



Smallholder Farmers' perception and adaptation to climate variability and change in Fincha sub-basin of the Upper Blue Nile River Basin of Ethiopia

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Abstract Climate variability and change make agricultural sector a risky venture for smallholders' farmers. This paper presents an assessment of smallholder farmers' perceptions of climate variability and change, associated impacts on agricultural sector and the adaptive responses given in Fincha'a sub-basin of the Blue Nile River Basin of Ethiopia. We interviewed 380 head of households selected through systematic random sampling from eight Kebeles, two each from highland, midland, wetland, and lowland agro-ecosystems. Furthermore, focus group discussion and key informant interviews also performed to supplement and substantiate the quantitative data. Descriptive statistics used to summarize quantitative data and χ^2 tests used to measure significance. The result revealed that increased temperature, frequency and severity of extreme weather events (drought and flood), and overall change in seasonality of rainfall over the last 20 years is a widely held perception. The associated impacts on agriculture include decline in length of growing period, the decreased and variability of water

availability, increased crop damage by insects, pests, disease and weeds. In response, farmers practiced different adaptation measures like modification in crop and livestock production practices, and investment in land and water management activities at household and community level. The study also revealed the presence of multiple barriers that hindered the adoption of adaptation measures. To meet the impending challenges, situate by climate variability and change the adaptation measures implemented until now is not adequate. There is also extrication between farmers' perceptions of climate variability and change, and actual adaptation level. Despite significant number of farmers' perceived changes in temperature (about 93%) and rainfall (about 88%), the number of farmers adopted certain adaptation measures are below average. These necessitate the need for planned interventions to identify and support effective adaptation measures.

Keywords Climate change · Perception · Adaptation · Adaptation barriers · Fincha'a sub-basin

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Background

Climate variability and change coupled with substantial threats for society and nature. To reduce these threats, adaptation and mitigation are the two possible

societal response options (Intergovernmental Panel on Climate Change [IPCC] 2014; Füssel 2007). In the climate change context, adaptation is the process of adjustment to actual or expected climate and its effects in order to either lessen or avoid harm or exploit beneficial opportunities and mitigation is the process of reducing emissions or enhancing sinks of greenhouse gases (IPCC 2014). The two possible options (mitigation and adaptation) cannot substitute with each other rather complementary to each other (IPCC 2014; Füssel 2007). The already surfaced impact of climate change possibly addressed only through adaptation because it is difficult to reverse the already changed climate condition by mitigation. However, mitigation activity undertaken now has a reduction power in the long-term requirement of adaptation. Undoubtedly, climate change could impair economic growth of the nations and other facets of societal and natural wellbeing if the required adaptive measures not well taken now (Ethiopian Panel of Climate Change [EPCC] 2015; IPCC 2014; Chambwera and Stage 2010).

Historically, farmers have always attempted to adapt to the changing environmental condition of the agricultural systems. The attempt of the farmers to adapt becomes sometime successful and other time vain. Therefore, adaptation to changing climate condition by farmers has been the norm rather than the exception (EPCC 2015; Below et al. 2010; Füssel 2007; Adger 2003). However, the current speed of climate change is inducing and modifying known variability patterns beyond the coping capacity of systems (FAO 2008). As a prerequisite for adaptation, awareness by society about the changing condition of the climate required (Tripathi and Mishra 2016). Different scholars argued the importance of knowing the perception of the local people about the changing condition of the climate to facilitate the adaptation process (Nega et al. 2015; Tiwari et al. 2014; Woldeamlak 2012; Woldeamlak and Dawit 2011). Perceptions of climate change may affect how people will respond and adapt to its multiple impacts (Woldeamlak 2012). Concurrently, for someone to take action to adapt to climate change autonomously, he has to recognize climate change first. It is thus important to have some understanding about the perception of climate change by people residing in Fincha'a sub basin.

Therefore, this study aims to comprehend the agro-ecosystem based perception, impact, adaptive

responses and barriers to adaptation of smallholder farmers in the study area. Agroecosystem used as a unit of analysis because this particular study wants to capitalize the variations among the AES in a broader geographical area. The specific objectives were to (1) examine the perception of smallholder farmers' and the impact of climate variability and change on agriculture, (2) describe the adaptive response of farmers to climate variability and change, and (3) identify the major barriers for adoption of adaptation measures. The study area identified as one of the erosion hot spot area, vulnerable and least researched parts of the Blue Nile River Basin of Ethiopia. The findings of the study provide context-specific contribution to the agro-ecosystem based understanding of the perception and adaptation responses.

Literature review

Conceptually, *Climate variability* is a variation in the climate system over short time scales such as months, years or decades and *Climate change* is conceptualized as longer-term trends in mean climate variables of periods of decades or longer (IPCC 2014; Watson 2001). Similarly, *Adaptation* is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Whereas, *Adaptive capacity* is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC 2014).

Agroecosystems are ecological systems modified by human beings to produce food, fiber or other agricultural products (Conway 1987). It is an intersection of a set of agriculturally relevant climatic factors; soils and physiographic variables relevant to crop production; and a prevailing set of cropping practices. Agroecosystems are fundamentally different from natural ecosystems because they are human constructs and as such managed for agricultural goals (Rapport 2004).

Broadly, agricultural adaptation to climate change studied either at macro- or micro-levels (Kandlikar and Risbey 2000). The macro-level focuses on agricultural production systems adjustments at national and regional levels, whereas the micro-level concerned with farm level adjustments and decision-making (Nhemachena and Hassan 2007;

Kurukulasuriya and Rosenthal 2003; Kandlikar and Risbey 2000; Risbey et al. 1999). Based on the intent, adaptation divided into autonomous (private/collective) and/or planned (policy decision/public sector) (EPCC 2015; Füssel 2007). Considering time of response as a category adaptation might be proactive (adaptation that takes place before impacts are observed) or reactive (adaptation that takes place after impacts of climate change already observed) (IPCC 2007b).

Ethiopian economy is driven by agriculture despite the issue of high rainfall variability that leads to frequent drought and severe land degradation (EPCC 2015; Conway and Schipper 2011; World Bank 2010; Diao and Pratt 2007). The sector contributes about 38.5% of the Gross Domestic Product (GDP), 85% of the employment, 90% of the export earnings, and 80.2% of the populations' earnings coming from this sector; and hence the prime contributing sector to food security (World Bank 2008; MoFED 2010; Central Statistical Agency [CSA] 2013; National Planning Commission [NPC] 2016).

