (3) how have tomato farmers responded to their perceived effects of climatic variations on tomato yield, (4) what are potential unintended maladaptive outcomes of tomato farmers' adaptive strategies to climate variability, and (5) what factors predict potential maladaptive outcomes of farmers' adaptation strategies.

Materials and methods

The study is part of a larger project conducted in the Offinso North District of Ashanti Region, Ghana, where previous studies centered on climate variability effects on tomato production and adaptation practices and barriers (Guodaar and Asante, 2018; Guodaar et al., 2016, 2017b). The Offinso North District was selected for its notable production of tomato in Ghana. The district is characterized by a bimodal rainfall pattern with a mean annual rainfall total ranging between 700 and 1200 mm. The major rainy season begins in March and continues to mid-July, the minor season rains start from

September and continues to mid-November. Minimum temperature in the region is 30°C in March/April; mean monthly temperature is 27°C.

The main livelihood is farming which engages over 70% of the active labor force. The area contains large tracts of land which remain uncultivated due to distance and financial constraints. The major vegetable crops are tomato, pepper (*Capsicum annuum* L), and okra [*Abelmoschus esculentus* (L.) Moench].

A survey using triangulation of quantitative and qualitative methods was used to obtain answers from tomato farmers on their perspectives of negative outcomes of adaptation strategies to climate variability. The focus on tomato farmers was because of their adoption and application of adaptation strategies in resolving climate variability risks. The approach provides an avenue for better coherence and understanding of the problem under investigation (Creswell, 2010). There were face-to-face interviews with respondents using structured interview guides administered to 378 smallholder tomato farmers sampled from the tomato farming population in the communities of Akomadan, Afrancho, and Nkenkaasu. Selection of respondents from the communities was based on systematic proportionate sampling where the nth term of respondents was selected from the sampling frame of tomato growers' association in the district. The nth term for each community was calculated based on the respective sampling frames. The calculation of the nth term was done for each community by dividing total population for the community by sample size of that community. A simple random sampling with a lottery method was used to select the starting point for the systematic sampling in each community. This sampling strategy was appropriate and preferred to other probability sampling techniques for its simplicity and periodic quality. The choice of the study communities was based on advice from the District Directorate of the Ministry of Food and Agriculture. The survey instruments covered the broad areas: (a) biographic information of farmers, (b) perceived changes in tomato production, (c) perceived effects of temperature and rainfall variability on tomato yield, and (e) adaptive strategies generally practiced by tomato farmers in response to climate variability.

Focus group discussions totaling 16 discussants were organized to solicit in-depth views from selected experienced tomato farmers (12) and extension officers (4) of the District Directorate of the Ministry of Food and Agriculture about potential maladaptive outcomes of tomato farmers' adaptive strategies to climate variability. The focus group discussions were moderated to ensure all farmers were able to express themselves in a comfortable environment. The focus group discussion protocol covered the dimensions: (a) background information of farmers, (b) adaptation strategies preferred by tomato farmers, and (c) potential unintended outcomes associated with farmers adaptive strategies. The qualitative results were triangulated with quantitative results to determine the extent of farmers adaptive strategies leading to unintended negative outcomes.

The study solicited views of smallholder tomato farmers about their awareness of potential maladaptive outcomes of farmers' adaptive strategies to climate variability using a binary format, "Yes" or "No" (Table 7). Descriptive statistics was used to indicate farmers' perspectives of negative outcomes of adaptation strategies. A binary logistic regression was used to determine the factors influencing perspectives of farmers about effects of climate variability (temperature and rainfall) on tomato production. A multiple regression was used to determine predictors of maladaptive outcomes of adaptation strategies. Independent factors considered for regression analyses included gender, age, level of education, farming experience, farm size, access to credit, and extension services. Data were analyzed with frequency, percent, and regression in SPSS (ver. 21, SPSS Inc., Chicago, IL). Analysis of variance in SPSS was used to determine differences between study sites on adaptation practices and potential negative outcomes of such practices. The qualitative data from focus groups were analyzed using Dey's (1993) thematic content analysis model for qualitative analysis involving transcription, categorization, and interconnecting.

