# Small-holder Farmers’ Perceptions of the Impacts of Climate Change on Maize Crop in Dodoma, Tanzania

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## Abstract

*Farmers have different perceptions of the impacts of climate change. This study examined smallholder farmers’ perceptions of the impacts of climate change on maize crops in Dodoma, Tanzania. A total of 216 household heads were involved in this study. The study used a cross-sectional design, where structured interview, Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) were used to collect both qualitative and quantitative data. Quantitative data were analysed using descriptive and inferential statistics, while qualitative data were analysed using content analysis. It was found that 69% of respondents perceived that climate change strongly has changed significantly over the last three decades. About 50.5% and 51.9% of the respondents highly agreed that climate change has contributed to the increase of weeds and pests or/and insects attack on the maize crops, respectively. The findings further revealed that age, farmland ownership, income, and education level of the small-holder farmers had a significant association with the perception of the impacts of climate change among smallholder farmers of maize at P<0.050. The study concludes that small-holder farmers’ perceptions of the impacts of climate change on maize crop are determined by their socio-economic and demographic factors. Thus, it is recommended that smallholder farmers should be provided with the sufficient knowledge of the impacts of climate change on maize crop so that they can have a proper understanding of the impacts of climate change and variability of maize crop. The farmers could use that knowledge to improve productivity.*
**Keywords:** Perception; smallholder farmers; Climate Change, Maize crop.

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Received on November 17th, 2022/Accepted on May 13th, 2023

## Introduction

The impacts of climate change are one of the serious problems confronting smallholder farmers, particularly in developing countries (Intergovernmental Panell on Climate Change (IPCC), 2022; Mushy, 2017; Twinomugisha & Mushy, 2020). The impacts, however, differ from one area to another depending on the level of technology, nature of the people, geographical location, crops cultivated, and level of affluence (Hirpha et al., 2020). The impacts of climate change on crops cultivation are so vivid in Sub-Saharan Africa, particularly in the semi-arid ecological regions. Long dry seasons, frequent recurrence of drought, irregular and short rainfall seasons, which have been experienced in recent decades (IPCC, 2014) have affected crops production including maize (Belay et al., 2017). Meanwhile, most of the small-holder farmers are incapable of adapting to climate change because of various reasons (Marie et al., 2020). The reasons include low levels of technology and affluence, a lack of timely and proper climate change information, and a lack of drought-tolerant seeds (Twinomugisha & Mushy, 2020).

Tanzania is not different from other Sub-Saharan African countries; maize, one of the common staple crops which are cultivated by the majority of small-holder farmers, has been also affected by Climate Change (CC) (Mkonda & He, 2017a). A large quantity (85%) of maize is produced by smallholder farmers (Stephen et al., 2014; Ismail et al., 2015). In recent years, however, the production of maize has been affected by climate change (Ephrahim & Fadhili, 2015; Mkonda & He, 2017a; Mkonda & He, 2017b). For instance, in the Kongwa district council of the Dodoma region, the production decreased from 41,500 tons (1.08 tons/ha yield) in 2006/2007 to 30,120 tons (0.63 tons/ha yield) in 2009/2010, from 25,900 tons (0.6 ton/ha yield) in 2010/2011 to 30,900 tons (0.5 ton/ha yield) in 2014/2015 (The United Republic of Tanzania (URT), 2020). Besides, Mkonda and He (2017b) reported that from 1980 to 2015, maize production in Kongwa district has been decreasing at a range of 2.2 to 1.5 tons per hectare $^{-1}$ due to climate change. Smallholder farmers have different perceptions about climate change variables and how these changes affect crop production as a result of the climatic effects on crops (Ndamani & Watanabe, 2016). For instance, some people perceive that rainfall seasons, intensity, and temperature have changed dramatically, while others perceive that little has changed (Falaki et al., 2012; Adebisi-Adelani & Oyesola, 2014; Rusinga et al., 2014). Similarly, there are different farmers' perceptions on how the changes have affected soil moisture and increased the presence of pest/insects, weeds, and diseases, thus affecting crop production (Mongi et al., 2010). Similar to the perceptions of climate change, farmers' perception of the effects of climate change on crop production vary from high, moderate, to low. Farmers of different crops also have different perceptions of the effects of climate change on their crops (Komba & Muchapondwa, 2018).

Some farmers have different perceptions, believing that the decline in crop production is unrelated to climate change. Instead, they believe that a decline in crop production has been contributed by factors such as poor farming methods, inadequate extension services, soil infertility, pests, and diseases (Mongi et al., 2010). Thus, it is important to examine the perceptions of smallholder farmers of maize crop, since their perceptions may determine the selection of their adaptation strategies. What is certain is that, farmers have different perceptions of the effects of climate change on crop production (Yusuf, 2018; Twinomugisha & Mushy, 2020). However, their perceptions are different, and they are influenced by different socio-economic activities (Yusuf, 2018). How the perceptions of smallholder farmers of maize crop in Kongwa are influenced by different socio-economic factors has remained an area of investigation, as there are limited empirical findings on this. The existing studies that have been conducted in Kongwa examined the impact of climate change on crop performance and crop yield and climate change adaptation strategies (Gwambene & Majule, 2010; Chitimbe & Liwenga, 2015; Mkonda & He, 2018; Gamba et al., 2020). Other similar studies elsewhere (Tazeze et al., 2012; Yila & Resurreccion, 2013; Ndamani & Watanabe, 2016; Marie et al., 2020; Tangonyire & Akuriba, 2020) have examined the influence of socio-economic activities on the adoption of climate change adaptation strategies. What influenced smallholder farmers to have different perceptions of climate change impacts on maize crop has remained an area worthy of investigation. This study intended to fill the existing knowledge gap. Because maize is important for food security, it is critical to investigate smallholder farmers' perceptions of the crop's impact at the time the crop is affected by climate change. The findings of this research will be used to assist smallholder farmers in adopting climate change and vulnerability adaptation strategies.

The findings of this study contribute to the discussion of smallholder farmers' perceptions of the impact of climate change on maize crop production and how it helps improve maize crop production at the household level. The findings are aligned with the Sustainable Development Goals 2 (SDGs) "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture", and the 13$^{th}$ SDG 'Take urgent action to combat climate change and its impacts'. Thus, the current findings will substantially enhance climate change adaptation strategies among smallholder farmers that will improve maize production.