According to the National Adaptation Program of Action (NAPA), the foremost-predicted impacts of climate change on Ethiopia's agriculture include dry spells and frequent droughts, reduced growing season, and increased occurrence of pests and diseases (National Metrological Agency [NMA] 2007). The same report also identifies drought and floods are the two major weather extreme events, and agriculture and food security are the sectors impacted most. Ethiopia frequently cited as a highly vulnerable country and the major underlying vulnerability factor is the heavy dependence of the economy on climate sensitive rain-fed agriculture system (Paul and Weinthal 2018; Arragaw and Woldeamlak 2016; EPCC 2015; Conway and Schipper 2011; World Bank 2010).

Studies have shown that smallholder farmers in different parts of Ethiopia are facing different climate variability and change related problems. Such problems include reduced or variable rainfall, warming of temperatures, change in length of growing seasons, crop and livestock pests and diseases, weed problems, flooding, shortage of water and land degradation (Arragaw and Woldeamlak 2017; Wagesho et al. 2013; Woldeamlak 2012). The impact of climate variability and change contributes to reduced agricultural productivity, and without sound adaptation strategies by farmers, jeopardized the future

sustainability of the sector in the area (Popoola et al. 2017; Arragaw and Woldeamlak 2016).

To overcome the problem, reported adaptation measures practiced by smallholder farmers of Ethiopia include crop/livestock diversification, soil and water conservation, planting trees, changing planting dates, and irrigation (Gebrehiwot and van der Veen 2013; Tessema et al. 2013; Woldeamlak 2012; Woldeamlak and Dawit 2011; Amdu 2010; Temesgen et al. 2009). Similarly, the most frequently cited barrier to adaptation include lack of information on adaptation options, land shortage, money shortage, labor shortage, lack of access to fertilizer, insecure land tenure, poor market access and poor potential for irrigation (Gebrehiwot and van der Veen 2013; Tessema et al. 2013; Amdu 2010; Temesgen et al. 2009).

Study area

Biophysical setting

Fincha'a sub-basin is one of the eighteen sub-basins of the Blue Nile River basin. The Ethiopian part of Blue Nile River basin also called Abbay River Basin and located in the northwestern region of Ethiopia. The Abbay River Basin has sixteen sub basins, which covers a total surface area of about 199,812 Km² (Denekeew and Bekele 2009). The study sub basin specifically covered an area of about 4089.5 km² and located in the south-central part of the Abbay River Basin, western-central Ethiopia (Fig. 1). The altitude of the sub basin ranges approximately between 836 and 3209 masl.

The average annual rainfall of the sub basin is about 1678 mm/year. About 73% of the annual rainfall of the sub basin falls between June and September. The average annual maximum and minimum temperature of the sub basin is about 24.8 °C and 11.5 °C respectively.

Socioeconomic setting

The Fincha'a sub-basin administratively located in Oromia regional state, Horo Guduru Wollega Zone of Horo, Guduru, Hababo Guduru, Abay Chomen, Jima Geneti, Jima Rare, and Jardega Jarte Districts. According to the Central Statistical Authority (CSA) (2013), the total population of the sub basin in 2017

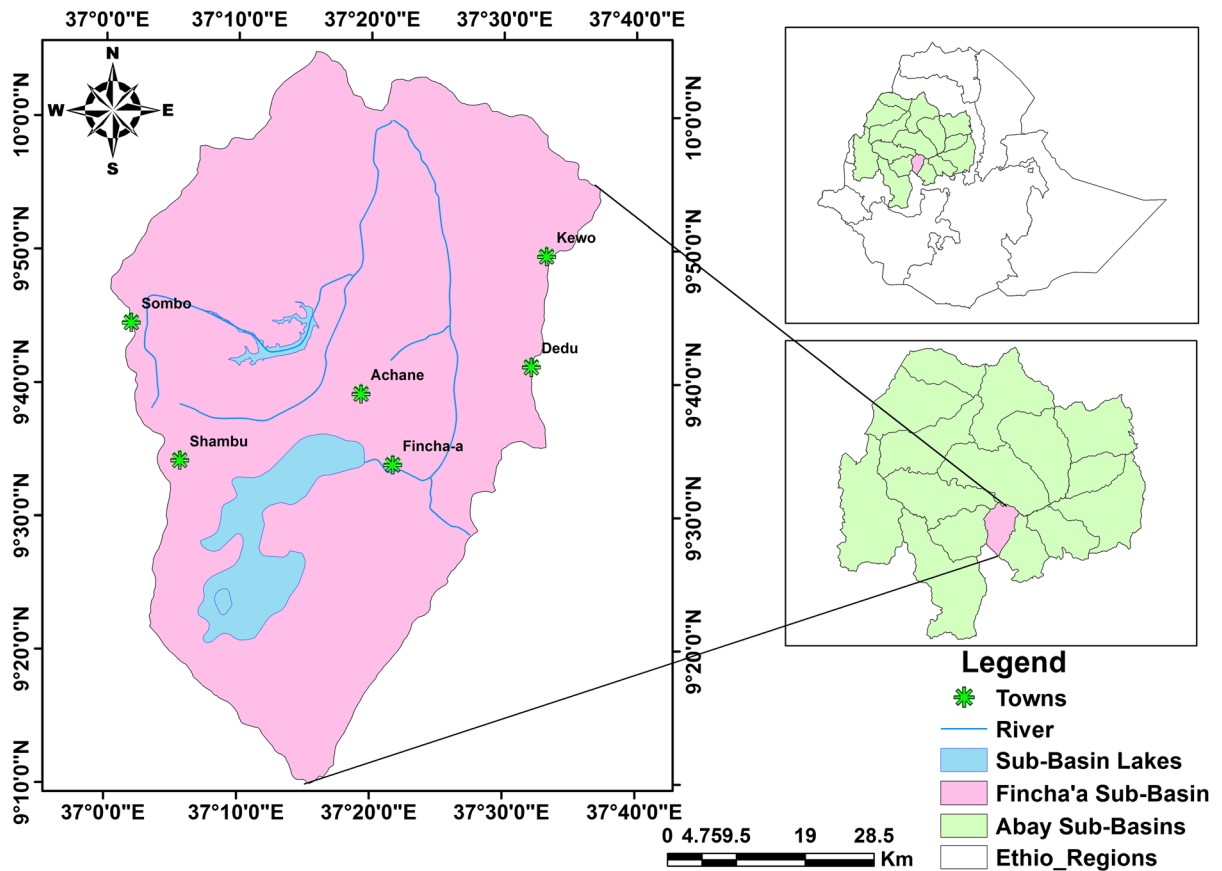


Fig. 1 Fincha'a Sub Basin and its associated Blue Nile/Abbay River Basin

assumed 577,467 and the average density of the population are about 153 people per km². Densities are highest on the plateau and ridges of the sub basin.

