

Research Application Summary

African subsistence farmers' perceptions on rainfall change trends and adaptation strategies on crop production in Tigray Region, North Ethiopia

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Abstract

Water is becoming the most pressing issues for global crop production and food supply and this poses risks on how to feed the rapidly growing global population. The issues of climate and its impacts are now a big challenges for famers that depend mainly on rainfall for crop production. With rainfall on the decrease in Tigray Region of Ethiopia, effective adaption strategies are needed to sustain agricultural production in the ever changing global climate. This study assessed the rainfall trends and how farmers perceive those changes in Tigray Region of Ethiopia. Perception is very important to appropriately repound to changing climate. The study also examined the real contributions of adaptation strategies on agriculture productivity. In addition, the research used climate and surveyed data from 400 subsistence farmers to examine rainfall changes and its implications on crops production and farmers adaption strategies used to reduce impacts of climate change. Majority of farmers perceive that rainfall has decreased in the past three decades (1983-2014). Late start and early offset of rainfall had negative impacts on crop production and most of smallholders farmers used 12 adaptation strategies to adapt to the negative impacts of rainfall fluctuation on crop production. The multiple regression model revealed that the most effective adaption strategies in the crop sector were irrigation, planting date adjustment, use of drought tolerant and short gestation crop varieties. Farmers' decisions on adaptation determines the growth potential of agricultural production in arid and semi-arid areas of the Africa continent. Agricultural production is under the risk of rainfall fluctuations and unprecedented climate changes and variability. More areas specific adaption research is needed to respond to specific adaptation needs and to effectively address the climate impacts. This study results can be used to tackle challenges related to climate change impact in other parts of the world which share the same climate conditions with Tigray Region of Ethiopia.

Keywords. Adaptation, climate impacts, crops, Ethiopia, perception, rainfall, Tigray

Résumé

L'eau devient le problème le plus pressants pour la production mondiale des cultures, l'approvisionnement alimentaire et ceci constitue des risques par rapport à la manière de nourrir la population mondiale en croissance rapide. Les problèmes du climat et ses impacts sont maintenant un grand défi pour les familles qui dépendent principalement de précipitations pour la production des cultures. Avec des précipitations qui diminuent dans la région de Tigray, des stratégies efficaces

d'adaptation sont désormais très urgentes pour soutenir la production agricole dans le contexte de climat mondial en constante évolution. Cette étude a évalué les tendances des précipitations et la manière dont les agriculteurs perçoivent ces changements dans la région de Tigray en Éthiopie. La perception est très importante parmi les agriculteurs pour motiver une réponse appropriée au changement de climat. L'étude a également examiné les contributions réelles des forces d'adaptation sur la productivité de l'agriculture. En outre, la recherche a utilisé le climat et enquêté sur des données de 400 agriculteurs de subsistance pour examiner les changements de précipitations et leurs implications sur les stratégies de production de cultures et d'adaptation des agriculteurs aux impacts du changement climatique. La majorité des agriculteurs perçoivent que les précipitations ont diminué au cours des trois dernières décennies. Le début tardif et le décalage précoce des précipitations ont eu des impacts négatifs sur la production des cultures et la plupart des petits exploitants agriculteurs ont utilisé 12 stratégies pour s'adapter aux impacts négatifs des fluctuations des précipitations sur la production de cultures. Le modèle de régression multiple a révélé que les stratégies d'adaptation les plus efficaces dans le secteur de la culture étaient l'irrigation, l'ajustement des dates de plantation, l'utilisation de variétés de cultures tolérantes à la sécheresse et à cycles courts. Les décisions d'adaptation des agriculteurs déterminent le potentiel de croissance de la production agricole dans les zones arides et semi-arides du continent africain. La production agricole est soumise à des fluctuations des précipitations et de changements climatiques sans précédent. Il est nécessaire d'entreprendre plus de recherches ciblant des zones spécifiques pour répondre à des besoins d'adaptation spécifiques et à résoudre efficacement la divergence des impacts climatiques. Ces résultats peuvent être utilisés pour lutter contre les défis liés à l'impact des changements climatiques dans l'ensemble du monde qui partagent les mêmes défis climatiques que la région Tigray de l'Éthiopie.