Results and discussion

Biographic data of respondents varied (Table 1). Respondents were relatively youthful with a large minority of respondents within a physically active range indicating that the farming population has the potential to undertake sustainability of tomato production. This also occurred across communities as a majority of the farming population were between 31 and 50, especially in Akomadan and Nkenkaasu. Most respondents were male implying that they were normally heads of households and would engage in farming to increase food production and enhance the quality of lives of the family. Age differentials of male and female respondents across the study sites were not different from the general population. There was a low level of formal education among respondents with a large minority having no formal education, especially within Afrancho where most people quit school and joined their parents on the farm. A sizeable minority had education at middle or junior high level and small minorities had education at the primary or secondary school level. The situation was spatially different across communities as most respondents at Afrancho had a low level of education compared to the other communities. Individuals in this community are attached to their farms more than other endeavors. This is because on the farms they have opportunities to earn money at early stages of their lives to improve their livelihood. Education is considered to be time consuming as a means to

Table 1. Descriptive statistics of biographic data of respondents, n = 378.

	Percent			
Socio-demographic characteristics	Akomadan	Afrancho	Nkenkaasu	Total
Age (years)				
<20	4.4	1,4	6.9	3.7
20-30	10.1	6.8	8.3	8.5
31-40	47.2	42.2	25	41
41-50	30.8	44.2	50	39.7
>50	7.5	5.4	9.8	7.1
Sex				
Male	66	70.1	75	69.3
Female	34	29.9	25	30.7
Educational level				
Primary	15	10.2	23.6	14.8
Middle/Junior High	42.8	24.5	41.7	35.5
Senior High	3.8	9.5	0.0	5.3
No formal education	38.4	55.8	34.7	44.4
Farming experience (years)				
<10	10	8	11	3.1
10-20	30	12	24	42.9
21-30	42	52	36	42.6
31-40	13	17	19	9.8
>40	5	11	10	1.6
Farm size (ha)				
0.40-0.81	13	14.5	15	13
1.21-1.62	38	37.2	42	41.8
2.02-2.43	30	25	28	31.2
2.83-3.24	11	13.3	9	10
>3.64	8	10	6	4.0

improve livelihood and prosperity. The lack of education may influence adoption of practices in response to climate variability.

Respondents had some level of farming experience with a small minority cultivating tomatoes for <10 years, and large minorities having cultivated tomatoes between 10 and 20 or 21 and 30 years. Small minorities cultivated tomatoes between 31 and 40 years. A very small number cultivated tomatoes for >40 years. Farming experience contributes to the probability of influencing adaptive strategies and capacities in response to impacts of climate variability.

Farm size of respondents varied with a large majority cultivating between 1.21 and 1.62 ha or 2.02 and 2.43 ha. Smaller minorities cultivated farm plot sizes between 0.40 and 0.81 ha, 2.83 and 3.24 ha, or 3.64 ha or more. Most respondents that cultivated between 1.21 and 2.43 ha could be attributed to the land tenure system where chiefs are owners of most of the land and sell out for infrastructure and other developmental purposes. Individual access to land has become limited due to population increases which may have necessitated sale of lands.

Views of tomato farmers about production varied across the study communities (Table 2). Most respondents experiencing reduced production attributed it to variability of temperature and rainfall. A small minority were uncertain about impacts of temperature and rainfall on tomato production. Only a few

Table 2. Descriptive statistics of farmers perceptions (n = 378) of climate variability impacts on tomatoes.

	Percent			
Production changes for tomato	Akomadan	Afrancho	Nkenkaasu	Total
Increase	1.1	1.0	1.1	3.2
Decrease	30.3	20.1	20.0	79.4
No change	6.2	5.1	6.1	17.4
Effects of high temperature on tomato				
Negative	40.7	24.0	29.0	93.7
Positive	1.0	4.0	1.3	6.3
Effects of rainfall variability on tomato				
Negative	42.0	26.5	25.1	93.1
Positive	2.4	2.0	2.5	6.9

respondents perceived increases in tomato production over the period. This agrees with Orindi (2009) who stated that yield from rain-fed agriculture could potentially be reduced up to 50% threatening food security and increasing poverty in sub-Saharan Africa. Almost all respondents thought that high temperature adversely impacted tomato production (Table 2). High temperatures, especially during the flowering stage, induce flower abscission, malformed flowers, and pollen sterility in tomato resulting in poor fruit quality which affects yield (Masahumi et al., 2011).

Almost all respondents in the study communities were convinced that rainfall variability had adverse effects on tomato production (Table 2). This supports Sinnadurai (1992) who reported that variable rainfall adversely affects production, processing, distribution, and consumption of tomato products. A reduction in rainfall could affect soil moisture content with a greater potential to cause a significant decrease in crop production (Tshiala and Olwoch, 2010).