Mixed crop-livestock agriculture is the main economic stay of the people of the sub basin. The result of the analysis of the sub basin revealed that there are four agro-ecosystems (Highland, Midland, Wetland and Lowland) within the sub basin. This gives an opportunity for the cultivation of range of crops like Wheat (*Triticum aestivum* and *T. durum*) and Barley (*Hordeum vulgare*) in the highland, Teff (*Eragrostis tef*) and Maize (*Zea mays*) in the midland and wetland, and Maize (*Zea mays*) and Sorghum (*Sorghum bicolor* Moench) in the lowland agro-ecosystem. There are also other cereal, pulse, oilseed, and vegetables crops grown in the sub basin.

The farming system in the sub basin dominated by cereal production that accounts for about 75% of the total cultivated area. From cereals: teff, wheat, and maize account 30.9%, 23.6%, and 19.9% respectively.

Most cereal crops particularly teff and wheat are planted on fine seedbed and provided little ground-cover during the most erosive storms in July and early August. This combined with steeply sloping upland area and poor land management practices contributes to land degradation currently observed in the area. Even though overall crop productivity in the sub-basin is increasing, the average productivity of different crops is much less than the potential productivity (Table 1).

Methodology

Data collection and method of analysis

The study employed a multi-stage sampling procedure to select the District, Kebeles¹ and households from

¹ The lowest tiers in the administrative structure of the country.

Table 1 Comparison of the average yield and potential attainable yield of major crops in the sub-basin. *Source:* Survey result; Zonal & District agricultural Offices

Crop	Proportion (%)	Current yield (T/ha)	Potential yield (T/ha)	Yield gap (%)
Maize	15	3.11	4.5	30.9
Teff	23.3	0.90	2.0	55
Wheat	17.7	1.83	3.5	47.7
Barley	9.0	1.6	2.2	27.3
Niger seed	7.4	0.55	0.6	8.3
Faba bean	5.9	1.02	2.0	49
Average		1.5	2.5	40

the most general level (areas having similar agro-ecosystem) to the most precise level (household). In the first stage, the sub basin divided into similar agro-ecosystems based on the overlay of three inputs: an agro-climatic zoning based on precipitation and temperature, a soil and terrain analysis, and a map of the distribution of farming systems (Table 2). Based on the analysis four agro-ecosystems (Highland, Midland, Wetland and Lowland) identified in the sub-basin (Fig. 2). In the second stage, the seven Districts found in the sub basin grouped into possible agro-ecosystems and three representative Districts (Horo, Jima Genete and Hababo Guduru) that represent the four agro-ecosystems selected randomly. The significance was to enable the research to focus on similarity and differences in vulnerability and adaptation strategy, depend on local context and circumstances, to climate variability and change on specific agro-ecosystem. Then, two kebeles selected randomly for each agro-ecosystem from the selected Districts. A systematic random sampling method employed for the selection of respondent household heads. The sampling frame (list of households residing in the Kebele)

used for selection of households obtained from kebele administration.

Finally, 380 randomly sampled households selected living in eight Kebeles (two Kebeles in each AES), 95 households from each agro-ecosystem, participated in cross sectional survey. The detailed survey questionnaire generated household level data on household socio-demographic characteristics, perceptions of climate change, perceived impacts of climate change on agricultural production, adaptive responses employed and barriers to implement adaptation measures to current climate variability and change. To augment the quantitative information obtained from household survey, focus group discussions [FGD] (two from each agro-ecosystem) and key informant interviews [KII] with individual farmers (two from each agro-ecosystem) undertaken by using semi-structured checklists to generate additional in-depth qualitative information. The timeframe considered to assess climate change perceptions was the past two decades. The fieldwork carried out from May to June 2017.

To analyze the data descriptive statistical method that comprises percentages, means and frequencies

Table 2 Fincha’a sbu-basin Agro-ecosystems and their characteristics

Agro-ecosystem (AES)	Farming systems	Traditional climatic zone	Major soils	Major crops
Highland	Semi-intensive Barley-Wheat based	Dega	Leptosols	
Luvisols	Barley, Wheat, Fave Bean			
Midland	Intensive Teff-Maize based	Upper Weyna Dega	Leptosols	
Nitosols	Teff, Maize, Niger seed			
Wetland	Intensive Teff-Maize based	Lower Weyna Dega	Nitosols	Teff, Maize
Lowland	Sorghum-based extensive	Upper Kola	Luvisols Vertisoil	Sorghum, Teff, Sesame