## Materials and Methods

### *Study area*

The study was conducted in Kongwa District, Dodoma (Figure 1). Kongwa District is found in the drought-prone semi-arid agro-ecological region in the central part of Tanzania. The study area is located between latitudes 5$^{o}$30' to 6$^{o}$00' South, and longitudes 36$^{o}$15' to 36$^{o}$00' East (Chitimbe & Liwenga, 2015; URT, 2016; Mkonda & He, 2017a). It occupies a land area of about 404,100 ha (Mkonda & He, 2017a).

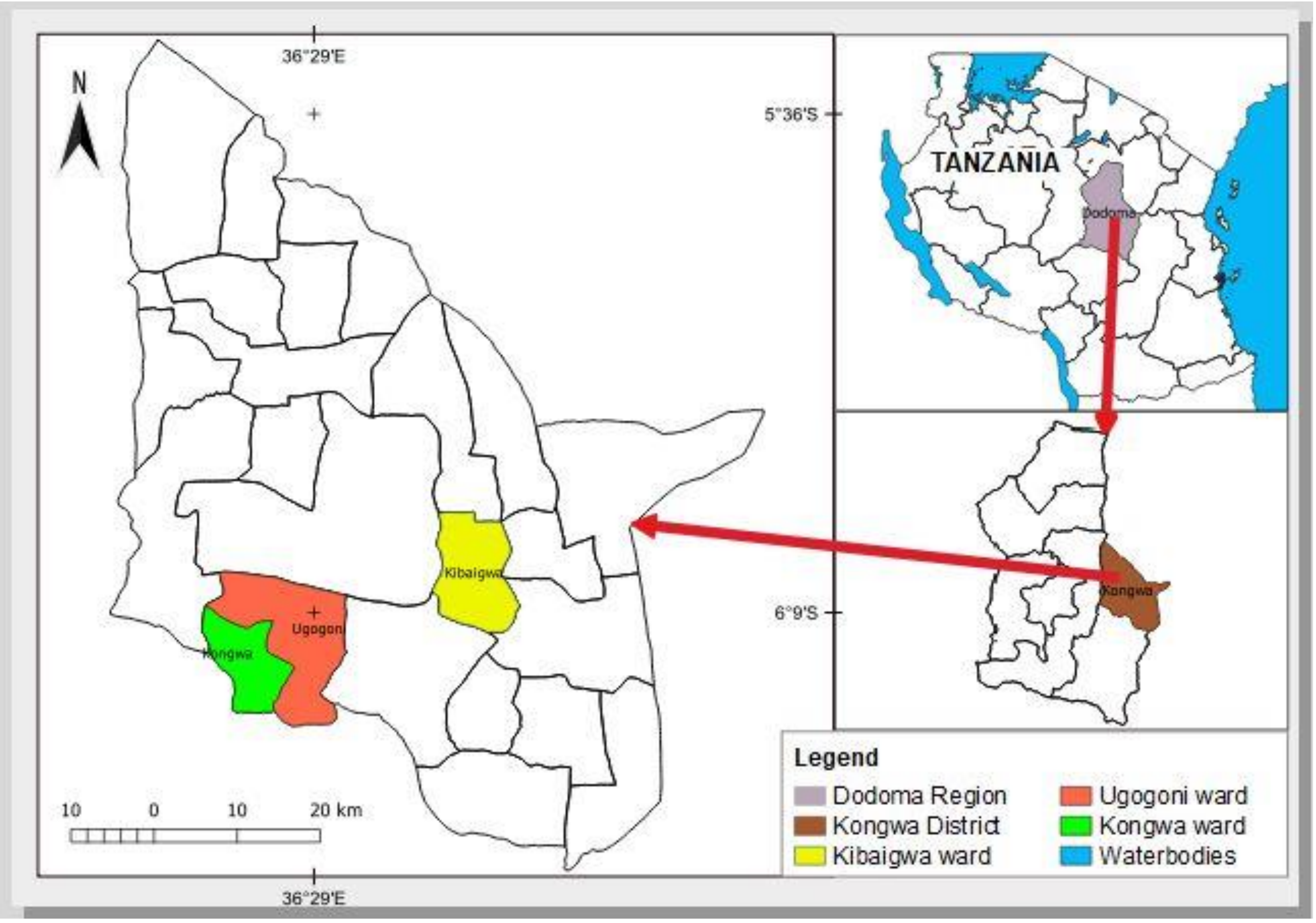


Figure 1: The Location of Selected Study Wards in Kongwa District, Dodoma Region

Kongwa District cultivates about 63,900 ha area of maize. The production was estimated to reach 41,500 tons (1.08 tons/ha yield) in 2006/2007 (URT, 2020). Such an area and amount of maize production is large compared to the semi-arid agro-ecological region in the central part of Tanzania (URT, 2020). According to Mkonda and He (2017a), Kongwa district has a total annual precipitation range from 400 to 600 mm in the northern part, while in the southern part, it ranges from 600 to 800 mm, with the maximum rain between December and April. The mean annual temperature varies from a mean minimum of 18°C to a maximum of 34°C.

***Data collection***

This study used a cross-sectional design to collect and analyse both quantitative and qualitative data. The study used purposive and random sampling techniques in selecting participants and the study area. Kongwa district was purposely selected because over 95% of smallholder farmers cultivate maize crops, and the production of maize crops has been affected by climate change (Mkonda & He, 2018). Similarly, empirical study of climate change found that smallholder farmers' perceptions varied greatly among the smallholder farmers in Kongwa (Mkonda & He, 2017a). In addition, Kongwa, Ugogoni, and Kibaigwa wards were selected purposively because they are among the common areas of maize production in the Kongwa district; meanwhile, the areas experience climate change and its impacts on the production of maize crop (Mkonda & He, 2018). From each of the three selected wards, one village was randomly selected for the study. These villages are Mnase from Kongwa, Nyerere from Kibaigwa and Ugogoni from Ugogoni ward. The villages were randomly selected due to their similarities in household activities, environmental, and agricultural characteristics. Household heads of the smallholder farmers who were thirty (30) years and above were selected randomly using a list of household heads from the respective village executive officers (VEOs). Household heads aged at least 30 and above years were selected as they believed to possess enough experience of climate change and viability. Purposive sampling was used to select key informants deemed to have important information for the study.

A total of 216 household heads who were smallholder farmers (100 from Mnase, 72 from Nyere, and 44 from Ugogoni) (Table 1) were selected for a structured interview using questionnaires to collect quantitative data. Information collected from the smallholder farmers included socio-economic and demographic information (for example, household size, household age, gender, and education level), the small-holder farmers' perceptions on climate change, and their perceptions of the impacts of climate change on maize crop production. Smallholder farmers who were the heads of household were selected because they were the main decision makers within their households. Also, they possess enough experience on climate change and its vulnerabilities and impacts on maize production. Nine (9) key informants, consisting of three (3) village executive officers (VEOs), three (3) agricultural extension officers (AEOs), three (3) ward executive officers (WEOs), and 21 FGDs participants (7 from each village), also participated in this study. Information collected from key informants and FGDs were perceptions of climate change, perceptions of the effects of climate change on maize crops, the initiatives and support provided to maize small-holder farmers, such as education on issues related to climate change and its effects, especially on the maize crop, and communication (training, extension, and advisory services).