Mots clés. Adaptation, impacts climatiques, cultures, perception, Éthiopie, précipitations

Introduction

Public perceptions on local risks from global warming are ever more important as communities face decisions on how best to adapt to impacts of climate change (Abuloye and Moruff, 2016). Most of local people perceptions on climate variability in West Africa are consistent with research evidences (e.g. Piya *et al.*, 2012; Oluwatobi and Oluwakemi, 2016; Ogallah *et al.*, 2017) but Juana *et al.* (2013) reported that majority of farmers in Sub-Sahara Africa are aware of only warmer temperature and precipitation pattern changes. In West Africa, only 30-50% farmers reported decreased rainfall for rainfed crops (Mertz *et al.*, 2010).

Onyeneke *et al.* (2008) reported that climate change and adaptation has significant impacts on farm productivity in Nile Basin of Ethiopia. Climate change perception varies with household's characteristics, namely, education level, age, willingness to accept risks, farm ownership and off farm employment status (Linden, 2015). Menike and Arachchi (2016) reported that farmers perceived that temperature exhibits an increasing trend while the trend in rainfall is decreasing but this was not cross-checked for consistency with instrumental climate records. Understanding farmers' perception on climate variability is very crucial as perception is the most significant barrier to adaptation (Haque *et al.*, 2012). Thornton *et al.* (2009) revealed that household with adaptation strategies have 10% more net revenue compared with households without adaptation strategies but failed to specify the types of adaptation strategies which generated more revenue and were most effective. Thornton *et al.* (2009) listed farm production adjustments, intensification of crop and livestock production, land use change and use of irrigation as adaptation strategies though the study did not provide enough information on the effectiveness of the adaptation strategies in

improving crop production. Some of the studies on impacts of climate change on agricultural production have focused on modelling of impacts of climate change using temperature and rainfall changes (Luck *et al.*, 2011). Others have focused on the specific adaptation strategies for crops, animals, and fishes, each in isolation (Amwata, 2013). Yet, different food production sub-sectors interact with each other by complementing and competing against each other. Continuous research work and monitoring systems is important to manage climate change, variability and its impacts (Kumar *et al.*, 2012). Campbell *et al.* (2016) reported that more researches on the impacts of climate on food system and adaptation strategies is needed to identify the adaptation strategies with significant impacts on crop production. The main aim of the study was to examine how farmers perceive rainfall changes and their area specific (bottom up) adaptation response to moderate impacts of climate change.

Methods

Data on farmers' perceptions of climate change impacts and adaptation strategies were collected from 400 sample households using the structured and semi structured interview schedules. The multistage sampling technique was applied to select the specific 400 households for the survey. In the first stage, four Kebeles (Kebele - administration unit) was selected using simple random sampling techniques out of the given 27 Kebeles in the District. After this, 400 households were selected from the lists of households in the four Kebeles (Newi, Awetbekalsi, Atakility and Begasheka) through the systematic random sampling techniques. The sample interval was calculated using total number of households divided by total sample size for each Kebele. From the list of farmers in each Kebele, a random start was selected between the households listed in number one and the interval number. The sampling interval was repeatedly added to select the subsequent households up to all the required 400 households in all Kebele were selected for the administration of questionnaires and interview. Questionnaire was tested before the full scale fieldwork was undertaken. The total number of households in each of the Kebeles was: Newi 1325, Awetbekalsi 1130, Atakility 1679 and Begasheka 1373. This translated to the following number of household samples per Kebele-Newi 96, Awetbekalsi 82, Atakility 122 and Begasheka 100 (Figure 1).

Data on farmers' perceptions on changes on rainfall characteristics (rainfall amount, rainfall duration, onset of rain, cessation of rain, frequency of rain duration, intensity of humidity, duration of humidity) were collected and classified into three groups (1 = Increase, 2 = Decrease, 3 = No change) (Peris *et al.*, 2002) to ease analysis and interpretation.