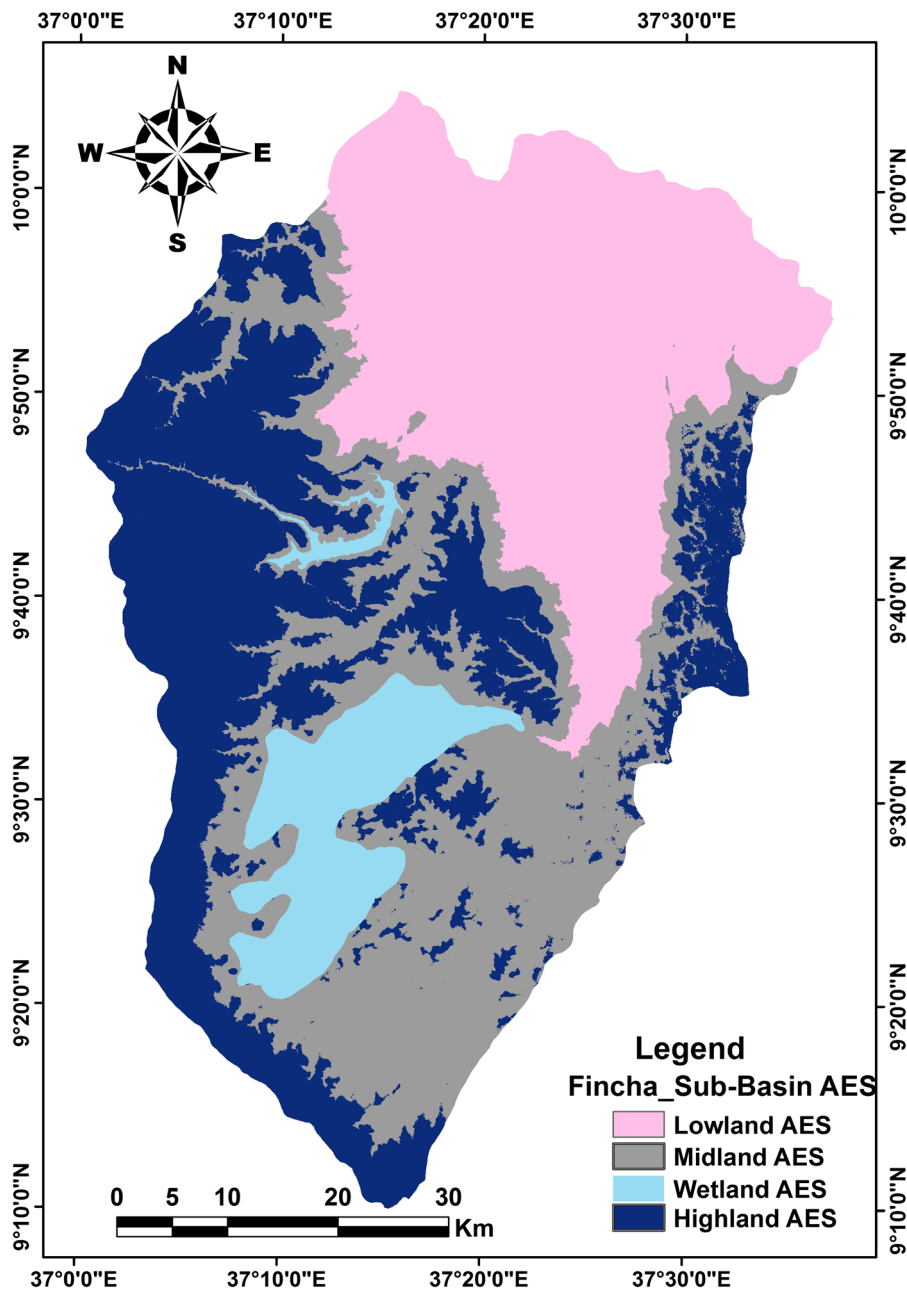


Fig. 2 Agro-ecosystems (AES) of Fincha'a Sub Basin

employed to summarize quantitative data on climate variability and change perceptions, impacts, adaptation strategies, and barriers to adaptation. Chi square test (χ^2) also used to test the statistical significance of variations across the four agro-ecosystems. Qualitative data used to augment and substantiate the quantitative analyses. The statistical software

packages SPSS (statistical package for social scientists) and MS EXCEL used for data management and analysis.

Composite Index of Adoption (CIA) developed by Barungi and Maona (2011) used to know the intensity of adoption of adaptation strategies. These help to understand the variation in utilizing technologies and

Table 3 Characteristics of the study population (n = 380)
Source: Field Survey, 2017

Characteristics	Category	%
Gender	Male Headed Households	92.9
	Female Headed Households	7.1
Age	15–30	28.7
	31–65	68.4
	> 65	2.9
Marital status	Single	4.2
	Married	91.6
	Divorced	1.05
	Widowed	3.15
Education	Illiterate	37.1
	Reading & Writing	37.9
	Primary School	16.6
	Secondary School & above	8.4
Religion	Orthodox	54.7
	Protestant	36.8
	Wakefetta	7.4
	Muslims	0.8
	Catholic	0.3
Ethnic background	Oromo	96.6
	Amhara	3.4

for effective formulation of adaptation strategies. CIA computed as follows

$$CIA = \frac{\sum_{i=1}^{t=n} (T_i/T)}{N}$$

where T_a denotes the total number of coping or adaptation strategies used by a farmer; T denotes the total number of coping or adaptation strategies available; N denotes the sample size and $T_a/T/N$ represents the index of adoption for a household.

Results and discussion

Farmers' perceptions of local climate variability and change and its impacts

Demographic characteristics of the respondents

Table 3 presents the demographic characteristics of sampled households in terms of gender, age

composition, marital status, education level, religion, and ethnic background.

Farmers' perceptions of local climate variability and change

Of the different climatic change parameters, respondents asked about their observations of local changes in temperature, precipitation, and climatic extreme events (drought and flooding) over the past two decades. In terms of temperature changes, about 92.9% (standard deviation of 6.6% among agro-ecosystems) of the total respondents perceived that the temperature has increased with significant difference among households in the four agro-ecosystems. In terms of total annual rainfall 87.9% (standard deviation of 11.5% among agro-ecosystems) of the total respondents perceived that, the total annual rainfall has decreased with significantly different at 1% level of significance across agro-ecosystems. About 88.7% believed that there is overall change in seasonality of rainfall; 85.6% experience drought extreme weather event; and 87.9% experience flooding extreme weather events in the past 20 years (Table 4). Findings from focus group discussions and key informant interview also substantiate the information from survey results. The findings of focus group discussion summarized below.

FGD in AES: As we heard from our forefathers and even in the past as elders mentioned, it is clear that the rain was so generous. Temperature increasing year by year, the rain usually used to come on time and rarely interrupts in a season, and the recurrence of drought increased.

Farmers' perception of increased temperature is consistent with what reported in the National Adaptation Plan of Action (0.37 °C every ten years) and Ethiopian Panel of Climate Change that the average temperature in the country increased for the last five decades (0.2 °C per decade). Conversely, the perceived decline in rainfall does not show decreasing records in many parts of the country rather show variability (EPCC 2015; NMA 2007). KIIs & FGDs unanimously witnessed increasing trends of temperature. Regarding rainfall, the discussants raised different views: all participants agreed the change in rainfall pattern but there are diverse views among the participants in overall amount of rainfall. Some argued total

annual amount increased and many others said decreased. The difference is mostly associated with the variation in agro-ecosystem. The results are compatible with similar findings of farmers' perception of increased temperature and decreased rainfall reported by earlier studies conducted in other parts of the country (Getachew et al. 2018; Woldeamlak 2012; Woldeamlak and Dawit 2011; Aklilu and Alebachew 2009; Temesgen et al. 2008).