Table1. Selected wards and sample size

| Types of respondents | Ward | village | Total household | Sample |
|---|---|---|---|---|
| Smallholder farmers (Household heads) | Kongwa | Mnase | 327 | 100 |
| | Kibaigwa | Nyerere | 235 | 72 |
| | Ugogoni | Ugogoni | 143 | 44 |
| TOTAL | | | 705 | 216 |

Furthermore, rainfall and temperature data from 1980 to 2010 (a period of 30 years) were collected from the Tanzania Meteorological Agency (TMA) and meteorological station within the study area. A time period was selected to realise rainfall and temperature changes, since climate change in an area is observed in a period not less than a period of 30 years (IPCC, 2021). Rainfall and temperature data from TMA were authentic and reliable, so they were collected to augment the respondents' perceptions for a robust analysis of the results.

***Data analysis***

Qualitative data from key informants' interviews were analysed through content analysis (Drisko & Maschi, 2016). Data were transcribed, summarised and themes and subthemes were developed to be discussed alongside descriptive statistics. Trend analysis was used to analyse the rainfall and temperature data from TMA. Quantitative data from the questionnaire were analysed using IBM Statistical Product and Service Solutions (SPSS) version 20 software. A multinomial logistic regression model (Equation 1) was employed to identify factors influencing smallholder farmers' perceptions of climate change.

$$P\left(Y = \frac{1}{x}\right) = 1 - (P_1 + P_2 + \cdots P_j) \quad \text{(Equation 1)}$$

P1+P2+..........Pj= 1

Because the probabilities (p) must add up to one unit, P(y=j/x) can be calculated once th probabilities for j = 2 are known.

$$P\left(Y = \frac{j}{x}\right) = \frac{e^{\alpha_j + x\beta_j}}{1 + \sum e^{\alpha_j + X\beta_j}} \quad \text{(Equation 2)}$$

The referent category in the logistic or the multinomial logistic has e0, which is

$$P\left(Y = \frac{j}{x}\right) = pij = \frac{1}{1 + \sum e^{\alpha_j + \beta_j X}} \quad \text{(Equation 3)}$$

Where: P = Probability,

Y = Dependent variable represents the perceptions of smallholder farmers on climate change; Y denotes a random variable with values (1, 2…J).

*J* = total categories of outcome,

*j* = the number of response categories which are 1, 2....., (J-1), (J-1) = the number of comparisons.

*x* = x = an explanatory or independent variables representing socioeconomic factors. For instance, this includes variables such as household heads' age, household heads' gender, household heads' education, marital status of household heads, and farmland size,

x = βj (gradient),

αj = intercept

i = the attribute of an individual or number of respondents.

## Results

### *Climate Change Perceptions of Smallholder Maize Crop Farmers*

The findings of this study show that the overall mean score on the perception of climate change among maize smallholder farmers was 1.4. More than half of the interviewed smallholder farmers (69%) strongly agreed that the climate has been changing, while only a small number of respondents (4.6%)

disagreed. Besides, only 1.4% of the respondents were not sure whether the earth's climate has been changing or not (Table 2).

Table 2. Respondents' Perceptions on Climate Change

| Variable | Frequency (N= 216) | | | | | Mean |
|---|---|---|---|---|---|---|
| | Strongly Agree | Agree | Neutral | Disagree | Strongly disagree | |
| Climate has been changing over the last three decades | 150(69 %) | 53(25%) | 3 (1.4%) | 10 (4.6%) | 0 (0%) | 1.4 |

Key: (1) < 1- < 2 Strongly Agree, (2) ≥ 2 - < 3 Agree, (3) ≥ 3 - < Neutral, (4) ≥ 4 - < 5 Disagree, (5) ≥ 5 Strongly Disagree

According to the findings of this study, the overall mean score of farmers' perceptions of seasonal rainfall and temperature change was 2. About 36.1% of the respondents perceived that there were great changes in temperature throughout the seasons, only 11.1% perceived little change. None of the respondent said there were no changes in temperature (Table 3).

Table 3. Smallholder farmers' perceptions of seasonal rainfall and temperature changes

| Long-term changes | Frequency (N=216) | | | | | Mean |
|---|---|---|---|---|---|---|
| | Great changes | Some changes | Neutral | little changes | No changes | |
| Temperature | 78 (36.1%) | 83 (38.4%) | 31 (14.4%) | 24 (11.1%) | 0 (0%) | 2.00 |
| Rainfall duration | 113 (52.3%) | 73 (33.8%) | 15 (6.9%) | 15 (6.9%) | 0 (0%) | 1.69 |
| Rainfall intensity | 116 (53. 7%) | 70 (32.4%) | 15 (6.9%) | 15 (6.9%) | 0 (0%) | 1.67 |
| Overall Mean | | | | | | 2.00 |

Key: (1) ≥ 1- < 2 Great change, (2) ≥2 - < 3 Some changes, (3) ≥3 - < 4 Neutral, (4) ≥ 4 - < 5 little changes, (5) ≥ 5 - < 6 No changes

Trend analysis of the meteorological data indicates that the minimum temperature has been increasing by ($y = 0.008x-0.139$ $R^2 = 0.0016$) and the maximum temperature has been increasing by ($y = 0037x-0554$ $R^2 = 0.668$) since 1980 to 2010, (Figure 2).