During the fieldwork, 12 types of adaptation strategies were identified as detailed in Table 1. Adaptation can be autonomous or planned. Autonomous adaptation is a strategy that can be initiated by individual households based on the level of understanding they may have on the changes. Autonomous adaptation is a bottom up and real world based approach whereas planned adaptation is an adaptation which is centralized, policy intervention and top-down based approach (IPCC, 2014). Adaptation strategies are important to reduce vulnerability and household's adaptation decisions depend on the level of understanding of the changes that are occurring. Identifying and comparing adaptation options are important to reduce vulnerability to climate change impacts (Reed *et al.*, 2013). This study was therefore mainly focused on the adaptation strategies which are practiced by individual households (bottom up approach) to respond to perceived changes in their agricultural activities. Household's existing adaptation strategies to actual climate impacts was also examined to investigate the consistency between adaptation strategies and change trends.

The means of livelihoods for farmers in Kola Temben is agriculture. More than 60% farmers in the district depends on crop production. The adaptation strategies practiced by farmers in response to the actual impacts of climate change was statistically tested to detect whether their adaptation decision had significant impacts on the agricultural production. Dummy or categorical variables were changed into numeric data using 0 and 1 to transform the data into a format that can be easily analysed by multiple regression analysis (Agresti and Finlay, 2009).

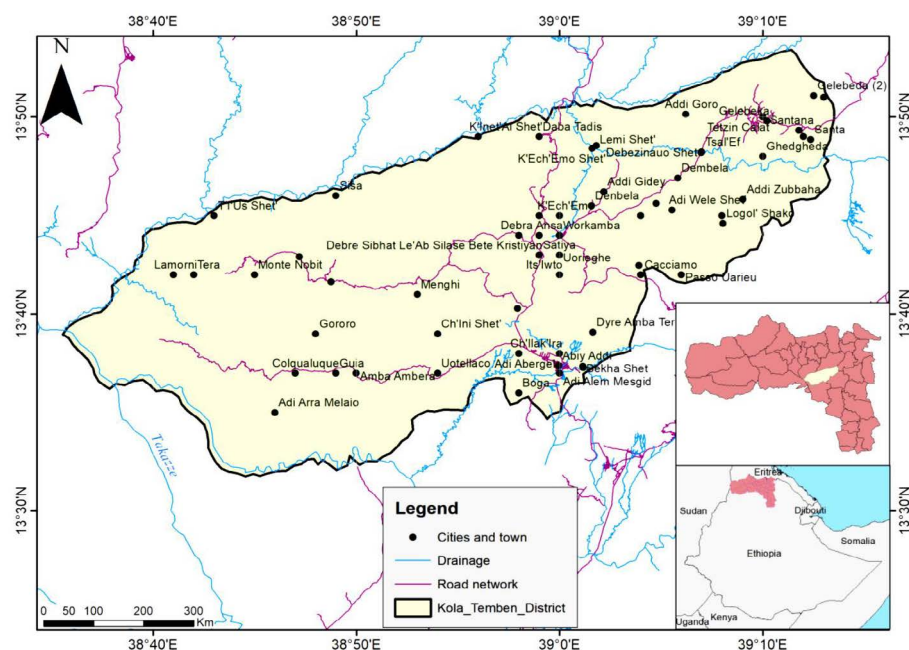


Figure 1. Map of the sampled households in Kola Temben District, Ethiopia

Source: Author, 2016

Multiple regression analysis examines a relationship between multiple independent variables with a dependent variable (Ghani and Ahmad, 2010). Multiple regression analysis was used to analyse the relationship between the farmers adaption strategies and its impacts on crop production.

