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Assessing effects of rainfall on farming activities as the predictor of climate changes in Sadi Chanka District of Kellem Wolega, Oromia, Ethiopia

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ABSTRACT

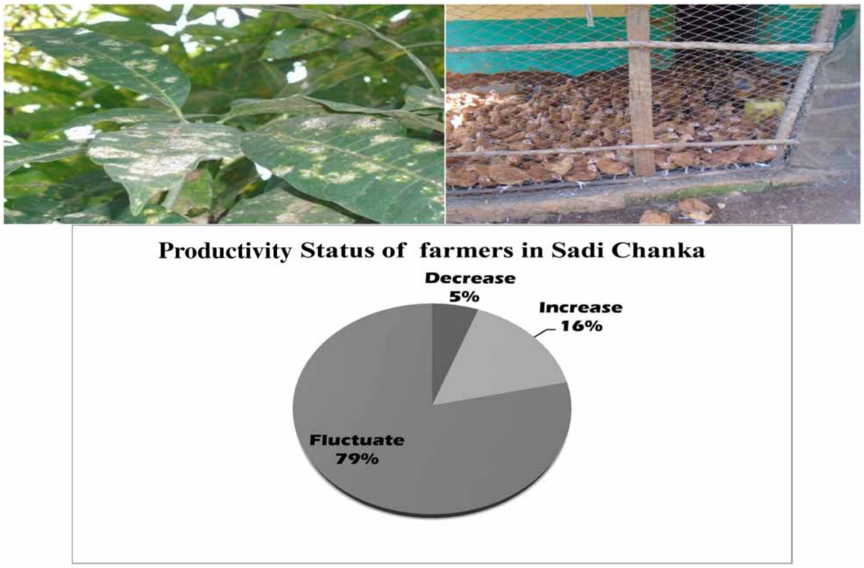
This study was carried out in Sadi Chanka District (Ethiopia) to assess effects of rainfall on farming activities as the predictor of climate change. This study used a mixed approach. Purposive sampling technique was used to select representative kebeles. Elkofale, Keto Shan and Komba were chosen and 128 farmers from each kebeles were involved in a survey. A simple random sampling technique was used to select representative farmers of the study area. In this study, interview, focus group discussion, questionnaires and site observation were employed as data collection tools. SPSS Version 20 was used for data analysis. The majority of the respondent farmers revealed that their productivity status had fluctuated patterns due to untimely rainfall and scarcity of water occasionally. The present study confirmed that choices of agricultural activities by farmers were linked with the change in climate and irregular distribution of rainfall patterns. The ecology of farmland in Sadi Chanka has been degraded critically. This work had also clearly demonstrated the existence of farmers' choices of agricultural activities, including coffee production, poultry production and production of fruits like mango and papaya. Community as whole and concerned governmental sectors should be alerted on participatory ecological management and climate change mitigation.

Key words: agriculture, climate change, farmers, rainfall, yields

HIGHLIGHTS

- Effects of fluctuated rainfall pattern.
- Yields and major productivity items of farmers.
- Farmers' choices for climate change adaptation.
- Forecasting the future fate of climate change.
- Climate change mitigation measures.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Climate change has been defined as the wide-scale change in average weather over a period of time (e.g. 30–70 years). Earth is facing more severe weather and that the average conditions are no longer the type of norm we might expect to continue (USEPA 2014). Global climate change is the hottest environmental issue today and will continue in the future. This is because of its devastative impacts in different ways (Gashaw *et al.* 2014). Globally, there has been an increased focus on sustainable adaptation and mitigation practices for climate change impacts, and the current changes in the essential climate variables have contributed to adverse climatic outcomes in many parts of the world (Zizinga *et al.* 2017). Intergovernmental Panel on Climate Change, published in 2014, stated that human influence on the climate system and recent climate changes have had widespread impacts (Testa *et al.* 2017) such as water scarcity, floods, famine and drought (Belloumi 2004). Climate-smart agriculture is an approach to help guide actions to transform and reorient agricultural systems (FAO 2016). The concept of climate-smart agriculture emerged to describe agricultural benefits as well as climate change adaptation and mitigation benefits and improved watershed and ecosystem management (FAO 2010, 2016).