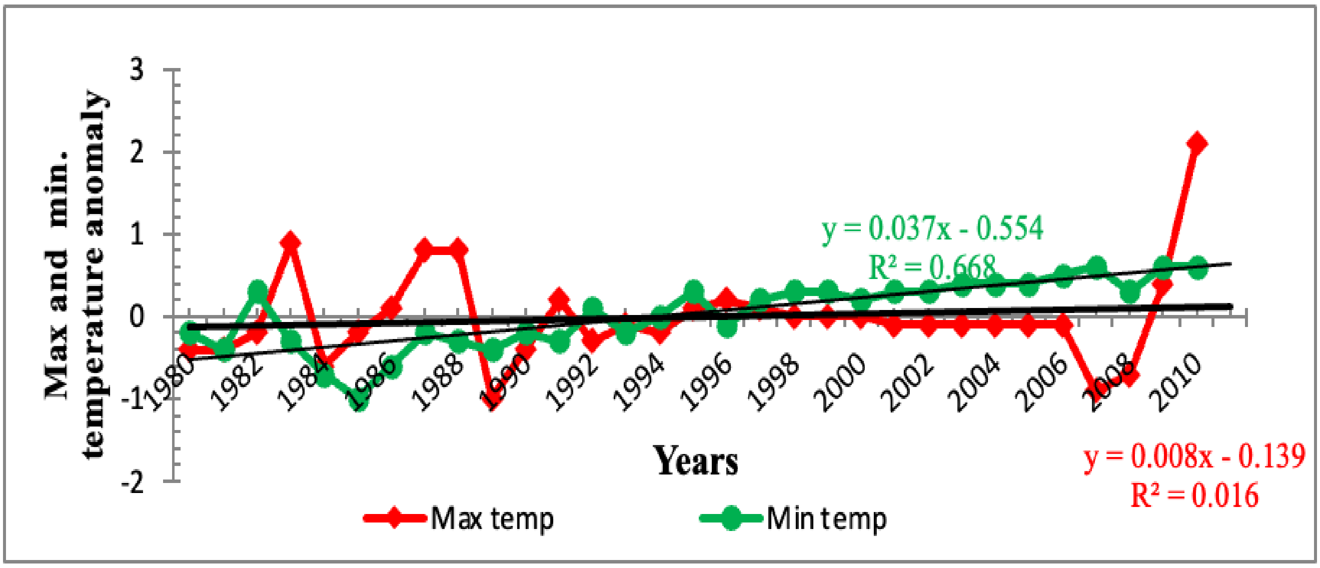


Figure 2: Trends of Maximum and Minimum Temperature Anomalies for Annual Average Temperature from 1980 to 2010

For the case of rainfall irregularities, 52.3% of the respondents perceived some changes in rainfall duration. Similarly, 53.7% of the respondents perceived a change in rainfall intensity (Table 2). None of the respondents said there was no change in the duration and intensity of rainfall during the known climate seasons. The findings from structured interviews correspond to the findings from the key informant interviewees, as most of the interviewees from all three wards (Kongwa, Ugogoni, and Kibaigwa) have been experiencing an increase in long dry spells and irregularity in rainfall seasons. They further reported that in 2020, Kongwa experienced high rainfall intensity.

One of the key informant interviewees said:

> *"Kongwa District has seen an increase in long dry spells and changes in rainfall, such as high rainfall intensity in 2020 (WAEO - ward 'A' 13th May 2021, Kongwa)*

The other key informant interviewees reported as follows:

> *"Kongwa District has been experiencing irregular rainfall patterns and shifting in rainfall season, for example; during 2020-2021 rainfall intensity increased." (WAEO - ward 'B' 25th May 2021, Ugogoni)*

According to the meteorological data (Figure 3), the total annual rainfall anomaly showed that annual rainfall in the study area had been increasing by (y = 3.085x-49.36, where $R^2$ = 0.051) from 1980 to 2010. However, TMA data (Figure 3), showed a shortage of rainfall in some of the years.

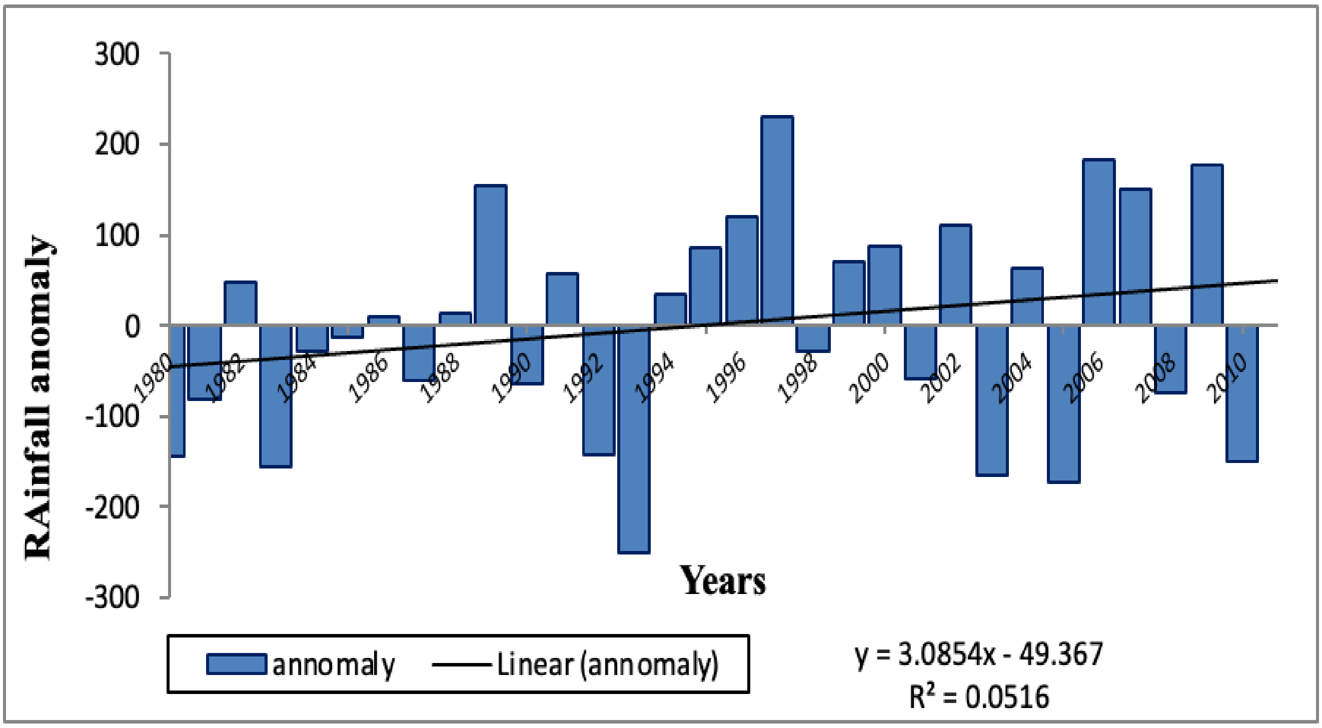


Figure 3: Trends of the Total Annual Rainfall Anomaly from 1980 to 2010

***Perceptions of smallholder maize farmers on the effects of climate change on production***

The mean score for the respondents' perceptions of the effects of climate change on maize crop production was 1.80. Over half of the respondents (59.2%), perceived that maize crop production has been affected by climate change (Table 3).