A large majority of respondents perceived an effect of climate variation on tomato to be poor yield. This was followed by those who perceived effects of climate variability leads to inadequate tomato supply, and a last group that perceived climatic variation caused high incidence of tomato diseases. A small minority perceived climate variation adversely affected livelihood (Table 3). A majority of farmers attributed decreasing tomato yield to climate variability. The overall effect is that decreases in tomato yield will ultimately affect tomato supply and livelihoods of farmers. A decrease in tomato production will

Table 3. Descriptive statistics of farmers perceived effects of climate variability on tomato production, n = 378.

	Percent			
Response	Akomadan	Afrancho	Nkenkaasu	Total
Poor tomato yield	21.3	8.7	15.2	45.2
Inadequate tomato supply	10.1	9.3	7.6	27
High incidence of tomato disease	9.4	4.1	7.6	20.1
Adverse effects on livelihoods	4.7	3.0	0.0	7.7

indirectly affect other sectors of the economy (e.g., tomato processing industries) which will consequently impact sustainable growth and development. High temperatures usually delay flowering and reduce numbers and size of tomato flowers which ultimately affects yield (Sinnadurai, 1992). He stated that tomato sensitivity to high temperatures matters when flowers and pollen are formed, and during pollination and fertilization. Excessive rainfall reduces light intensity and adversely affects tomato yield and increases incidence of diseases of tomatoes (Mensah et al., 2013).

The binary logistic regression indicated the factors influencing farmers' perception of effects of climate variability on tomato production (Table 4). Age, level of education, farming experience, and farm size are factors significantly influencing farmers' perceived effects of climatic variation on tomato production. Age of respondents was significant, and positive, for perceiving temperature variability to have a significant effect on tomato production. Older farmers are more likely to perceive that a rise in temperature affects tomato production than do younger farmers. The coefficient of farmers' age was positive regarding the perceived overall effect of rainfall variability on tomato production.

The coefficient of education of farmers was significant, and positive, for those who perceived a rise in temperature to have an impact on tomato production. This finding is consistent with Mustapha et al. (2012) who identified a positive relationship between education level of farmers and their perspectives of climate variability. Farming experience of respondents was significant, and positive, for those who perceived rainfall variability to impact tomato production.

Farm size was significant, and positive, for respondents who perceived temperature rise to adversely impact tomato production. Farming on a large farm size requires substantial investment throughout the production processes. The perception of rainfall variability on tomato production was significant, and positive, with farm size. There is a possibility that as farmers increase farm

Table 4. Logistic regression results of factors influencing farmers' perceived effects of climate variability on tomato.

	Temperature rise effect on tomato			Rainfall variability effect on tomato		
Variable	*B*	SE	*p*-Value	*B*	SE	*p*-Value
Gender	−0.378	0.486	0.44	−0.260	0.633	0.68
Age	1.025*	0.280	0.00	2.83*	0.478	0.00
Level of education	1.078*	0.510	0.03	0.306	0.616	0.62
Farming experience	0.640	0.546	0.24	1.38*	0.707	0.05
Farm size	0.648*	0.267	0.01	1.39*	0.475	0.00
Access to credit	−18.136	8080.858	0.99	−18.069	7984.557	0.99
Economic diagnostic						
Chi^2 value: 36.560, $p > Chi^2(6) = 0.00$						
Chi^2 value: 85.101, $p > Chi^2(6) = 0.00$						

*Significant at 5% level.

size, without irrigation to augment production, tomato crops become more vulnerable to rainfall variability and its associated risks.

Respondents' perception of effects of climate variability on tomato production affected decisions in employing adaptation strategies to reduce vulnerability associated with the phenomenon. While some adaptation measures were on-farm, others were off-farm depending on financial capacity of farmers' coupled with other farm resources (Table 5). The respondents identified adaptive strategies to contend with climate variability effects on tomato production as changing the location of farm, changing the crop variety, crop diversification, application of agrochemicals, mixed cropping, irrigation, diversification to nonfarm activities, and migration. There were some statistically significant differences between farmers' adaptive strategies across communities (Table 6). While the majority of farmers at Akomadan diversified to other nonfarm activities, those at Nkenkaasu and Afrancho did not. While the majority of farmers at Nkenkaasu resorted to migration as livelihood alternatives to climate change, those at Akomadan and Afrancho did not. The most preferred strategies were crop diversification, application of agrochemicals, and mixed cropping. A majority changed farm location largely because of financial concerns. A major reason why most farmers changed the location of farm plots was to reduce localization of pests and diseases which can detrimentally affect tomato crop yield. Changing farm location provided an opportunity for the land to fallow which was perceived as a benefit.