The present adverse changes in climate that are manifested globally have emphasized the need to identify and are often seen in modes of prolonged drought spells and marked variations in temperature (Zizinga *et al.* 2017). Socioeconomic impacts arising from floods are likely to include shortages of potable water, food insecurity, poor health, extreme events and damage to infrastructure, mostly houses and other infrastructure (CLACC 2004). Africa is highly vulnerable to the impacts of climate change, which threaten to stall or reverse its efforts on food security, human health and broad-based economic growth and development due to its current level of economic development (Climate Challenges for Africa 2012). The changes in climate are affecting farmers and threatening farming livelihoods in sub-Saharan Africa (Zizinga *et al.* 2017). Changes in rainfall patterns are likely to lead to severe water shortages and flooding and developing countries are most vulnerable (UNFCCC 2007). East Africa depends heavily on rain-fed agriculture making rural livelihoods and food security highly vulnerable to climate variability such as shifts in growing season conditions (IPCC 2001). Climate variability, therefore, has the highest impact on agricultural production. Rainfall and temperature regimes are perhaps the most important factors in determining the potential productivity of various agricultural activities. The effects of irregular rainfall distribution patterns include nutrient leaching and erosion, reduced availability of water and changes in the distribution and incidence of pests and diseases including weeds. Developing countries have less capacity to cope with the impacts due to limited financial resources, skills and technologies, and high levels of poverty (Amsalu 2011). The mean annual temperature of Ethiopia has increased by 1.3 °C between 1960 and 2006, an average rate of 0.28 °C per decade (ECA 2016). According to Bausch & Mehling (2011), climate change has been widely recognized as a political priority by the international community. Climate change brings out wide-ranging effects including water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity (Dahal 2011).

Communities in developing countries are vulnerable to the adverse effects of climate change and variability, and they have limited coping capacity due to poverty (Amsalu 2011). Ethiopia is one of the most vulnerable countries of the world to climate change. Severe droughts, flooding, wildfire and disease spread increase the frequency of occurrence and intensity (Amsalu 2011). According to Ethiopia Climate Action Report (ECP) (2016), Ethiopia is prone to droughts, floods, landslides, pests, earthquakes, and urban and forest fires due to factors like dependence on rain-fed agriculture, land degradation and weak institutions. Climate change poses a serious threat to agricultural production, natural resource base and the livelihood of communities, although the governments have signed and ratified all the Rio Conventions, on Climate Change and the Conventions to Combat Desertification (Gashaw *et al.* 2014). Anthropogenic effects, for instance, forest destruction, poor management and environmental degradation, continue with negative impacts on marginal communities that depend on forests and forest products (Mariki 2001; Policy Brief 2017). Similarly, deforestation due to farmland expansion has brought hampering effects on farming activities in Sadi Chanka District. Consequently, struggle of country for development is being rigorously challenged by disasters that undermine agricultural production and ecological health. These disasters cause degradation of water sources, loss of productive household assets, degradation of cropland and pastures, drying up of springs and streams, and deforestation for settlement and expansion of farmland. Thus, the present study aims at effects of rainfall on farming activities as the predictor of climate change in the Sadi Chanka District of Kellem Wolega, Oromia, Ethiopia with the view of forecasting the future fate of climate change.

2. MATERIALS AND METHODS

2.1. Description of the study area

Ethiopia is the second-most populous country in sub-Saharan Africa with an estimated population of over 100 million and a population growth rate of 2.5% (2015), 80% of whom live in rural areas. The increasing trend of Ethiopian population might be one of the factors that leads to environmental and climate changes, as more than 85% of the Ethiopian population rely on agriculture as a source of their livelihood (personal communication). Geographically, Ethiopia is a landlocked country covering 1,104,300 km^2 with extreme climatic diversity ranging from equatorial rainforest in the south to the desert-like conditions in the northeast. Ethiopia has a diverse topography, with elevations ranging from 126 m below sea level and mountains exceeding 4,500 m (ECA 2016). Sadi Chanka District (Table 1) is located in the Kellem Wolega zone. It is slightly characterized by hotter temperature. There were high anthropogenic effects in Sadi Chanka due to agricultural activities expansion and associated issues practiced in the area that are resulting from oversettlements (personal communication).