Table 1. List of adaptation strategies practiced Tigray

List of adaptation strategies practiced in the district	Farmers responses	
	No ('0')	Yes ('1')
Households using different planting dates		
Households diversify farm activities		
Household changed from livestock to crop production		
Households using irrigation facility		
Household practicing soil conservations		
Households using drainage		
Households using increased cultivated land		
Household using short gestation crops varieties		
Household use flood tolerant crops		
Households used drought tolerant crop varieties		
Households used disease and pest resistant crop varieties		
Households used water harvest practices as adaptation strategies		

Sources: Fieldwork, 2016

Results

Annual and monthly mean rainfall changes and trends

The linear trend analysis results revealed that annual mean rainfall in Kolla Temben District has decreased by 0.06 mm per year over the period 1983 to 2014 (Figure 2). There was high variability of annual mean rainfall in the past three decades (1983-2014) in Kolla Temben District (Figure 2). The month of October 1998 was found to be the month with extremely high rainfall records in the past three decades. Months that had no rainfall in the past three decades (1983-2014) was reported as March, April, May, July, December, January and February. This shows that there is high variability of monthly rainfall in Kolla Temben District. This implies that the crop sector in Kolla Temben District is under an intense pressure of high rainfall variability and decrease. The variability trend plot analysis result revealed that rainfall variability was in decreasing trend in Kolla Temben District but the rainfall variability is insignificant (Figure 2). This implies that mean annual rainfall has decreased continuously using variability trends (Figure 2) in Kolla Temben District in the past three decades (1983-2013).

Households perceptions on rainfall characteristics

The results in Table 2 show the characteristics of rainfall in terms of the amount, duration, onset of rain, frequency of the rainy season, intensity of rain, humidity, duration of humidity and dry season. About 52.7% farmers reported an increase in early cessation of rainfall with one month

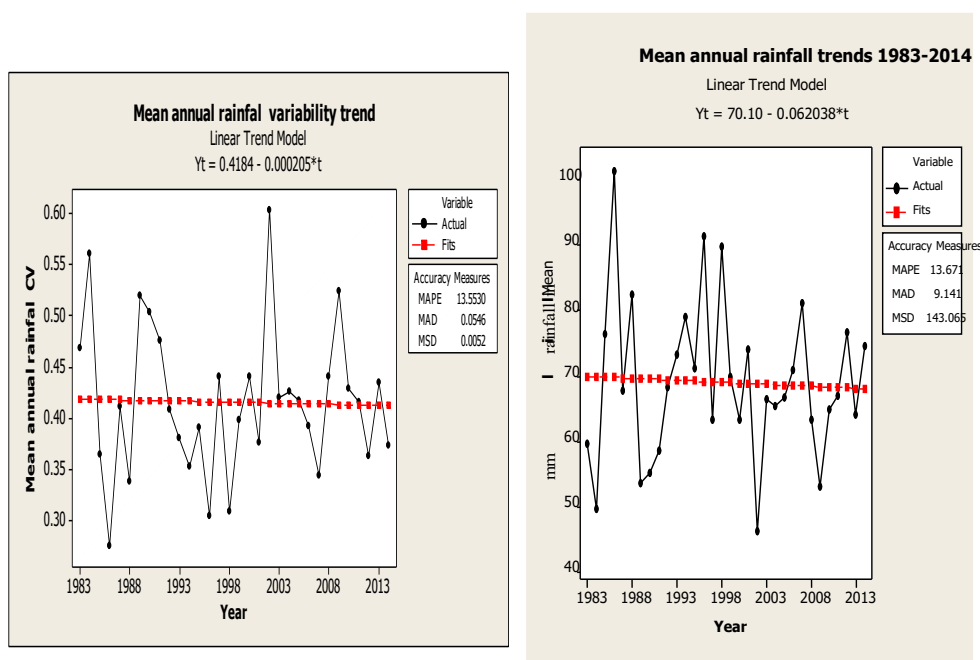


Figure 2. Mean annual rainfall time series trends of Kolla Temben District for 1983-2014 and forecasts (Source: Ethiopia Met (TAMSAT Satellite), 2017)

while 68.5% reported an increase in dry season periods for two months. Majority of farmers (72.3-85%) reported declining precipitation, change in precipitation duration from four months to two and half months, and change in early onset of rain by one month, high intensity and long duration of humidity while 2.6 and 9.5 % of farmers reported that they had not noticed any observable changes in rainfall characteristics (changes in rainfall amount and frequency of rainy days in a month) over the past three decades (1983-2013) (Table 2).