Study conducted in the Amhara National Regional State of Ethiopia (Menz Mama Midir District) reported similar findings of perceived increased temperature and decreased annual rainfall from study covered 90 households in three rural Kebeles (Woldeamlak 2012). Similarly, in a study conducted in Abay and Baro-Akobo river basins of Ethiopia, 82% and 96% perception of the respondents reported increased in temperature and decreased in annual rainfall respectively from 500 households in five sample Districts (Woldeamlak and Dawit 2011). Furthermore, in a study conducted in the southern lowlands of Ethiopia out of the 359 respondents 93% and 88% of them perceived increased mean temperatures and

decreased annual rainfall respectively (Aklilu and Alebachew 2009).

Studies conducted in other parts of Africa have also shown a similar trend of an increase in temperature and decrease in precipitation of the climate change parameters. For instance, studies conducted in 10 sub-Saharan African countries by World Bank on perceptions of an adaptation to climate change that covered over 9500 smallholder farmers found that significant numbers of farmers across 10 countries believed average temperatures had increased (Maddison 2007). Similarly, study conducted in different parts of Kenya (n = 710) reported that 94% of the farmers perceived an increase in average temperatures and 88% perceived a decrease in average rainfall over the last 20 years (Bryan et al. 2011).

Generally, the people's perception of increased temperatures is consistent and shows similar result with meteorological records in many parts of the country (EPCC 2015; NMA 2007). According to the respondents, the frequency and severity of extreme weather events (drought and flood) increased in the study sub-basin. Over the past 20 years, on average

Table 4 Farmers' perceptions of local climate variability and change (% of respondents)

Climate change factors	Agro-ecosystems of the sub basin				Total	χ^2 value
	Highland	Midland	Wetland	Lowland		
Temperature						
Increasing	85.3	89.5	97.9	98.9	92.9	23.67**
Decreasing	8.4	4.2	1.1	0	3.4	Df = 6
No change	3.2	1.1	0	0	1.1	
I don't know	3.2	5.3	1.1	1.1	2.6	
Precipitation (total annual)						
Increasing	21.1	5.3	10.5	0	35	36.06***
Decreasing	72.6	91.6	87.4	100	87.9	Df = 6
No change	6.3	3.2	2.1	0	2.9	
Change in seasonality	82.1	89.5	85.3	97.9	88.7	13.29***
Extreme events						
Experience of extreme weather event (drought) in the past 20 years	76.8	94.7	77.9	93.7	85.6	22.2***
How frequent does drought occur in the past 20 years?	2.81	1.5	1.88	3.58	2.4	
Experience of extreme weather event (flood) in the past 20 years	76.8	91.6	91.6	91.6	87.9	14.6***
How frequent does flood occur in the past 20 years?	2.95	1.53	5.49	3.02	3.3	

**Significance at 0.05 probability levels

***Significance at 0.01 probability levels

Box 1 Elderly key informant from Gitilo Najor Kebele (highland agro-ecosystem) about the perceived climatic and other changes

Mr File is a 61-year-old farmer (male) in highland agro-ecosystem. He has lived in the area all his life and is currently head of a family of seven household members. Over the past 20 to 30 years, he reported that he had observed the following climatic and related changes

Rainfall variability increased over the past years. Shift in the seasonal rainfall pattern, especially sudden interruption of rainfall by the end of the rainy season is a common phenomenon

Temperatures are increasing year by year, and in consequence crops like teff (*Eragrostis abyssinica*), noug (*Guizotia abyssinica*) and even maize (*Zea mays*) at the periphery that were not grown in the highland agro-ecosystem have now started growing. The incidence of disease and pest frequency increased, and consequently our crop production and productivity level affected highly

The number of people in the area is increasing and the per capita land holding of the farmers decreasing from time to time

each study households experience 2.4 times drought and 3.3 times flooding. Similar finding reported by Mahoo et al. (2013) that states the frequency and severity of natural shocks has increased in recent years in Ethiopia (Box 1).

Farmers' perceptions of climate variability and change impact on agriculture

Table 4 presents respondents' observation of climate variability and change impact on crop and livestock production in the study sub-basin. Though there are variations among AES, more than 85% of farmers had observed decline in length of growing period during the main Kiremt season. The finding is compatible with Paul et al. (2013) who stated climate change scenarios and models suggest that many parts of Ethiopia are likely to experience a decrease in the length of growing period, and even the decrease is severe in some areas. Any change in the crop-growing period is a challenge as it considerably affects farmers' decisions on what and when to plant (Woldeamlak 2012). With statistically significant differences among the AES, about 41.6% of total respondents reported decline in water availability, while 39% believed that there was more variability in water availability.

Similarly, about 79% of respondents observed an increased incidence of crop damaged by disease, 93% respondents observed an increase incidence of crop damage by insects and pests, and 96% respondents observed the severity of weed infestation in crop fields as one of the manifestations of climate variability and change. As farmers confirmed during FGDs and KIIs, though, the problems of agricultural crop diseases, insects, pests, and weeds are an already existing

problem in the study area; it is aggravated and increased in incidence over the past 20 years. With a statistically significant difference among the AES, about 68% of respondents reported an increase in the incidence of livestock diseases and the rest (32%) observed no change in the occurrence of livestock diseases. During FGDs, shortage of livestock-feed raised as one major problem and farmers agreed, as the problem is shortage of grazing land rather than climate change.

The perception of the farmers residing in different AES, which is the reflections of local impacts, can vary with variations in agro-ecosystem conditions. A higher proportion of households in highland, midland, and wetland AES areas perceived changes in length of crop growing period as compared to the lowland AES. Change in water availability is higher in lowland AES as compared to the other AES being the difference is statistically significant at 0.01 probability level. The incidence of agricultural pests, diseases, and weeds are comparable being the difference is statistically significant. The shift in crop growing areas is higher in highland, midland, and wetland AES as compared to households in lowland AES, the difference being statistically significant. The incidence of livestock disease increased in lowland, midland, and wetland AES as compared to the highland AES. The result supports scientific predictions and evidence elsewhere that climate change impacts are more likely felt visibly in the climatically extreme areas (cold highland and dry lowland areas) compared to those in intermediate conditions (EPCC 2015). Generally, there was a statistically significant difference in the different indicators of climate change perceptions across the four AES (Table 5).