Table 1 | Compositions of land cover in Sadi Chanka District

No.	Land cover types	Area (hectare)
1	Farm land	9,372.9
2	Woodland	3,994.5
3	Natural forest land	3,547.6
4	Artificial forest land	2,446.9
5	Mixed trees and grass	5,374.5
6	Grazing land	2,320
7	Bare land	10.5
8	Cultivated land	567
6	Wetland	1,717.6
7	Water body	2,576.4
8	Land covered with coffee	13,038
9	Land for irrigation	3,308
	Sum	48,273.9

2.2. Study design, targeted population and sample size determination

In the present study, the targeted population was the farmers in the selected village of Sadi Chanka District. This study applied a mixed approach, i.e. both qualitative and quantitative, as outlined in Cresswell (2009), which uses as a means for seeking to integrate qualitative and quantitative data. In this study, targeted population will be the household farmers who dwell in Chanka District. The sample size was obtained using the following equation:

$$n = \frac{Z^2\,P(1-P)}{e^2}$$

where n is the sample size without considering the finite population correction factor, and n is the actual sample size at 95% confidence level with margin of error (at confidence interval 95%), which is $\pm 5\%$ and $z\alpha/2 - \text{score} = 1.96$.

Accordingly,

$$n = \frac{Z^2\,P(1-P)}{e^2} = \frac{(1.96)^2 * 0.5(1-0.5)}{(0.05)^2} = 384.16$$

So, 384 samples will be selected from the approximated 10,000 population of farmers who inhabit Sadi Chanka District. This number (384) is the minimum sample size needed to estimate the true population. Among the estimated 10,000 population, only 384 farmers were surveyed. Purposive sample sampling technique was used to select representative villages/ kebeles. Accordingly, three kebeles, namely, Elkofale, Keto Shan and Komba kebeles were chosen, and 128 farmers were surveyed for each kebeles. Likewise, a simple random sampling technique was used to select representative farmers of the study area.

2.3. Variables

Variables were classified into two main groups, namely, demographic variables such as age, sex education status, occupation status and family size, and yield-related issues such as productivity status and estimated amount of annually harvested yields.

2.4. Data collecting tools

In this study, interview (for illiterate farmers who cannot write and read), focus group discussion (FGD), questionnaires and site observation were employed as data collection tools. House-to-house surveys were carried out to gather data (crops or yield, pests and its infestation period) from communities. The documents were also provided by government offices. In this study, interview, FGD, questionnaires and site observation were employed as data collection tools. Questionnaires and interviews were provided for gathering data from respondent farmers, whereas the FGD and interview were also used to gather data from concerned agricultural offices and organizations/institutions/workers of Sadi Chanka District.

2.5. Data analysis

SPSS Version 20 was applied for data analysis. Both quantitative and qualitative data were used to analyze the data concurrently. The data from closed-ended items of the questionnaires were analyzed quantitatively. Then the data were expressed in graphs and tables, whereas the data from the open-ended items of the questionnaires and interviews were analyzed qualitatively by narrating the status of study area and were expressed in words. Then based on the analysis and interpretation of data, precise conclusions and recommendations were given.

3. RESULTS

3.1. Questionnaire return rate

As indicated in Table 2, 98.44% of the farmers and 100% of the agricultural experts filled in and returned the questionnaires (Table 2). The level of return could be affected by factors such as the length of questions and the mood of the respondents. The overall status of the questionnaire return rate was ideal for all targeted respondents in the present study, as it was over 80% for all respondents. A questionnaire return rate of 80% and above is absolutely satisfactory (good), while 60–80% is quite satisfactory as reported by Mugenda & Mugenda (1999).

Table 2 | Questionnaire return rate

Targeted respondents	Sample size	Responses	Return rate (%)
Farmers	384	378	98.44
Agricultural experts	9	9	100.00

Source: Researchers' Field Data (2019).