A large majority did not change the tomato variety used. Females agreed to changing varieties, males did not. Female farmers who did not change the tomato variety explained it was for marketing reason. Males who changed varieties explained it was for high tolerance and resistance to diseases. Male and female respondents unanimously agreed that having different varieties of

Table 5. Adaptation practices of farmers as a response to climate variability, $n = 378$.

	Akomadan		Afrancho		Nkenkaasu		Total	
Farmers adaptation strategies	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Change in farm location	37.7	62.3	25.9	74.1	27.8	72.2	31.0	69.0
Change in crop variety	18.9	81.1	22.5	77.6	22.2	77.8	20.9	79.1
Crop diversification	77.4	22.6	65.3	34.7	72.2	27.8	71.7	28.3
Application of agrochemicals	100	0	100	0	100	0	10	0
Irrigation	32.7	67.3	19.0	81	30.6	69.4	27.0	73.0
Mixed cropping	87.4	12.6	76.9	23.1	68.1	31.9	79.6	20.4
Diversification to nonfarm activities	54.7	45.3	27.2	72.8	30.6	69.4	39.4	60.6
Migration	31.4	68.6	30.0	70.1	54.2	45.8	35.2	64.8

Table 6. Analysis of variance for adaptation strategies across communities.

	Sum of squares	df	Mean square	*F*	Sig.
Between communities	111.321	2	55.660	15.038	0.000
Within communities	1388.013	376	3.701		
Total	1499.334	378			

tomato gives them the option and opportunity to make a choice to meet consumer demand.

Diversifying from tomato to other crops was adopted by most respondents in mitigating effects of climatic variables on tomato productivity. Diversification to other crops prevents buildup of pests and diseases. Diversifying crops helps improve farmers' economic livelihood by reducing risk associated with growing a single crop (Uddin et al., 2014).

Irrigation was employed by a small minority of respondents. Use of irrigation as a strategy helped farmers cultivate crops without concern for rain. Farmers that did not have access to modern irrigation due to economics used watering cans. Access to irrigation equipment was a major barrier to tomato farmers' adaptation strategies to climate variability. Affordable irrigation materials could increase production and improve livelihood opportunities, especially during the dry season when surface water is lacking (Tshiala and Olwoch, 2010).

All farmers applied agrochemicals, fertilizers, and pesticides. Mixed cropping was a common practice among farmers. Corn (*Zea mays* L.), okra, and pepper were the predominant crops cultivated with tomatoes on the same land. The rationale for mixing crops was that the other crops served as insurance against crop failure.

Diversification into nonfarm activities was another strategy among a majority of smallholder tomato farmers. The diversification strategy of some of farmers helped to offset consequences of climatic variability on tomato. Even though some farmers held the view that tomato farming as a business is a legacy, they recognized the significance of diversification in providing an opportunity to improve their livelihood. As diversification provided an alternative livelihood strategy, it removed them from agriculture. For instance, most respondents at Akomadan diversified to nonfarming activities.

A small number of respondents resorted to migration as an adaptive strategy in response to effects of climate variability on tomato production. The migration adopted by farmers was rural–urban. The rationale for most migration was to seek alternative livelihood in cities where menial jobs are available compared to rural areas. While some active populations migrated to cities, others migrated to seek protection from financial obligations.

Generally, a large majority of farmers indicated that they are aware of a potential maladaptive outcome resulting from adaptation strategies in response to climate variability (Table 7). Farmer opinion indicated that adaptation strategy could erode sustainable development or shift or rebound vulnerability (Table 8). There was no difference between negative adaptive outcomes across the communities (Table 9). Application of agrochemicals, especially chemical fertilizers, was identified by a majority of smallholders as an adaptive strategy that could potentially become maladaptive (Table 10). According to farmers if these chemicals leach, or drain, into water bodies, it could reduce biodiversity and adversely affect inhabitants within catchment communities and sustainability of the aquatic

Table 7. Awareness of unintended maladaptive strategies of farmers, n = 378.

	Akomadan		Afrancho		Nkenkaasu		Total	
Farmers perception of potential maladaptive outcomes	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Response	34.9	3.0	38.9	2.1	19.0	2.0	92.8	7.1

Table 8. Unintended maladaptive outcomes of tomato farmers' adaptation strategies to climate variability.