Table 5 Perceived impact of climate variability and change on agriculture (% of respondents)

Indicator	Response	Agro-ecosystems of the sub-basin				Total	χ^2 value
		Highland	Midland	Wetland	Lowland		
Change in length of growing period	Increase	0	0	0	1.05	0.26	79.92***
	Decrease	93.7	96.8	92.6	56.9	85.00	Df = 6
	No change	6.3	3.2	7.4	42.1	14.7	
Change in water availability	Increase	6.3	0	28.4	0	8.7	159.65***
	Decrease	18.9	52.6	29.5	65.3	41.6	Df = 9
	More variable	40.0	43.2	37.9	34.7	38.9	
	No change	34.7	4.2	4.2	0	10.8	
Change in crop disease	Increase	65.26	82.1	83.16	85.26	78.95	14.56**
	Decrease	0	0	0	0	0	Df = 6
	No change	34.74	17.9	16.84	14.74	21.05	
Change in crop damage by insects and pests	Increase	82.1	100	91.58	100	93.42	33.69***
	Decrease	0	0	0	0	0	Df = 6
	No change	17.9	0	8.42	0	6.58	
Change in the problem of weeds	Increase	89.47	100	92.63	100	95.52	25.18***
	Decrease	0	0	2.11	0	0.53	Df = 6
	No change	10.53	0	5.26	0	3.95	
Any shift in suitable growing areas	Yes	100	76.84	80.0	0	64.21	240.3***
	No	0	23.16	20.0	100	35.79	Df = 3
Change in livestock disease	Increase	42.11	78.95	69.47	82.11	68.16	43.38***
	Decrease	0	0	0	0	0	Df = 6
	No change	57.89	21.05	30.53	17.89	31.84	

*Significance at 0.10 probability levels

**Significance at 0.05 probability levels

***Significance at 0.01

Farmers' adaptive responses to climate variability and change

The adaptive responses of the farmers to the perceived climate variability and change categorized into two broad categories of adjustments in crop and livestock production, and responses through natural resources management.

Adaptive responses in crop and livestock production

In the study area, where the total annual average precipitation volumes are relatively higher (about 1678 mm), as farmers verified the greatest impacts on agricultural production are from changes in rainfall variability, such as prolonged periods of drought and changes in the seasonal pattern of rainfall. To overcome the challenges different types of adaptation

measures have been used by farmers in crop and livestock production activities. Table 6 presents the adaptation measures implemented by smallholder farmers to overcome the challenges of climate variability and change in crop and livestock production system. The adaptation measures implemented in crop production includes: (1) using new crop varieties (50.8% of the total respondents), (2) incorporation of crop residue (37.6% of the respondents), (3) adjusting the agricultural calendar/dates of planting and harvesting (32.9% of the respondents) and (4) use of early maturing crop varieties for the crops traditionally produced (26.6% of the respondents). Despite the number of adaptors are relatively small, practices such as increased diversification of crops produced (25.8% of the total respondents), use of drought tolerant crop varieties (20.5% of the respondents), use of disease/pest tolerant crop varieties (4.5% of the respondents),

Table 6 Adaptation measures in crop and livestock production (% of respondents)

Adaptation Measures	Highland	Midland	Wetland	Lowland	Total	χ^2 value
Crop						
Crop diversification (Increasing the number of crops produced)	37.9	46.3	13.7	5.3	25.8	56.38***
Using new crop varieties	44.2	69.5	60	29.5	50.8	35.42***
Adjusting date of planting	32.6	42.1	23.2	33.7	32.9	7.76*
Use of early maturing crop varieties	17.9	29.5	14.7	44.2	26.6	26.04***
Use of drought tolerant crop varieties	15.8	22.1	4.2	40.0	20.5	36.58***
Use of disease/pest tolerant crop varieties	6.3	11.6	0	0	4.5	20.87***
Incorporation of crop residues	17.9	44.2	40.0	48.4	37.6	22.45***
Planting high value fruit trees	6.3	0	0	0	1.6	18.28***
Livestock						
Livestock diversification (Increasing the type of animals kept)	15.8	24.2	14.7	4.2	14.7	15.24**
Changing the type of animals kept	0	7.4	0	9.5	4.2	17.23***
Reducing the number of animals kept	41.1	24.2	10.5	17.9	23.4	26.93***
Sale weak and old animals before the outbreak of long dry season	49.5	55.8	12.6	30.5	37.1	46.59***
Keeping improved animals' breeds	2	0	0	0	0.5	6.03
Practicing improved animal feed production/planting trees for animal feed	8.4	14.7	0	0	5.8	26.84***
Moving with animals in search of pasture and water	0	12.6	0	0	3.2	37.18***

*Significance at 0.10 probability levels

**Significance at 0.05 probability levels

***Significance at 0.01 probability levels

and planting high value fruit trees (1.6% of respondents) had been practiced by smallholder farmers (Table 6). Such adaptation practices believed to increase the resilience against climate change, particularly for an increase in climate variability like prolonged periods of drought, and seasonal shifts in rainfall. It also maintains production under changing rainfall patterns, such as changes in the timing of rains or erratic rainfall patterns. In addition, adaptation measure like incorporation of crop residue improves soil fertility and water holding capacity of the soil (FAO 2009).

Measures implemented by farmers in the livestock sub-sector includes: (1) sale weak and old animals before the outbreak of long dry season (37.1% of respondents), (2) reducing the number of animals kept (23.4% of respondents), and (3) livestock diversification (14.7% of respondents). Small number of farmers also practiced improved animal feed production/planting trees for animal feed (5.8% of respondents), changed the types of animals kept from cattle to small

ruminants (4.2% of respondents), moved with animals in search of pasture (3.2% of respondents), and kept improved animal breeds (0.5% of respondents) as an adaptation strategy. Significant statistical differences observed among the four agro-ecosystems in terms of almost all adaptation measures used (Table 6). Many authors including (Woldeamlak 2012; Bryan et al. 2011; FAO 2009; Temesgen et al. 2009) have mentioned the above widely used adaptation strategies in different parts of Ethiopia & Africa.