3.2. Demographic characteristics of the respondents

The major age distribution of farmers fell in the age range of 30–39 (43.65%), followed by 40–49 (38.10%). The lower age (20–29) and upper age (50 years and above) ranges of farmers represented as 3.17 and 15.08%, respectively (Table 3).

The mean ($\bar{x}$) family size distribution in the present study was 7. In total, 63% of the respondent farmers had the family size ranged from 5 to 8 (Table 4).

This study found that 29.37% of the respondent farmers were unable to write and read (Figure 1). This inability of the farmers to write and read may have been the factors that hindered improvement in agricultural practices and deteriorated the farmers' livelihood.

The majority of the respondent farmers (78.57%) revealed that their productivity status had fluctuated patterns (Figure 2). This could be due to untimely rainfall and scarcity of water occasionally occurred in the study area. In total, 84% of respondent farmers also stated that the effect of drought on farming activities was observed occasionally in this area (Table 5).

3.3. Effects of fluctuated rainfall patterns on farming activities

Malnourished livestock (due to insufficient forage) (Figure 3(a)) and termite infestation of the grazing land (Figure 3(b)) occurred in the study area. Consequently, livestock was exposed to disease as a result of polluted water for livestock consumption (Figure 3(d)). The present study observed the infestation of vegetation leaves by insects (Figure 3(c)). The information obtained from agricultural experts also revealed that there were floods, drought, over-grazing and insect infestation. This could be due to irregular rainfall patterns, water scarcity, overgrazing, disease and the associated factors (Table 5). The present study also found that livestock faced malnutrition due to lack of sufficient forage and water scarcity due to drought (information from agricultural experts of Sadi Chanka 2019).

In this study, termite infestation is one of the critically problematic constraints on farming activities. Consequently, yield deterioration was shown by some predominantly produced cereal crops. Specially, the harvested Sorghum before (36.5 quintals per hectare) and after termite (16.6 quintals per hectare) infestation has shown huge yield variation (Table 6).

Table 3 | Age distribution of farmers

Age	Frequency	Percent
20–29	12	3.17
30–39	165	43.65
40–49	144	38.10
≥50	57	15.08
Sum	378	100.00

Average data of 5 years (2015–2019).

Table 4 | Family size distribution ($n = 378$, mean ($\bar{x}$) = 7)

Family size structure	Frequency (f)	Mid-points of the class (x)	Frequency (f) × mid-points of the class (x)	Percent
1–4	96	5	480	25
5–8	237	6.5	1,540.5	63
9–12	45	10.5	472.5	12
Sum	378		2,493	100