Table 1. Perceptions of Smallholder Farmers of Maize on the Effects of Climate Change on Maize Production

| Variable | Frequency (N=216) | | | | | Mean |
|---|---|---|---|---|---|---|
| | Highly affected | Moderately affected | Neutral | Limited affected | little affected | |
| climate change effect on maize crop production | 128 (59.2%) | 46 (21.3%) | 12 (5.6%) | 12 (5.6%) | 18 (8.3%) | 1.80 |

Key: (1) ≥ 1- < 2 highly affected, (2) ≥ 2 - < 3 moderately, (3) ≥ 3 - < 4 Neutral, (4) ≥ 4 - < 5 little, (5) ≥ 5 Limited.

Data from the ministry of agriculture indicate that maize production in Kongwa District has been decreasing from the 2006/2007 season to the 2017/2018 season (Figure 4).

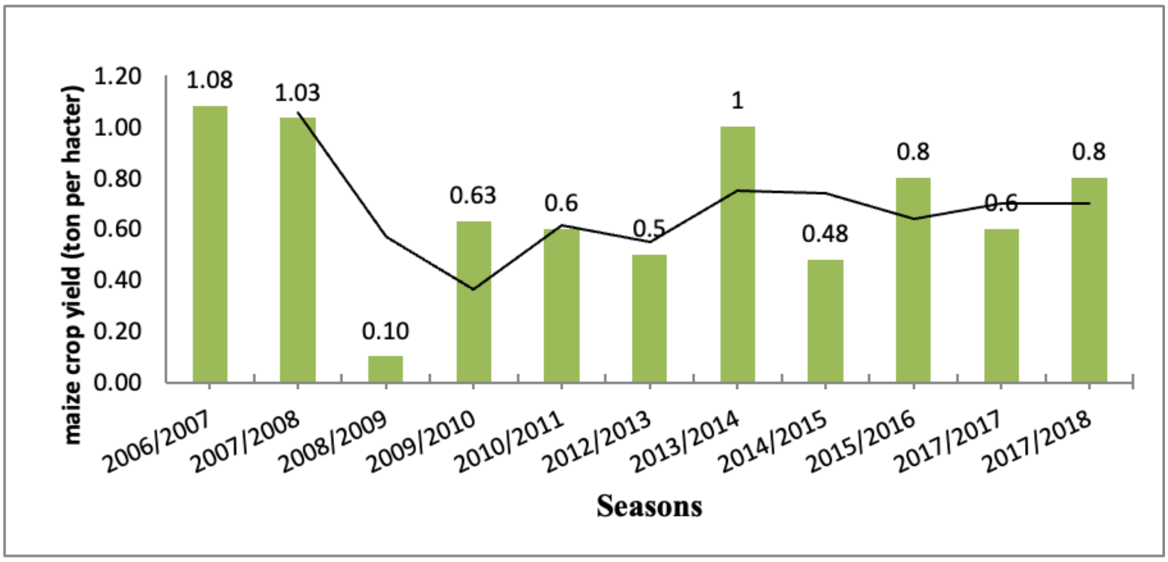


Figure 4: Kongwa Maize Crop Production Trend for the 2006/2007 to 2017/2018 Season

Climate change has caused changes to various factors that have affected maize production. Table 4 presents findings on farmers' perceptions of climate change effects on maize crop due to changes in soil moisture, maize germination, growth, and maturity, invasive weeds, pests/insect attacks and aflatoxin-contamination. The overall mean score of the farmers' perception from those listed aspects is 2. Accordingly, 34.7% of the respondents highly agreed and 30.6% agreed that soil moisture has been reduced due to long dry spell. Only a few (5.6%) strongly disagreed. These findings are also supported by most of the key informants, who reported that the land became dry for a long time in a year, which is not good for maize cultivation.

One of the key informants narrated as follows:

> *The drought has put a strain on the maize crop. Short term seeds grown in Kongwa require soil moisture availability between 60 and 70 days after the farmer sows his or her seed. Unfortunately, in some of the years it has rained shortly and the dry spell has become long, thus the land lacks soil moisture for maize to grow well to maturity"* (General Agriculture Field Officer - ward 'A' 13th May 2021, Kongwa).

The findings also show that 36.1% of the respondents strongly agreed that maize germination had been affected by climate change. Meanwhile, only 5.1% highly disagreed. Nearly half of the respondents (48.1%) strongly agreed that the growth of maize plants had been affected by climate change, while a few respondents (1.4%) highly disagreed. Also, the majority (34.7%) of the respondents highly agreed that maize maturity is affected by climate change. Only a few (4.2%) strongly disagree. Furthermore, the majority (50.5%) and (51.9%) of the respondents strongly agreed that climate change has increased the impact of invasive weeds and pests or/and insects attack on the maize crop, respectively.

The findings from the questionnaire are supported by the findings from key informants, since most of the key informant interviewees reported that the production of maize in recent years has been affected by unpredictable rainfall and a long dry season. Accordingly, the experienced changes in climate are contributing to the stunted growth of maize seedlings, and sometimes maize plants become dry and die before they mature. The WEOs from Kongwa and Ugogoni wards also reported that in recent years, there has been an increase in invasive weeds, pest/insects and other diseases that attack the maize crop.

One of the key informants elaborated on this as follows:

> *Maize growth in recent years has not been as rapid as it was 20 years back. Nowadays there is stagnant growth of maize crop because of erratic rainfall distribution. Farmers are facing difficulty knowing the right time to plant because the rainy seasons are not predictable. In most of the year, it rains shortly and very late; thus, maize crops do not grow well, and many*

> *of the plants become dry and die before they are matured. In 2019 and 2020, however, it rained above average''* (WEO – Kongwa, ward 'A' 13th May 2021, Kongwa).

Another key informant interviewee elaborated on this as follows:

> *"As we practise rain fed agriculture, normally farmers start to sow maize between November and December, when the rainy season starts. Nowadays, there are a lot of variations, as in some of the seasons, growing might take place in January if the rainfall season delays. Nevertheless, the rains mostly end in February. To deal with the situation, we have advised farmers to grow short-term varieties such as Situka 1, Situka M1, ZM521, and ZM401 that take 90 to 120 days to complete a growth cycle; however, there is still a problem because those varieties grown require at least three months of rain to mature. When it rains shortly before the stage of tasseling, pollination does not take place, and thus grain filling does not occur, and sometimes the maize plants become dry and die. Thus, we advise the farmers to plant millet species and sorghum cultivars to ensure food security"* (General Agriculture Field Officer - ward 'A' 13th May 2021, Kongwa).