Types of farmer's adaptation strategies in agriculture

The farmers practising agriculture in the study area were found to be using different types of adaptation strategies as shown in Table 3. The adaptation strategies practised were: planting of different varieties of crops (98.8%), use of different planting dates (87.5 %), diversification of farm activities (75.5%), shift from livestock to crops (23.5 %), use of short duration crops (51.3%), use of flood-tolerant crop varieties (53.5 %), use of disease or/and pest resistant crop varieties (66.8%), and water harvesting practices (62.5%). Each strategy was considered independently depending on the number of farmers utilising it. The most preferred adaptation option was use of different planting dates, followed by use of drought tolerant varieties and diversification of farm activities while the least adopted were practising of soil conservation, shift from livestock to crop production and use of irrigation facility in a descending order.

Table 2. Household observation and perceived change in rainfall characteristics compared to the past three decades (1983-2013) and above in Kolla Temben District

Rainfall characteristics	Households perceptions and responses on changes in rainfall characteristics in the past 30 years			Total households that responded	Total households with non- responses
	Increase Frequency	Decrease Frequency	No change Frequency	Total Frequency	No response Frequency
Changes in rainfall amount	36 (9)*	340 (85)	31 (2.6)	397(99.3)	3(0.8)
Changes in rainfall duration	30 (7.5)	334 (83.5)	27 (6.8)	391(97.8)	9(2.3)
Changes in early onset of rain	38 (9.5)	329 (82.3)	27 (6.8)	394(98.5)	6(1.5)
Changes in early cessation of rain	211 (52.7)	154 (38.5)	28 (7.0)	393(98.3)	7(1.8)
Changes in the frequency of shorten rainy time(few rainy days in a month)	262 (65.5)	97 (24.3)	38 (9.5)	397(99.3)	3(0.8)
Intensity of humidity	71 (17.8)	294 (73.5)	30 (7.5)	395(98.8)	5(1.3)
Duration of humidity	85 (21.3)	289 (72.3)	22 (5.5)	396(99.0)	4(1.0)
Dry season time duration	274 (68.5)	93 (23.3)	28 (7.0)	395(98.8)	5(1.3)

*Figures in brackets are percentages. Source: fieldwork (2016/17)

Table 3: Household's adaptation strategies in agriculture (crops) sector

Local adaptation strategies to climate change impacts	Households status in using these adaptation strategies in response to climate change impacts		Total households that responded	Total households non responses
	No	Yes	Freq.	Freq
	Freq	Freq		
Drought tolerant crop varieties	89(22.3)*	302(75.5)	391(97.8)	9(2.3)
Use different planting dates	45(11.3)	350(87.5)	395(98.8)	5(1.3)
Diversifying farm activities	89(22.3)	302(75.5)	391(97.8)	9(2.3)
Shifting from livestock to crop production	300(75.0)	95(23.8)	395(98.8)	5(1.3)
Using irrigation facility	331(82.8)	64(16.0)	395(98.8)	5(1.3)
Practicing soil conservations	294(73.5)	101(25.3)	395(98.8)	5(1.3)
Use drainage	102(25.5)	291(72.8)	393(98.3)	7(1.8)
Use of short gestation crops	191(47.8)	205(51.3)	396(99.0)	4(1.0)
Use of flood tolerant crops	182(45.5)	214(53.5)	396(99.0)	4(1.0)
Use of disease or/and pest resistant crop varieties	129(32.3)	267(66.8)	396(99.0)	4(1.0)
Water harvesting practices	145(36.3)	250(62.5)	395(98.8)	5(1.3)
Increase in cultivated land	110(27.5)	286(71.5)	396(99)	4(1)