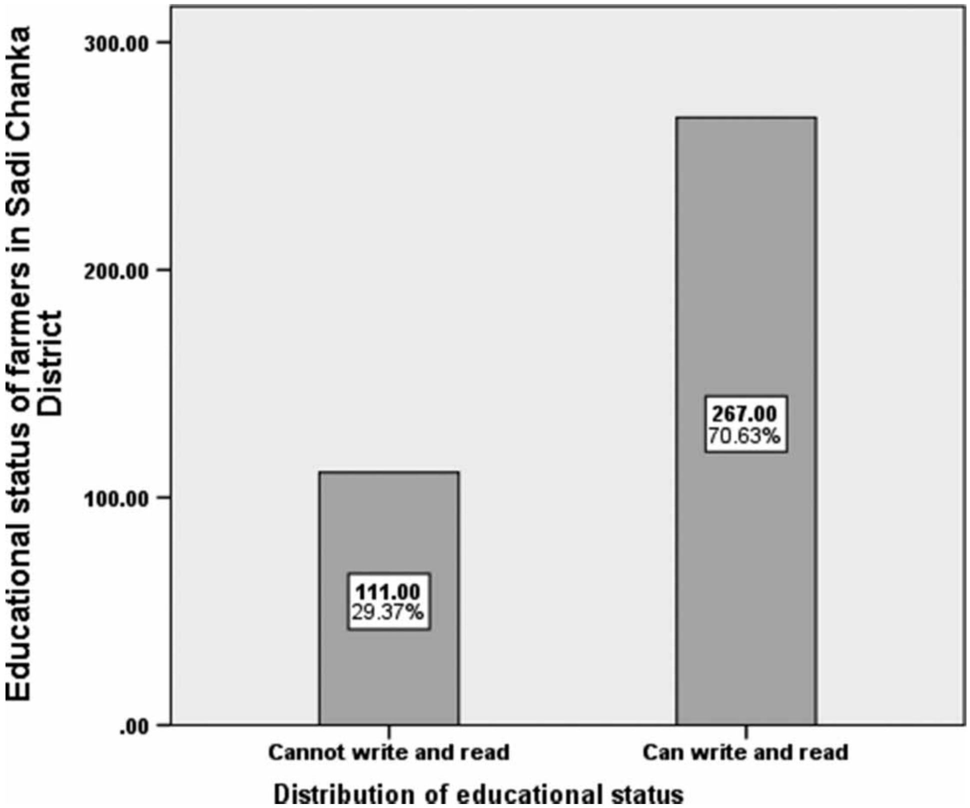


Figure 1 | Educational distribution of respondent farmers in Sadi Chanka District ($n = 378$).

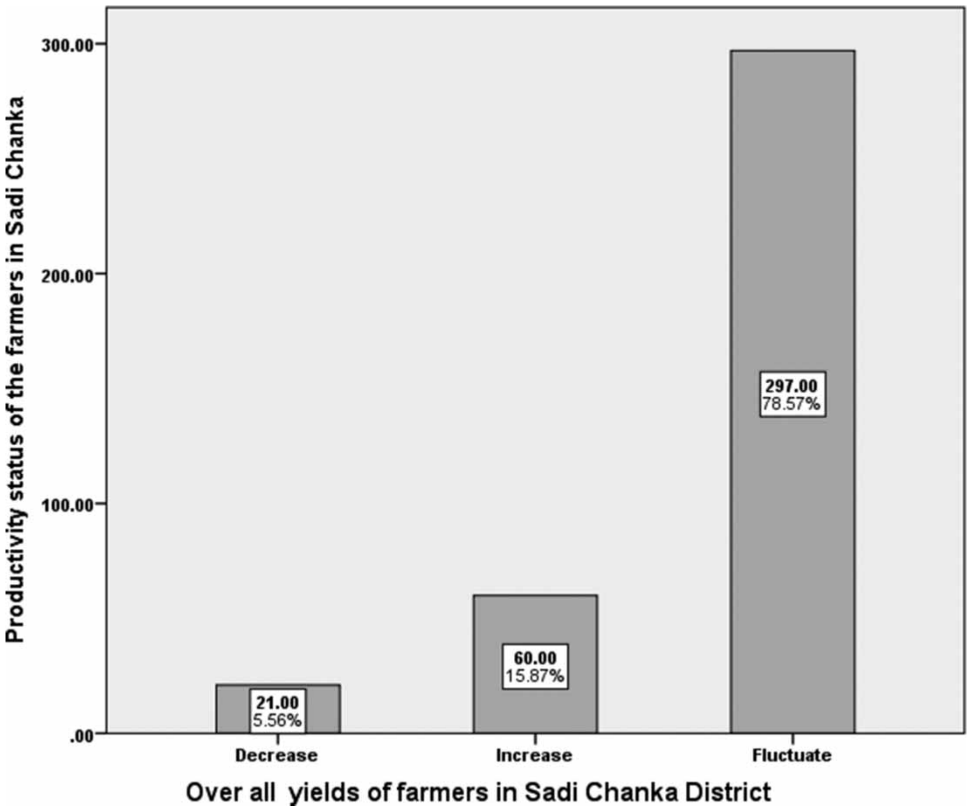


Figure 2 | Overall yield distribution of respondent farmers in Sadi Chanka District ($n = 378$).