In addition, 27.3% of the respondents agreed that temperature changes have contributed to aflatoxin-contamination of the maize crop. Nevertheless, 44.5% of the respondents were not sure if aflatoxin-contamination of the maize crop was caused by a change in temperature. During the interview, ward agriculture extension officers reported that in very recent years, the case of aflatoxin in maize has started to be observed, although it is not very serious. The officer reported that an increase of heat and drought stress may cause seed coat fracture and increase the opportunity of molds and fungi to attack the seeds, as they attack the seeds they produce aflatoxin.

Table 2. Perceptions of Maize Smallholder Farmers on the Impact of climate change on Maize crop (N=216)

| Perception of maize smallholder farmers on the effects of Climate *change* on the maize crop | Frequency | | | | | Mean |
|---|---|---|---|---|---|---|
| | highly agreed | Agreed | Neutral | Disagreed | Highly disagreed | |
| Soil moisture has decreased. | 75(34.7%) | 66 (30.6%) | 37(17.1%) | 26 (12.0%) | 12 (5.6%) | 2.23 |
| Poor germination of maize seedlings | 78 (36.1) | 68 (31.5%) | 14 (6.5%) | 45 (20.8%) | 11 (5.1%) | 2.27 |
| Stunted growth of the maize plant. | 104 (48.1%) | 78 (36.1%) | 10 (4.6%) | 21 (9.7%) | 3 (1.4%) | 1.80 |
| Maize maturity has been affected. | 75 (34.7%) | 72 (33.3%) | 17 (7.9%) | 43 (19.9%) | 9 (4.2%) | 2.25 |
| Invasive weeds have increased. | 109 (50.5%) | 60 (27.8%) | 23(10.6%) | 19 (8.8%) | 5 (2.3%) | 1.85 |
| Pests/insect attack on maize crop has increased. | 112 (51.9%) | 65 (30.1%) | 11 (5.1%) | 23 (10.6%) | 5 (2.3%) | 1.81 |
| Aflatoxin-contamination has increased. | 51 (23.6%) | 59 (27.3%) | 96 (44.5%) | 7 (3.20%) | 3 (1.4%) | 2.31 |
| Overall Mean | | | | | | 2 |

Key: (1) ≥ 1- < 2 high agreed, (2) ≥2 - < 3 agreed, (3) ≥3 - < 4 Neutral, (4) ≥ 4 - < 5 disagreed, (5) ≥ 5 - < 6, (5) ≥ 6 Highly disagreed

***Factors influencing smallholder farmers' perceptions of the impacts of climate change on maize crops in Kongwa District***

Smallholder farmers' perceptions on the impacts of climate change were associated with age, gender, level of education, marital status, farmland ownership, farm size, and income from farming activities and were found to be statistically significant ($P < 0.05$). Smallholder maize farmers who were aged between 18 and 36 years were 94% less likely to perceive the impacts of climate change compared to those who were aged above 74 years (AOR = 0.061, 95% CI: 0.007- 0.547, P = 0.012). Besides, the results indicate that male-headed households were two times more likely to perceive the impact of climate change compared to female-headed households (AOR = 2.218, 95% CI: 1.177- 4.1181, P = 0.014) (Table 5).

Furthermore, respondents' perceptions of the impacts of climate change were analysed in relation to education. It was found that smallholder farmers who had only primary education were 86% less likely to perceive the impact of climate change compared to smallholder farmers who had college education (AOR = 0.141, 95% CI: 0.020 - 0.977, P = 0.047). Besides, smallholder farmers who had informal education were 71% less likely to perceive the impact of climate change compared to smallholder farmers who had college education (AOR = 0.290, 95% CI: 0.038 – 2.231, P = 0.235). Married smallholder farmers were 3 times more likely to perceive the impact of climate change compared to the respondents with a widowed marital status. (AOR = 3.774, 95% CI: 1.292- 11.019, P = 0.015). Smallholder farmers who had purchased farmland were six times more likely to perceive the impact of climate change compared to those who had inherited farmland (AOR = 6.753, 95% CI: 1.197- 38.112, P = 0.031) (Table 5).

Smallholder maize farmers cultivating on less than 0.5 hectares of farmland were 75% less likely to perceive impacts of climate change than smallholder farmers cultivating on 4 to less than 4.1 hectares of farmland (AOR = 0.251, 95% CI: 0.066 - 0.951, P = 0.042). In addition, maize smallholder farmers cultivating 0.5 to 1.9 hectares farmland were 77% less likely to perceive the impacts of climate change than those cultivating on 4 to less than 4.1 hectares farmland (AOR = 0.226, 95% CI: 0.070 - 0.728, P = 0.013) (Table 5). It was revealed that maize smallholder farmers who were earning less than 1 million Tanzania shillings (TZS) (USD 429.74) per season from farm activity were 89% less likely to perceive climate change impacts on maize compared to those who were earning more than 4 million TZS (USD 1718.95) (AOR = 0.114, 95% CI: 0.013 - 0.979, P = 0.048) (Table 5).

Table 3. Multivariate logistic regression on socio-economic factors influencing Smallholder farmers' perceptions on climate change impacts