*Figures in brackets are percentages. Source: fieldwork (2016/17)

Farmer's adaptation strategies and crop production

The relationship between farmer's adaptation strategies and crop production (in kg per year) was tested using multiple regressions revealed that use of different planting dates, irrigation and drought tolerant crops were found to have significant impacts on total crop production: Use of irrigation, planting date adjustment and short gestation and drought tolerant crop varieties were the most effective adaptation strategies for improvement of crop production in Kolla Temben District (Table 4). Farmers decision on adaptation strategies is very important for improving crop production in the ever changing climate. This result demonstrated that climate change is challenging the existing crop varieties. This clearly implies that human beings should invest more capital in research and innovation to feed the rapidly growing global population as the land preferences for production is shifted to improved varieties (Table 4). The crop varieties we are consuming now are not in position to grow and mature as before as climate change impacts have already started restricting their natural growing and maturity potential. Farmers are trying to respond to the changing climate using their local knowledge and some varieties tried by farmers have been very effective in improving production (Table 4). The results show that farmers' adaptation decisions have significant impact on crop production in Kolla Temben District.

Table 4: Multiple regression results of household's adaptation strategies and annual total crop production (2015) (B- unstandardized slopes – extent of changes, Beta- standardize slops (Standard deviation), Constant-predictors)

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	395.886	145.482		2.721	0.007	109.796	681.977
Households use of different planting dates	80.562	92.497	0.047	0.871	0.038	-101.334	262.457
Households diversify farm activities	131.608	70.577	0.103	1.865	0.063	-7.183	270.398
Household changed from livestock to crop production	106.105	77.394	-0.084	-1.371	0.171	-258.300	46.090
Households using irrigation	227.664	90.770	0.159	2.508	0.013	49.164	406.164
Household practicing soil conservations	-81.437	72.727	-0.066	-1.120	0.264	-224.455	61.580
Households use drainage	79.740	71.335	0.065	1.118	0.264	-60.541	220.021
Households increase in cultivated land	6.667	66.872	0.006	0.100	0.921	-124.838	138.171
Use of short gestation crops	106.543	58.844	0.099	1.811	0.05	-9.174	222.260
Household use flood tolerant crops as adaptation strategies to climate change	42.210	59.256	0.039	0.712	0.477	-74.317	158.738
Use of drought tolerant crops	-9.054	66.391	0.008	0.136	0.048	-139.611	121.504
Use of disease or pest resistant crop varieties	-20.326	61.117	0.018	-0.333	0.740	-140.513	99.861
Water harvesting practices	-40.208	62.466	0.036	-0.644	0.520	-163.048	82.632

Sig. – significance ($p \leq 0.05$ –in bold). Adjusted R Square= 0.41, R Square=0.53, F-value=0.018

Source: fieldwork, 2016/17,

Discussions

The results in Table 1 showed that most of farmers perceived changes in the rainfall period and 85.3% experienced longer dry seasons in Kolla Temben District. The instrumental climate data showed that there was a change in the frequency and magnitudes of extremely high and low rainfall events with decreasing trend of mean annual rainfall over the past three decades (Figure 3). This is in tandem with the perceptions of farmers in the wider context of the eastern Africa region that rainfall was generally decreasing and temperature was rising. Gebre *et al.* (2013) indicated that farmers in Northern part of Ethiopia perceived decreasing rainfall trend. Further, the Rao *et al.* (2011) study in Kenya revealed that 34% and 45% of farmers perceived that the rainy seasons had shortened and rainfall amounts had also declined. In the same country, Ovuka and Lindqvist (2016) reported that majority of farmers in Murang'a District perceived that rainfall had decreased over the past 40 years. For instance, Evelyn *et al.* (2017) indicated that 74% and 100% of farmers in Mikuyuni and Kaveta villages of Kenya noticed a decrease in the average annual rainfall over the last two decades. Osbahr *et al.* (2011) reported that 48% of farmers in Uganda perceived rainfall season changes over the past 20 years. As the years 1997 to 1998 and 1999 to 2001 were the years of strong El-Nino and La-Nina respectively (IPCC, 2013), this might be the case for all the reported changes by farmers in East Africa, which is consistent with the findings of this study. Ayanlade *et al.* (2017) reported that 67% of farmers in Southern Nigeria had noticed a rainfall decrease over the past 30 years. Similar findings have been reported by Mensa *et al.* (2012), who reported that 92% farmers perceived temperature increases while 87% perceived decrease in precipitation and temperature. This supports the IPCC (2013) reports that volcano eruptions in Mexico in 1982 and in Philippines in 1991 had impacted on the "energy budget of the global climate system". This is also in agreement with the findings that volcanic eruptions have caused RF of -11 WM-2 (-0.15 to -0.08 WM-2 in 2008 to 20011) IPCC (2013).

