SMALLHOLDER COFFEE PRODUCER'S PERCEPTION AND ADAPTATION STRATEGIES TO CLIMATE CHANGE AND VARIABILTY IN MANA DISTRICT, JIMMA ZONE, SOUTHWESTERN ETHIOPIA

MSC THESIS

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Smallholder Coffee Producer’s Perception and Adaptation Strategies to Climate Change and Variability in Mana District, Jimma Zone, Southwestern Ethiopia

MSc Thesis

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I have completed my thesis research work as per the approved proposal and it has been evaluated and accepted by my advisors. Hence, here by kindly request the Department to allow me to present the findings of my work and submit the thesis.

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Abayineh Amare (PhD, Assistance Prof.) ____________________ July 16/2020

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DEDICATION

I dedicated this thesis document to my family!

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETC

The author was born in 1994 in Abeku Ano kebele, Ilu gelan woreda, west Showa Zone of Oromia Regional State. He attended his primary education starting from 2002-2009 at Dano Roge and 2009-2010 at Sire Silase Primary School, and his secondary and preparatory education from 2010-2013 at Gedo Secondary and Preparatory School. He joined University of Gondar, College of Agriculture and Rural Transformation at 2014, and he graduated in BSc degree in Rural Development and Agricultural Extension at 2016. As soon as he graduated from the University of Gondar, he was competed the Federal Agricultural College instructor at Ministry of Agriculture and Natural resource, and he recruited as Junior Instructor at Mizan Agriculture Technical and Vocational Education Training (MATVET) in South Nation, Nationality and People regional state. After one year, he joined Mizan-Tepi University and recruited as Assistance Lecturer. And in order to develop his level of education and to be competent in knowledge, skills and attitude, Mizan-Tepi University gave the chance of MSc study leave and sent him to Jimma University in coordinated with Ministry of Education. By the time he joined Jimma University, he had two years of professional working experience particularly in teaching of higher education.

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ACRONYMS AND ABBREVIATIONS

CC	Climate Change
CC	Contingency coefficient
CSA	Central Statistical Agency
ECFF	Environment and Coffee Forest Forum
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
HH	Household Head
ICA	International Coffee Association
ICO	International Coffee Organization
IPCC	Intergovernmental Panel on Climate Change
IPPCC	Intergovernmental Panel on Climate Change
MDAO	Mana District Administration Office
MoANR	Ministry of Agriculture and Natural Resource
MVP	Multivariate probit
SNNPR	South Nation Nationalities and People Region
SML	Simulation Maximum Likelihood
UNDP	United Nation Development Program
USAID	Unite State Agency for International Development
VIF	Variance Inflation Factor
WCR	World Coffee Research
WMO	World Meteorological Organization
WOMSC	Western Oromia Metrology Service Center

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Smallholder Coffee Producer's Perception and Adaptation Strategies to Climate Change and Variability in Mana District, Jimma Zone, Southwestern Ethiopia

ABSTRACT

Climate change and variability is one of the great change agricultural productions of smallholder farmers of the developing countries. Coffee crop is the major cash crop that plays foremost role in earning foreign revenue of the Ethiopian and needs suitable climate to give yields. The study aimed to assess smallholder coffee producer's perception and adaptation strategies to climate change and variability in Manna district, Jimma zone, Southwestern Ethiopia. The study used mixed research approach which requires quantitative and qualitative data. Using simple random sampling design, 377 households were selected. Interview schedule, focus group discussion and key informants were used for data collection. Descriptive statistics and multivariate probit model were used in quantitative data analysis, and content analysis was used in qualitative data analysis. The survey result showed that 80.37% of sample household have perceived climate change and 19.63% of households have not perceived. Soil conservation, planting shade trees, adjusting harvesting date, and improved coffee variety were the major climate change and variability adaptation strategies household have employed in the study area. The outcomes of multivariate probit indicated that being male household head, household size, farm size, farming experience, educational level, frequency of extension contact, access to climate change information, perception to climate change, farmer-to-farmer extension, access to credit service, and nonfarm activities participation of household were significant and positively influenced households in adoption of adaptation options. But, age of household was negatively affected households. However, agro-ecological setting of household, market distance and the number of household membership in local institutions were insignificant in the study. Therefore, it was recommended that agricultural extension service should be encouraged, the agenda of planting trees should be expanded and familiar with households, financial institution should be affordable in making suitable policy for farmers, and households should be participate nonfarm activities, and aged households and female headed households should be motivated.

Key Words: climate change and variability, perception, adaptation, determinant, coffee farmer, MVP, Mana

1. INTRODUCTION

1.1. Background of the Study

Climate change is the worldwide environmental threats that seriously affect agricultural productivity and one of the biggest global problems posing challenges to sustainable livelihoods, food security and economic development (Enete and Amusa, 2016). Particularly, developing countries are the most adversely affected by climate change due to their large reliance on natural resources and low level of adaptive capabilities (Kibassa, 2013; Enete and Amusa, 2016). Similarly, African agriculture's are vulnerable to climate change due to agricultural systems remain mainly rain-fed and underdeveloped, because of the majority of Africa's farmers are smallholder farmers are highly vulnerable to climate change because they are dependent on rain-fed agriculture, cultivate marginal areas, limited access to infrastructure, and disparate access to information and lack access to technical or financial support that could help them invest in more climate-resilient agriculture (Pereira, 2017; Holland *et al.*, 2017 and Donatti *et al*., 2018).