Table 5 | Response of the respondent farmers ($n = 378$)

No.	The given statement and the options (1 = not occurring, 2 = occasionally, 3 = frequently)	1 Frequency (%)	2 Frequency (%)	3 Frequency (%)
1.	Effect of drought on farming activities	42 (11)	318 (84)	18 (5)
2.	The seedling faced wilting	3 (0.8)	228 (60.3)	147 (38.9)
3.	Low yields of cereal crops have been obtained	6 (1.6)	192 (50.8)	180 (47.6)
4.	The farmland was affected by flood	18 (4.8)	312 (82.5)	48 (12.7)
5.	Grazing land has faced overgrazing	0	133 (35.2)	245 (64.8)
6.	Streams drying up occurred	0	133 (35.2)	245(64.8)
7.	The livestock has obtained insufficient food	0	120 (31.75)	258 (68.25)
8.	Livestock has provided you sufficient income	3 (0.8)	151 (39.9)	224 (59.3)
9.	Low dairy yields have been obtained	0	39 (10.3)	339 (89.7)
10.	The livestock has faced scarcity of water	0	261 (69)	117 (31)
11.	The livestock has got disease	0	57 (15.1)	321 (84.9)
12.	Rainfall has irregular patterns across seasons	6 (1.6)	243 (64.3)	129 (34.1)
13.	Cereal crops were affected pre-harvest	6 (1.6)	240 (63.5)	132 (34.9)

Figure 3 | Effect of climate changes: malnourished livestock due to lack of sufficient forage (a) and termite infestation of the grazing land (b), Infested leaves of mango (c) and polluted water source for livestock consumption (d) of the study area.

3.4. The farmers' choices for the adaptation and mitigation of fluctuated rainfall

The present study observed the choices of farmers for adaptations of change in climate and irregular rainshed (see Figure 4(a)–4(c)). In total, 48.41% (crop rotation) and 38.89% (mulching) of the respondent farmers are frequently

Table 6 | Yield status of predominantly produced cereal crops

	Predominantly produced crops	Yield status (quintals per hectare) Before termite infestation	After termite infestation
1	Maize	40	39.5
2	Millet	22	14
3	Sorghum	36.5	16.6

Figure 4 | Farmers' choices for the adaptation of climate change in Sadi Chanka: (a) coffee production; (b) irrigation and (c) poultry production.

implementing mitigation practices in use to cope with challenges of climate. About 56% of respondent farmers occasionally used strip cultivation to cope with challenges of climate change (Table 7).

In total, 126 (33%) of the respondent farmers responded that they were not producing coffee, whereas 141 (37.3%) of them were predominantly producing coffee. The productivity of maize and sorghum showed better yields in 2018 than the 2019 harvesting time (Table 8).

Table 7 | Mitigation practices in use to cope up with challenges of climate changes ($n = 378$)

	Mitigation practices for climate changes: The given statement and the options (1 = not occurring, 2 = occasionally, 3 = frequently)	1 Frequency (%)	2 Frequency (%)	3 Frequency (%)
1	Strip cultivation was used	18 (4.76)	213 (56.35)	147 (38.89)
2	Terracing was practiced	36 (9.52)	147(38.89)	195 (51.59)
3	Mulching was used	45 (11.9)	174 (46.03)	159 (42.06)
4	Crop rotation was practiced	24 (6.34)	171 (45.24)	183 (48.41)

Table 8 | Response of respondent farmers on yield harvested in last year (2018/2019)

Yield distribution (quintals)	Coffee Frequency (%)	Maize Frequency (%)	Sorghum Frequency (%)
Major productivity items harvested in last year (2018) (*n* = 378)			
1–10	0	0	21 (5.6)
11–20	15 (4)	9 (2.38)	180 (47.6)
21–30	96 (25.4)	69 (18.25)	75 (19.8)
≥31	141 (37.3)	300 (79.37)	102 (27)
Others (unproductive)	126 (33.3)	0	0
Sum	378 (100)	378 (100)	378 (100)
Major produced crops harvested in this year (2019) (*n* = 378)			
1–10	0	0	18 (4.8)
11–20	4 (1)	0	171 (45.2)
21–30	51 (13)	21 (5.6)	57 (15.1)
≥31	201 (53)	357 (94.4)	132 (34.9)
Others (unproductive)	126 (33)	0	0
Sum	378 (100)	378 (100)	378 (100)