Adaptive responses through water and other natural resources

Agricultural management practices that increase agricultural production and reduce production risk also tend to be support climate change adaptation as they increase agricultural resilience and reduce yield variability under climate variability and extreme events, which might intensify with climate change (Bryan et al. 2011). Such activities implemented both

Table 7 Soil and water management measures used in individual farm (% of respondents)

Adaptation Measures	Highland	Midland	Wetland	Lowland	Total	χ^2 value
Crop rotation	90.5	99	85.3	99.0	93.5	21.03***
Intercropping	17.9	23.2	11.6	32.6	21.3	13.41***
Compost preparation	26.3	24.2	7.4	49.5	26.9	43.48***
Manure heaping	29.5	21.1	11.6	0	15.6	34.89***
Contour plowing	100	94.7	92.6	95.8	95.8	6.79
Irrigation practice	31.6	16.8	42.1	0	22.6	54.53***
Soil & Stone bunds	43.2	32.6	34.7	65.3	44.0	25.75***
Water ways/Cut of drain	43.2	9.5	42.1	33.7	32.1	32.11***
Check Dam	21.1	32.6	35.8	11.6	25.3	18.63***
Planting trees	35.8	29.5	37.9	76.8	45.0	53.36***

***Significance at 0.01 probability levels

at household and community levels to adapt to the changing climatic conditions and local environmental change more broadly. Management practices undertaken at household level include crop rotation, contour plowing, intercropping, manure preparation and application, and land management activities.

Of the different adaptation measures implemented at household level crop rotation and contour plowing activities practiced almost by the entire respondents. Out of the soil management activities that include intercropping, compost preparation, and manure heaping practiced by 21.3%, 26.9%, and 15.9% of the total respondents respectively. Similarly, physical and biological soil and water conservation activities like soil and stone bunds, water way, check dams, and planting of trees carried out by 44%, 32.1%, 25.3%, and 45% of the total respondents respectively. Irrigation practiced by about 22.6% of the respondents. In almost all of the conservation adaptation measures applied at household level, statistically significant difference observed among the four agro-ecosystems (Table 7).

Likewise, community level interventions to create assets include physical and biological soil and water

conservation measures, afforestation and reforestation activities, and river diversion activities for traditional small-scale irrigation activities. Among the total respondents' majority of them participated in the adaptation measures implemented at the community level: soil and water conservation (81.6%) and afforestation/reforestation activities (78.4%). The relative high number of household participation in community asset creation attributed by the fact that such adaptation measures coordinated and implemented by District and Kebele government officials as a planned adaptation strategy. Statistically significant difference observed among the four AES in participation of river diversion by the community (Table 8). The result revealed community participation in river diversion is higher in highland AES, where as nil in the lowland AES, which is simply the result of have no access to such irrigation schemes in this specific AES. This shows the prevailing agro-ecological conditions and available environmental resources influence options for agricultural adaptation.

Rainwater storage in the soil (in situ) or in any reservoir (ex situ) is widely promoted adaptation option to climate change in Ethiopia and elsewhere in

Table 8 Adaptation through water & other natural resource management: community asset creation (% of households)

Adaptation Measures	Highland	Midland	Wetland	Lowland	Total	χ^2 value
Participating in soil and water conservation with community	87.4	82.1	71.6	85.3	81.6	9.31*
Participating in afforestation/reforestation with the community	76.8	86.3	78.9	71.6	78.4	6.28
Participating in river diversion with the community for irrigation	40.0	16.8	18.9	0	18.9	49.89***

*Significance at 0.10 probability levels

***Significance at 0.01 probability levels

the world. However, it was hard to find such intervention in the study area. Water based intervention promoted as an adaptation strategy by smallholders' farmers because it offers a suitable means for upgrading rain-fed agriculture through in situ soil moisture conservation and on-farm runoff storage for complete and supplementary irrigation (Mahoo et al. 2013). Additionally, rainwater-harvesting techniques can prevent degradation of natural resources through reduced soil erosion especially in the fragile highland agro-ecosystems.

Asset creating collective action-based adaptation measures like watershed land and water management activities increases the resiliency of the systems. Once the resilience of the systems enhanced the adaptive capacity increased. Adaptive capacity means the whole of capabilities of systems, resources and institutions of a country/region to implement effective adaptation measures to varied changes (Smit and Pilifosova 2003; MEA 2005; IPCC 2014). Therefore, such type of measures should be encouraged and supported as a planned adaptation measure.

Generally, the adaptation measures implemented in the study area until now are not adequate to meet the impending challenges situate by climate variability and change. According to EPCC (2015), climate change has been happening and will continue to happen with severe impacts on crop and animal production as well as on food security and the national economy. Based on our observation of the area and as verified during FGDs there is high encroachment of agricultural land to the forest and grazing land use system in the area. These aggravated the land degradation problem found in the highland AES, and flooding and siltation problem in the wetland AES including the hydropower dams. Recent studies have shown that flood hazard is increasing in the highland areas due to changes in land use/land cover, rainfall pattern, and drainage (Kassa et al. 2014). Therefore, any planned adaptation approach implemented in the area should incorporate forms of land use and land use change, and targeted payment for environmental services.

Intensity of adoption of adaptation measures at the household level

The sample households totally utilized 27 adaptation measures in response to the perceived climate

variability and change. To know the intensity of adoption of adaptation measures, composite index of adoption (CIA) computed by utilizing the total number of adaptations measure a single farmer practiced from the possible available options. The adaptation measures implemented vary from AES to AES. The most widely practiced adaptation measure in all the AESs is contour plowing (96%) followed by crop rotation (94%). The least implemented adaptation measures are keeping improved animal breeds (1%) and planting high value fruit trees (2%) found only in the highland AES. Of the total adaptation strategies identified in the sub-basin (27), the actual implemented strategies by farmers range from 3 to 15 and the overall mean is 8.7. This shows that the intensity of adoption of adaptation measures by farmers in the sub-basin is below average. Adaptation is a process and its outcome affected by many factors and widely varies between countries, communities, and over time. Factors that influence adaptation of smallholder farmers include farmers' characteristics, extension services, social networks, financial services, and technological factors. These groups of factors are not only influencing adaptation but also responsible for difference choices of adaptation strategies and behaves differently in different countries and regions depending on the level of development (Rass 2006).