Adaptation strategy	Unintended maladaptive outcome	Type of maladaptation
Changing crop variety	N/A	N/A
Application of agrochemical	• Release greenhouse gas • Pollute nearby water bodies • Increase soil acidity above the optimum requirement of crops	• Erode sustainable development; shifting vulnerability
Migration rural–urban	• Affect household farm labor • Increase vulnerability of dependents • Increase pressure on social facilities	• Shift vulnerability; rebounding vulnerability
Crop diversification	N/A	N/A
Irrigation	• Conflict for water accessibility and use	• Eroding sustainable development; shifting vulnerability
Changing farm location	• Deforestation • Increase greenhouse gases • Reduce biodiversity through slash and burn method of farming	• Eroding sustainable development
Mixed cropping	• Competition for nutrients, moisture, and sunlight • Enhances the spread of pest and diseases	• Rebounding vulnerability
Diversification to nonfarm activity	N/A	N/A

Table 9. Analysis of variance of maladaptive strategies across communities.

	Sum of squares	df	Mean square	F	Sig.
Between communities	0.549		0.275	1.277	0.280
Within communities	80.615	375	0.215		
Total	81.164	378			

Table 10. Unintended maladaptive response to strategy of farmers, n = 378.

	Akomadan		Afrancho		Nkenkaasu		Total	
Farmer adaptation strategy resulting in negative outcomes	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Changes in farm location	57.0	43.0	60.0	40.0	55.0	45.0	59.0	41.0
Application of agrochemicals	70.0	30.0	85.0	15.0	74.0	26.0	73.5	26.5
Mixed cropping	55.0	45.0	69.0	31.0	72.5	27.5	79.6	20.4
Irrigation	78.0	22.0	57.0	43.0	67.0	33.0	69.0	31.0
Migration	82.5	17.5	78.3	21.7	76.2	23.8	65.7	24.3

ecosystem. Application of agrochemical is a potential maladaptive strategy (Zhao et al., 2013). The lack of access to water could expose community members to diseases which could reduce adaptive capacity of farmers. This will increase vulnerability of farmers and households around catchment communities as well as erode sustainability of environmental resources and well-being of people in nearby communities. Chemicals used by tomato farmers have the potential to increase soil acidity which could be detrimental to growth and yield of tomato crops, especially when it is beyond its optimum.

Migration was identified as a potential maladaptive strategy by a majority of respondents.

Internal migrations adopted by some farmers (generally the youth), especially to urban centers where menial jobs are available, pose adverse effects to the migrants, out-migrated communities, and recipient communities. Former farmers in the Offinso North District migrated because of inability to pay farming loans due to crop failure. They migrated to cities to look for jobs to enable them pay back loans and improve their livelihood. The unintended outcome associated with this movement of farmers to cities affects the out-migrated household's farm labor. Since most farmers who normally migrate are the youth, the elderly and dependents in their households are mostly left behind. The implication is that farm labor is reduced and vulnerability of the aged and dependents is increased. Migration increases pressure on limited social facilities culminating in poor quality of life (Adepoju, 1995). The vulnerability of migrants is shifted to the receiving inhabitants and creates possible undesirable consequences on the migrants making them more vulnerable.

Though irrigation is regarded as an effective measure to increase water accessibility to farmers to help improve production, there were reported cases of unwanted consequences attached to the practice. A large majority of respondents identified competition and shifting of vulnerability as potential maladaptive outcomes when irrigation is adopted. It is possible to create conflict because of shifting vulnerabilities. These actions can prevent catchment communities from getting sustainable water to support their quality of life. Irrigation may result in less water becoming available for domestic uses (Antwi-Agyei et al., 2018).

A majority of respondents determined change in farm location had a potential maladaptive outcome due to deforestation through preparation of new land for farming. In most cases, tomato farmers abandoned their original farms to other places because the land had lost its fertility. Even though it is considered a good practice, there is a potential maladaptive outcome associated with it. In the process of preparing the new land for farming deforestation occurs and native understory vegetation is removed. This can increase carbon dioxide concentration in the atmosphere which in turn warms the atmosphere and changes dynamics of rainfall and temperature. Deforestation leads to loss of biodiversity affecting sustainability of forest resources which have economic value. There is a direct relationship between adaptive strategies of farmers and environmental degradation culminating in the increase in greenhouse emissions (Banette and O'Neill, 2010).