4. DISCUSSION

4.1. Challenges of fluctuated rainfall patterns on farming activities

The present study has observed that 78.57% of the respondent farmers had faced fluctuated productivity patterns. This could be due to untimely rainfall and scarcity of water occasionally occurred in the study area. Studies on the impact of climate change on agricultural water resources under various emission scenarios have shown that there will be an increase in evapotranspiration (Getnet *et al.* 2014) and a decrease in soil water, groundwater and stream flows (Haregeweyn *et al.* 2016; Nigatu *et al.* 2016; Tesfaye *et al.* 2016). This study found that livestock had been facing malnutrition, which might lead to getting diseased. This could be associated with climate and irregular rainfall patterns that resulted in water scarcity, overgrazing, disease and the termite infestation of the grazing land. This insect infestation of the grazing land might have resulted from the favored climatic condition for insects' life. There is evidence that climate change could affect the geographic range of specific species of insects and diseases for a given crop-growing region and increase crop losses (IPCC 2014; Tesfaye *et al.* 2016).

4.2. Farmers' choices for the adaptation and mitigation of fluctuated rainfall

In the present study, choices farmers for adaptations of change in climate and irregular rainshed have been observed. This was practiced to cope with water scarcity that was linked with the change in climate and irregular distribution of rainfall patterns. Agricultural production is dependent on rainfall and irrigation in the study area. Because of alternating wet and dry seasons, the yields harvested by farmers were on the way to decreasing trend. This trend could predict rainfall fluctuation driven by climate change. Belloumi (2004) predicted that the future climate of Southern and Eastern Africa (including Kenya) will be hotter and drier based on analysis done. Ochieng *et al.* (2016) also predicted that the overall analysis shows that rainfall will increase between 2020 and 2040 in Kenya. This study also found that farmers' choices more or less rely on coffee production, poultry production and productions of fruits like mango and papaya and vegetables. This study observed that coffee production, poultry production and productions of fruits like mango and papaya and vegetables prefer cereal crops due to less dependence on water scarcity, floods and drought over the last 5 years to cope with fluctuated rainfall.

5. CONCLUSIONS

The ecology of farmland in Sadi Chanka has been degraded over time due to ongoing human activities and lack of appropriate management. Farmland has started to show deterioration in terms of ecological service as a manifestation of poor management options used so far. The challenges of fluctuated rainfall and its effects on farming activities have been portrayed in the presence of anthropogenic impacts that led to progressive alteration of the formerly familiar ecological and climatic condition of the study area. It was observed that the malnutrition faced by livestock, occurrence of disease, termite infestation of the grazing land and infestation of leaves by insects, pollution of water source as well as stream dry up was seen as a good predictor used for assessing effects of fluctuated rainfall patterns on farming activities. This work has also clearly demonstrated the existence of farmers' choices of agricultural activities including coffee production, poultry production and productions of fruits like mango and papaya, which were seen as the means of adaptation mechanism and mitigation practices against fluctuated rainfall and water scarcity. This study, thus, created awareness for farmers so that they can take environmental and societal issues into accounts and pay attention to enhancement measures by choosing ecologically fitted farming activities. Implementing mitigation practices with the aid of agriculturalists, ecological managers and other related experts was more advisable while choosing agricultural activities. This study also highlighted information-related effects of rainfall on farming activities such as effects of fluctuated rainfall pattern, yields and major productivity items of farmers, farmers' choices for climate change adaptation and the future fate of climate change and climate change mitigation measures in a function that informs agricultural experts, managers and other decision makers to give serious consideration at all levels on taking participatory and integrated measures so that ecological viability of land in use within the study area is ensured.

6. RECOMMENDATIONS

Taking the finding of the present study into account, the following recommendations were suggested:

1. This study was limited to Sadi Chanka, so further study is encouraged on the effect of fluctuated rainfall patterns on farming activities at the zonal/Western Oromia level.
2. Community should be alerted on driving factors of climate changes like flooding, soil erosion and vegetation clearance.
3. Community as a whole and concerned governmental sectors better cooperate on ecological maintenance practices such as forest and water conservation, forestation, encouraging eco-friendly livelihood practices like bee farming, poultry and coffee production.

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AUTHORS' CONTRIBUTIONS

All of the authors were working in collaboration during data collection, analysis and manuscript writing.

CONFLICT OF INTEREST

The author declares that there is no competing interest for this article.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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