When we evaluate the sub-basin based on percentage of farmers practicing certain type of adaptation measures, on average 32% of farmers adopted certain adaptation measures. The value is higher 35%, 34%, and 33% for midland, highland, and lowland AESs respectively. Whereas, the corresponding value for the lowland AES is below the average (27%). Relatively, farmers found in the midland AES implemented higher number of adaptation strategies from the available list of options. The calculated value of CIA for midland, highland, lowland, and wetland AESs were 0.36, 0.34, 0.32, and 0.26 respectively. The CIA value is higher for midland AES and lower for wetland AES as compared to the other AESs. Although, the surveyed farmers at least practiced three adaptation strategies, the overall result of the finding verifies that the adoption of the adaptation measures is below average.

From the result, one can conclude that there is extrication between farmers' perceptions of climate variability and change, and actual adaptation level. Despite significant number of farmers' perceived

Table 9 Barriers affecting adaptation to climate variability & change (% of respondents)

Adaptation Barrier	Agro-ecosystems				Mean	χ^2 value
	Highland	Midland	Wetland	Lowland		
Lack of knowledge & Information	71.6	61.1	77.9	88.4	74.8	19.85***
Lack of modern agricultural inputs	65.3	58.9	67.4	80.0	67.9	10.19**
Labor shortage	67.4	44.2	35.8	71.6	54.8	35.0***
Low potential for irrigation	29.5	50.5	18.9	92.6	47.9	121.2***
Lack of finance	49.5	41.0	40.0	58.9	47.3	8.87*
Lack of technical support	18.9	14.7	22.1	30.5	21.6	7.51*

*Significance at 0.10 probability levels

**Significance at 0.05 probability levels

***Significance at 0.01 probability levels

changes in temperature (about 93%) and rainfall (about 88%), the number of farmers adopted certain adaptation measures are below average. The finding supports some previous study conducted in Ethiopia (Temesgen et al. 2009; Bryan et al. 2009). According to Temesgen et al. (2009), almost half of their surveyed farmers in the Nile Basin of Ethiopia (n = 1000) did not attempt to adapt to climate change and variability. Similar result also obtained by Bryan et al. (2009) in which 37% of respondents did not adapt to perceived climate change. Whereas study conducted by Arragaw and Woldeamlak (2017) in central highlands of Ethiopia revealed that more than 63% adapted certain adaptation measures.

Barriers to adaptation

Barriers are the interaction of complex of factors that influence adaptation. According to Islam et al. (2014), barriers that hamper adaptation are a function of “the people involved, the nature of the specific systems involved and/or the larger context in which the people and systems operate”. On the other way Biesbroek et al. (2013) views barriers as factors and conditions that emerge from the actor, the governance system or the system of concern. From this, it is apparent that barriers are the interaction of complex of factors that influence adaptation. Respondents in the study area mentioned many factors that hindered them in the adoption of adaptation measures. Among which knowledge and information are the most frequently cited barrier in the study area (75%). Other barriers

include lack of insufficient supply of modern agricultural inputs (like improved seed, fertilizer, and crop protection inputs) (68%), labor shortage (55%), low potential for irrigation (48%), lack of finance (47%), and lack of technical support (22%).

During FGDs, farmers raised the issue of free grazing animals for the low level of adoption of biological and physical soil and water conservation measures. Lack of adequate information and technical support is another area that farmers broadly speaking about for lack of effective adaptation strategies. This implies that farmers in the area requires to raise their level of awareness about changes of the climate condition, implement controlled grazing and create the possibility of better access to technologies to cope with the changes and/or adapt to it. Statistically significant differences observed among the four agro-ecosystems in terms of almost all adaptation barriers (Table 9). Similar studies conducted in other parts of the country obtained almost similar results despite the difference in the order of their influence that vary across the areas (Getachew et al. 2018; Arragaw and Woldeamlak 2017; Temesgen et al. 2009).

Conclusion and recommendation

Ethiopia as a country suffers a lot from climate variability and change, and upcoming change in climate constitutes a major development challenge. Therefore, understand the nature of climate change impacts, farmers perception of these changes and

indigenous adaptation practices at local levels have gained importance to design and implement appropriate adaptation strategies at local and household levels. This particular study examined farmers' perception of climate variability and change, the impact of climate variability and change on agriculture sector, adaptation measures taken by smallholder farmers and barriers faced during the course of adaptation in four agro-ecosystems of the Fincha's sub-basin. It is evident that the majorities of farmers in the sub-basin are aware of warmer temperatures and changes in rainfall patterns and overall decrease of the annual total rainfall. Farmers' perception of increased temperature and changes in rainfall pattern evidenced by meteorological data, whilst decreased in annual total rainfall not proofed. The main impact of the change on crop and livestock production as reported by respondents include decline in length of growing period, the decreased and variability of water availability, increased crop damage by insects and pests, increased infestation of weeds, and increased incidence of livestock disease.

To respond to these changes, farmers have adopted a range of measures like crop diversification, planting different crop varieties, changing planting and harvesting dates to correspond to the changing pattern of rainfall, irrigation, implementing different land management measures, and different biological and physical soil conservation measures. The adaptation measures implemented until now are not adequate to meet the impending challenges situated by climate variability and change. There is also extrication between farmers' perceptions of climate variability and change, and actual adaptation level. Despite significant number of farmers' perceived changes in temperature and rainfall, the number of farmers adopted certain adaptation measures are below average. The finding also revealed the presence of multiple barriers that hindered the adoption of available adaptation measures.

These necessitate that there is a need for planned interventions to identify and support effective adaptation measures. Some of the possible interventions include increase the awareness of the community to avert their information and knowledge barriers, and increase their predictive capacity by government and non-governmental organizations, investments in integrated natural resources management by government and non-governmental organizations, dissemination

of improved and suitable crop varieties, agro-ecosystem specific in situ and ex situ rainwater harvesting technique, crop diversification, and integrated pest control are some to mention. It is also obvious that such interventions should build on farmers' knowledge by following farmer-participatory processes.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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