Mixed cropping was identified by a majority of respondents as having potential to reduce vulnerability of tomato farmers. The mixed crops can compete for nutrients, moisture, and sunlight. The effect is that competition for nutrients may hamper development of tomato crops causing reduction in yield. The reduction in yield may in turn increase vulnerability of tomato farmers through reduction in income which may affect poverty level. Even though intercropping could be argued to reduce pest and disease problems due to some crops not being able to appeal to insects, when other crops are mixed with tomato on the same land, there is the higher possibility of transfer of pests and diseases to the tomato crop which could cause a reduction in tomato production and income levels of the farmers.

A multiple regression indicated predictors of farmers' perceived maladaptive outcomes of adaptation strategies (Table 11). Age, gender, formal education, farming experience, and access to extension services are predictors of farmers' perceived maladaptive outcomes to adaptation strategies. Gender of respondents was significant, and positive, for farmers perceiving application of agrochemicals as adaptation strategies that could turn out to be maladaptive. More males who engage in tomato production, particularly application of agrochemicals, are likely to understand the dynamics of how agrochemical application can become maladaptive. Gender was significant, but negative, for farmers perceiving migration as maladaptive. Since men usually migrate to cities to search for opportunities leaving the women behind, they are likely to experience the adverse effects of migration as an adaptive strategy.

The coefficient of age of respondents was significant, and positive, regarding farmers' perspective of mixed cropping and migration resulting in maladaptive outcomes. As farmers grow older, they are more likely to perceive negative outcomes of adaptation strategies.

Farmers' access to formal education was significant, and positive, for perceiving change in farm location, application of agrochemicals, and irrigation as strategies that can produce negative outcomes. Formal education increases knowledge level and broadens their perspectives of understanding of the environment, particularly regarding environmental changes. Farmers with formal education are more likely to understand adverse effects of human impact on the environment.

Farming experience was significant, and positive, for farmers perceiving changes in farm location, application of agrochemicals, and mixed cropping as adaptive strategies which can produce negative outcomes. As farmers gain experience on application of adaptation strategies, they are likely to identify potential strategies that can be maladaptive. Experienced farmers' perception of maladaptive outcomes is more likely to relate to the on-farm adaptation

Table 11. Predictors of farmers' perceived maladaptive outcomes of adaptation strategies.

Variable	Changes in farm location		Application of agrochemicals		Mixed cropping		Irrigation		Migration	
Gender	Parameter	Odds ratio	Parameter	Odds ratio	Parameter	Odds ratio	Parameter	Odds ratio	Parameter	Odds ratio
	−16.300 (393.4)	8.33	1.639** (0.552)	0.19	−1.445 (0.576)	0.24	−0.584 (0.635)	0.56	−1.188** (0.723)	0.31
Age	0.319 (0.513)	1.38	0.353 (0.421)	0.70	0.469** (0.438)	1.59	0.198 (0.458)	0.82	1.805** (0.521)	0.17
Formal education	1.722** (0.616)	5.59	0.609** (0.521)	1.83	0.491 (0.543)	1.60	2.336** (0.597)	10.34	−0.216 (0.671)	0.81
Marital status	0.416 (0.437)	1.52	0.600 (0.304)	1.82	0.173 (0.316)	1.12	0.630 (0.337)	1.87	−0.450 (0.656)	0.64
Farming experience	0.968** (0.851)	2.63	0.668** (0.675)	1.95	0.883** (0.723)	2.42	0.159** (0.727)	0.85	1.212 (0.990)	3.36
Access to extension service	0.632 (0.343)	0.53	0.357** (0.305)	0.70	0.836** (0.320)	0.42	0.637** (0.350)	1.89	0.225 (0.377)	1.25
Chi^2 value: 1491.703, $p > Chi^2(6) = 0.00$										

**Significant at 0.05; standard error (SE) in parentheses.

strategies changing farm location, application of agrochemicals, mixed cropping, and irrigation.

The coefficient of access to extension services of farmers was significant, and positive, for perceiving application of agrochemicals, mixed cropping, and irrigation to produce negative outcomes. Extension services often involve education on application of technologies, e.g., irrigation, use of modern crop varieties, and agrochemical application, and agronomic practices that can improve crop yield. Farmers who have access to extension services are more likely to gain knowledge helping them identify negative outcomes resulting from adaptation strategies.

Climate variability is a serious environmental challenge facing agriculture. Improving adaptive capacities of farmers could improve tomato production and enhance farmers' economic livelihood.

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