Ali and Erenstein (2017) reported that farmers adaptation strategies in terms of agriculture production included sowing time adjustment (22%), drought tolerant crops varieties (15%) and shifting to new types of crops (25%). This is in agreement with the findings of this field study where the most practiced adaptation strategies in agriculture in Kola Temben District were; use of different crop varieties, change in planting dates, diversification of farm activities, production shift from livestock keeping to crop production and vice versa, irrigation, use of pest resistant crops varieties, and water harvesting practices. Elum *et al.* (2017) reported that drought- tolerant varieties were the most common adaptation strategies to climate change impacts. This supports the fact that the use of crop varieties that are resistant to drought and insect and pest infestations is important to moderate the adverse impacts of climate change on crop yields (cf. Elum *et al.*, 2017; Shrestha *et al.*, 2018; Ahmed *et al.*, 2019; Etten *et al.*, 2019) (Table 2). This is further in agreement with Okonya *et al.* (2013) who identified 'storing of food, household's income diversification, digging drainage channels, planting trees with high-yield, use of early-maturing, drought and disease tolerant and pest-resistant varieties of crops, planting at onset of rains and increased use of pesticides as the most used adaptation strategies by smallholder farmers. This is also in agreement with Zampieri *et al.* (2019) and Zampieri *et al.* (2020) that agricultural production is among the most sensitive sectors to weather and climate anomalies and climate extremes. Kidist *et al.* (2018) reported that adaptation strategies practiced by farmers can reduce negative impacts of climate change and take advantages of changes to improve production. These reports are in agreement with the findings of this study result that households who used drought and flood tolerant, disease

and pest-resistant varieties of crops and use of different planting dates had significant positive impacts on their total annual income from crops in ETB, total annual food consumption from own harvest, total annual crop sales and total annual crop production (Table 3). In support, Elum *et al.* (2017) also reported that drought-tolerant varieties as the most common adaptation strategies to climate change impacts. Farmer households that used drought tolerant crops as an adaptation strategy to climate change impacts had higher total income than the farmers households that did not.

Conclusion

Temperature increase, high frequencies of occurrences of drought and strong winds are becoming common in rural areas. Early cessation of rain, shorter rainy period and dry season duration are on the increase. Most farmers perceived that rainfall is in decreasing trend and early cessation of rainfall is becoming a big challenge for crop production. Farmers have perceived the changes that have happened in their villages as results of climate change impact. A majority of farmers perceive that rainfall has decreased the past three decades. Rainfall decrease has negatively impacted crop production. Adaptation strategies have significant impacts on crop production. The commonly used adaption strategies in the crop sector are; crop varieties that can resist diseases and pests; water harvesting practices; shift from animal husbandry to crop farming and use of irrigation. Most effective adaption strategies are irrigation, planting date adjustment, drought tolerant and short duration crop varieties. The soundness of farmer's decisions on adaptation determines the potential of crop production in arid and semi-arid areas. Agricultural production is under the risk of rainfall fluctuations and unpredictable changes. Agricultural policy makers should give more emphasesis for the promotions of drought resistant crop variaties and irrigation supported agricultural practices.

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