| Variable | OR | 95% CI | | *P*-value | AOR | 95% CI | | *P*-value |
|---|---|---|---|---|---|---|---|---|
| | | Lower | Upper | | | Lower | Upper | |
| Age | | | | | | | | |
| 18-36 years | 0.061 | 0.007 | 0.523 | 0.011 | 0.061 | 0.007 | 0.547 | 0.012 |
| 37-55 years | 0.321 | 0.038 | 2.676 | 0.294 | 0.285 | 0.033 | 2.466 | 0.255 |
| 56-74 years | 0.250 | 0.028 | 2.202 | 0.212 | 0.254 | 0.028 | 2.328 | 0.225 |
| > 74 years (ref) | | | | | | | | |
| Gender | | | | | | | | |
| Male | 2.508 | 1.405 | 4.474 | 0.002 | 2.218 | 1.177 | 4.1181 | 0.014 |
| Female (ref) | | | | - | | | | |
| Education level | | | | | | | | |
| Informal | 0.133 | 0.057 | 0.313 | 0.000 | 0.290 | 0.038 | 2.231 | 0.235 |
| Primary | 0.051 | 0.024 | 0.108 | 0.000 | 0.141 | 0.020 | 0.977 | 0.047 |
| Secondary | 0.000 | 0.000 | - | 0.998 | 0.000 | 0.000 | - | 0.998 |
| College education (ref) | | | | | | | | |
| Marital status | | | | | | | | |
| Single | 0.450 | 0.102 | 1.982 | 0.291 | 1.228 | 0.191 | 7.909 | 0.829 |
| Married | 2.944 | 1.322 | 6.557 | 0.008 | 3.774 | 1.292 | 11.019 | 0.015 |
| Separated | 0.900 | 0.180 | 4.489 | 0.898 | 2.379 | 0.325 | 17.421 | 0.394 |
| Divorced | 0.375 | 0.037 | 3.777 | 0.405 | 0.551 | 0.040 | 7.591 | 0.656 |
| Widowed (ref) | | | | | | | | |
| Farmland ownership | | | | | | | | |
| Purchased | 5.529 | 1.029 | 29.716 | 0.046 | 6.753 | 1.197 | 38.112 | 0.031 |
| Rent | 2.384 | 0.598 | 9.502 | 0.218 | 1.999 | 0.492 | 8.124 | 0.333 |
| Inherited (ref) | | | | | | | | |
| Farm size | | | | | | | | |
| < 0.5 hectares (ha) | 0.192 | 0.055 | 0.676 | 0.010 | 0.251 | 0.066 | 0.951 | 0.042 |
| 0.5 – 1.9 ha | 0.201 | 0.066 | 0.614 | 0.005 | 0.226 | 0.070 | 0.728 | 0.013 |
| 2 – 3.9 ha | 0.305 | 0.085 | 1.102 | 0.070 | 0.346 | 0.088 | 1.350 | 0.126 |
| 4 - < 4.1 ha (ref) | | | | | | | | |
| Income | | | | | | | | |
| <1million TZS | 0.112 | 0.013 | 0.952 | 0.045 | 0.114 | 0.013 | 0.979 | 0.048 |
| 1- < 2 million TZS | 0.208 | 0.023 | 1.875 | 0.162 | 0.212 | 0.024 | 1.916 | 0.167 |
| 2- < 3 million TZS | 0.458 | 0.041 | 5.085 | 0.525 | 0.475 | 0.043 | 5.288 | 0.545 |
| 3-4 million TZS | 0.167 | 0.005 | 5.452 | 0.314 | 0.171 | 0.005 | 5.612 | 0.322 |
| >4 million TZS (ref) | | | | | | | | |

## Discussion

### *Climate Change Perceptions of Smallholder Maize Crop Farmers*

The majority of the smallholder farmers of maize in the semi-arid ecological region of central Tanzania have perceived that the climate has changed over the last three decades. The reported changes include: an increase in temperature, a long dry season, and a change in rainfall intensity. These findings could explain that smallholder farmers have knowledge of climate of their area, thus they are aware of the changes of climate which are taking place. Likewise, Mayaya et al. (2015), Chitimbe and Liwenga (2015) found that, in general, farmers in the Dodoma region, Tanzania were well-informed about climate change. However, there are a few smallholder farmers who remained undecided about whether there is climate change or not, while very few farmers disagree that there is climate change. Such findings could explain the existing diversity of perceptions among smallholder farmers in Kongwa districts. Furthermore, the findings indicate that not all smallholder farmers are aware of the climate change, such implication could contribute to the slow adoption of climate change and vulnerability adaptation strategies among the farmers.

Famers' perceptions of climate change are justified by the meteorological data, which indicate that the minimum temperature and maximum temperature have been increasing since 1980 to 2010 (Figure 2). Likewise, the meteorological data of rainfall (Figure 3) correspond to farmers' perceptions of the observed change in rainfall. An increase in the total annual rainfall anomaly by ($y = 3.085x-49.36$ where $R^2 = 0.051$) from 1980 to 2010 explains the increasing intensity of rainfall, however, the distribution has changed as it rains in short periods but at high intensity. These findings are consistent with the findings of the study by Jackson et al. (2018), Ojoyi et al. (2015) who found that farmers in semi-arid central Tanzania perceived that climate had been changing.

### *Smallholder farmers' perceptions of the effects of climate change on maize crop production*

Although smallholder farmers' perceptions of the effects of climate change on maize crop vary, the majority of them agree that the change has had an impact on maize production. A shortage of rainfall seasons, increasing intensity of rainfall, and temperature increases have resulted in a decrease in maize production. These findings explain that farmers have realised the existing impacts of climate change on maize, but they are not capable enough to cope with the changes. Farmers' observation is justified by maize production data from the Ministry of Agriculture; the data indicate a declining trend in maize production in Kongwa from the 2007/2008 season to the 2017/2018 season (URT, 2016; 2020). The findings of this study explain that farmers perceive that the declining trend of maize production is contributed by changes in several factors, including decreasing soil moisture, poor germination of maize seedlings, stunted growth of maize plants, an increase in invasive weeds and pest/insect attacks on maize, a change in maturity duration, and contamination with aflatoxin. Most of the farmers are knowledgeable on the impacts of climate change, as they have realised the seriousness of the problem of climate change impact on maize crop production. Farmers' perceptions correspond to empirical findings from related climate change studies. Thierfelder et al. (2017), Tumbo et al. (2012) and Mongi et al. (2010) explained that the major constraint to maize production is seasonal soil moisture insufficiency due to low rainfall and high potential evapotranspiration caused by an increase in temperature and prolonged drought spells. Gamba (2020) and Thierfelder et al. (2017) also found that germination of maize is hampered by limited soil moisture due to climate extremities like prolonged drought spells which have been causing low crop yield.

The smallholder farmers have also noted that climate change has contributed to an increase in living organisms which affect maize production. Such living organisms include invasive weeds and pest/insect as well as other microbials that cause aflatoxin. Such farmers' observations are justified by the findings of Gamba et al. (2020) who found that in the semi-arid region of central Tanzania, crops production is affected by organisms such as army worms (*Spodoptera frugiperda*), and Crickets (*Gryllus assimilis*). Accordingly, those pests were mostly affecting the maize crop during the germination stage (Gamba et al., 2020). Cairn et al. (2013) found that drought stress, weeds, pests, and diseases were among the major constraints to high crop yields in sub-Saharan Africa. The findings of this study, however, reveal that there are many smallholder farmers who are not informed on the influence of climate change on aflatoxin-contamination in maize. These findings may explain that knowledge of aflatoxin was low among the majority of farmers. However, Cairns et al. (2012) maintained that increased temperature and drought incidences are likely to increase the incidence and severity of outbreaks of fungal diseases caused by aflatoxin and fumonisin mycotoxins in maize in the near future.

***Socio-economic factors determining farmers' perceptions of the impacts of climate change on maize in Kongwa District***

Several socio-economic aspects determine smallholder farmers' perceptions of climate change impacts on maize production. Such aspects include age, gender, education, marital status, farm ownership, farm size, and income. As farmers differ in socio-economic attributes, their perception may have been determined by the attribute they possessed.

Age of the farmers have an influence of the farmers' perception. The old aged famers are more likely to perceive the climate change impacts on maize compared to young aged farmers. Since older farmers have long experience in agriculture they may compare the climates of past times with the present. Mongi et al. (2010) reported that the local understanding of climate is time based, as the climate has been found to be continuously changing and getting worse over time across tropical countries. Older smallholder farmers have grown up witnessing and can remember many events related to climate change, such as the shift in rainfall seasons, changes in rainfall patterns and distribution, as well as the change in global temperature. Mongi et al. (2010); Rapholo & Makia (2020) found that there was variation in understanding climate change among the farmers depending on various factors including their age. This study found that farmers at the age of 41 and above perceived that the temperature is higher in comparison to how it was in the last three decades. Similarly, Benson et al. (2015) revealed that experienced farmers perceived climate change better as they had been exposed to past and present climatic conditions over their lifetime.

Male-headed households are twice as likely to be aware of climate change and its effects. Men probably have a greater chance of getting information related to climate change than women since men have more sources of information concerning climate change compared to women due to their social roles. Nyasimi and Huyer (2017) argued that women encounter barriers that constrain their ability to adapt to climate change. Accordingly, constraints include societal norms, limited access to climate services, and agro-advisory. In contrast to this study's findings, Rapholo & Makia (2020) reported that there was no significant difference in perception ($p < 0.05$) of climate variability based on gender.

Furthermore, level of education is a significant determinant of farmers' perceptions. Smallholder farmers who had only a primary education were 86% less likely to perceive climate change compared to smallholder farmers who had a college education. These findings would explain that the knowledge of climate change is taught better at the higher levels of school and college that at the primary level. Thus, those farmers who have had the opportunity to attain secondary and tertiary education are likely to perceive and explain the impacts of climate change. In addition, farmers who attained formal education are more likely to be aware of the impacts of climate change compared to those who have obtained informal education. As such, this study found that smallholder farmers with informal education were 71% less likely to perceive the impacts of climate change compared to smallholder farmers who had attended college education. Rapholo and Makia (2020) also reported that the level of education influences the chance of farmers to precisely perceive climate change, as they found that most farmers (61%) who perceived that there was climate change, had attained post primary education, while (33%) had up to primary education. The study by Mongi et al., (2010) revealed that education levels influence the perceptions of small scale farmers on climate change. Many countries have mainstreamed climate change into their policies and made it a top priority. Thus, schools, colleges, and universities' curricula consider knowledge of climate change as important to be taught.

Those who attain formal education, therefore, are likely to know better on the issue of climate change impact than those who have not attained it.

Marital status was also found to determine farmers' perceptions. Married smallholder farmers were 3 times more likely to perceive climate change and its impact compared to respondents with a widowed marital status. It is possible that being married influences awareness on the climate change since partners can share experiences and information on their production activities, including the challenge from the impacts of climate change. However, the couple's characteristics such as education and access to relevant information are important in influencing the sharing of necessary information. These findings contrast with those of Myeya (2021) who found that respondents' marital status did not have any influence on climate change knowledge and in adopting adaptation measures among smallholder farmers.

Farm ownership also has an influence on farmers' perceptions. Smallholder farmers who have purchased farmland are more likely to perceive the impacts of climate change compared to those who have inherited farmland. Those who have purchased are most likely eager to produce in order to earn a return on their investment; thus, they closely monitor the production trend of their crop as well as the causes of production effects. As climate being the main important determinant of maize production, those who purchased land/farm are more likely to make follow up and learn on climate and its impacts on agriculture. The findings of this study are not different from those of Yila and Resurreccion (2013) who found that those who own their farmland through inheritance were not associated with the farmers' knowledge of the impacts of climate change in the semi-arid areas in the Northeastern Nigeria. The existing difference in the perception of the impacts of climate change between those who purchased farmland and those who aquired farmland through inheritence does not mean the climate change normaly affects those who purchase land. Instead, factors such as the cost incurred for production and knowledge of climate change are likely to cause the difference in perceptions among the farmers.

Smallholder farmers, who have low income from farming activities, were less likely to perceive the impact of climate change on maize production. Probably, those who have low income from maize production mainly earn their income from other production activities instead of maize cultivation. Thus, they do not have much concentration on maize cultivation. The findings are not different from those of (Rahman, Toiba, & Huang, 2021) who found that those who had high income from farming activities realised the impacts easily and were those who applied the adaptation strategies in Indonesia. Most of the smallholder farmers with low income from agricultural activities were found to cultivate on small farms, and their main purpose was for domestic use. Thus, they could manage their farm to produce enough food for domestic use. Differently from those who were receiving more income from the maize crop, they cultivated large farms mainly for commercial purposes. As their intention is to make profit, it is possible to observe the effects caused by climate change in the production.

## Conclusion

Smallholder farmers who cultivate maize had realised climate change and its impacts in Kongwa DC. The farmers have experienced an increase in the average temperature and fluctuations in rainfall duration and intensity. Consequently, the changes have been perceived to have affected maize crop production, as soil moisture was reduced, maize germination, growth, and maturity were affected as well. In addition, the invasive weeds, pests and diseases attack were noted to have been enhanced by the climate change. However, most of the smallholder maize farmers were not well informed about the issues related to climate change and aflatoxin contamination of the maize crop. Farmers' perceptions are supported by the meteorological data, which show pattern changes in both temperature and rainfall. Smallholder farmers differ in their perceptions. There were those who were less likely to perceive the impacts and those who were more likely to perceive the impacts. Their perceptions were determined by their socio-economic factors, where age, level of education, farm ownership, and income from farming activities had significant associations with farmers' perceptions of the impacts of climate change on maize production. Therefore, we recommend that government and other development actors such as NGOs provide more education on climate change, its impact, and adaptation strategies, particularly at the household level, to improve production. There is also a need for decision makers to emphasise the cultivation of crop varieties such as millets and sorghum cultivars to enhance food security.

## Acknowledgments

We would like to thank Dodoma Regional Administrative Secretary (RAS), Kongwa District Executive Director, and Kongwa District Agriculture and Irrigation Cooperative Officer (DAICO) for their cooperation during the data collection period. Further, our thanks should go to the agricultural extension officers, ward executive officers (WEOs), village executive officers (VEOs), and maize smallholder farmers of the Kongwa, Kibaigwa, and Ugogoni wards for their cooperation during the data collection period.

## Conflict of interest

The authors declare that there is no conflict of interest.

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