Climate change is expected to increase the temperature in coffee growing areas, change precipitation patterns and enhance climate variability with severe impacts expected on coffee yield and quality if no adaptation takes place (Ovalle-Rivera *et al*., 2015). Ninety percent of the coffee that is traded is produced by smallholders, and climate change will fall most heavily damage the coffee farm of these small producers who have few agricultural alternatives to provide their livelihoods (World Coffee Research, 2015). According to Craparo *et al* (2015) conducted a study in Tanzania increasing night time temperature is the most significant climatic variable responsible for diminishing Coffee Arabica yields between 1961 and 2012 and expected that without adequate adaptation strategies every 1^0C rise in in temperature will result in annual yield losses of 137 ± 16.87 kg ha−1, and 145 ± 41 kg ha−1 by 2060 the average coffee production will drop, coffee production will be severely reduced in the Tanzanian in the near future and recommended as attention should also be drawn to the coffee Arabica growing regions of Brazil, Colombia, Costa Rica, Ethiopia and Kenya.

Agriculture is the most important economic sector of Ethiopia, which now a days contributes 41% of GDP, 80% of employment and 90% of export earn (Ministry of Agriculture and Natural Resource, 2018). The country's topographic diversity results in varied farming systems, enabling crop and livestock production in the highlands and agro-pastoralism in the lowlands. Despite the country's natural potential is high, the agricultural performance remains weak; high dependency on rain-fed agriculture, low rate of use improved seed varieties as well as land degradation and deforestation as a result climate change impacts agricultural productivity. World Bank (2010) reveals that Ethiopia is highly vulnerable to climate change impacts because it is predominantly an agrarian country and agriculture is severely impacted by the changing climate. Similarly, UNDP (2010) explained Ethiopia's climate profile, the country's mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade and the mean annual temperature is projected to increase by 1.1 to 3.1°C by the 2060s, and 1.5 to 5.1°C by the 2090s, and USAID (2012) predicted a larger percentage of precipitation falling during heavy events can increase the risk of disasters such as floods and landslides.

ECFF and Kew (2017) conducted a rigorous assessment using general circulation models on coffee farming and climate change in different area of Ethiopia's coffee producer potential. The result revealed that southern coffee areas were increased with unpredictability of rainfall, in the number of warmer days and nights and, Coffee farms in the western parts were increased in drought and diminishing rainfall during the end of the dry season that caused to a general decline in coffee production, and they expected that climate change will continue to impact and alter coffee growing in Ethiopia over the coming decades. Similarly, Capitani *et al*, (2018) conducted a study in Taita Hills in Kenya and Jimma rural area in Ethiopia, by using participatory scenario development framework, the result found that in Jimma area rising temperatures are expected to disrupt traditional coffee production as a resulting in the loss of coffee-forest canopies and reduction of forest biodiversity. Coffee land coverage and dependency of smallholder farmers on coffee is high especially in southwest Ethiopia. For example, Samuel *et al*., (2018) found that the share of coffee income from total income in coffee producing districts of Jimma zone is seventy seven percent.

The study was conducted in Manna district, one of the districts of Jimma zone, which is known by predominant coffee production, in south west of Ethiopia. The average production of coffee in Mana district for nine years (2010-2018) is about 9364.98 ton (Manna district, Agriculture and Natural Resource Management Office, 2019). Adaptation to climate change has become an important issue for smallholder farmers who are the most affected by climate change.

Understanding farmers' perceptions on impacts of climate change and variability helps to explain why they respond to various stimuli in the way that they do. Adaptation to climate change requires that farmers first notice that climate has changed, and then identify useful adaptations and implement them (Maddison, 2006). Even if adaptation strategies were recognized as a critical response to the impacts of climate variability and change and, different national policies, programs and strategies that intend to address the impact of climate change have been designed by the Ethiopian government (NMA, 2006; MoFED, 2010; FDRE, 2011; NPC, 2016;) rather than so far to design and promote such policies and strategies, the level of adoption of adaptation options that would reduce vulnerability and enhance agricultural production is below the expectation (EPCC, 2015). Since design and implementation of climate change strategies require adequate knowledge about perception on the change in climate and adoption factors (Jems *et al*, 2013). In recognizing that, the study was aimed to analysis smallholder coffee farmer's perception to climate change and adaptation strategies and determinants to choice it in the study area.

1.2. Statement of the Problem and Justification

Many studies were conducted on the trend of climate change and future projection of its elements particularly temperature and rainfall. Their findings revealed that climate change already had happened and it will continue to have a severe and negative effect on agricultural production throughout the world, particularly smallholder farmers of developing countries. According to Imbach (2017), the impacts of climate change on smallholder agriculture are likely to intensify in future years, as climate models project rising temperatures, more erratic rainfall, and a potential increase in the intensity and frequency of extreme weather events.

Coffee is one of the world's most important agricultural commodities and the primary source of income for 125 million people globally (Fetzek, 2017). Ethiopia is the largest coffee producer and the world's fifth largest exporter of Arabica coffee in Africa, even though yields (kg/hectare) are low compared to other producing countries and, coffee farming alone provides a livelihood income for around 15 million Ethiopians and of which 4 million smallholder farms and for many of them coffee is their single most important source of income (Minten *et al*., 2014 and Tefera, 2015).

While now a day's climate change is threated coffee producer countries as it affects directly and indirectly coffee production in quantity and quality. Increase in temperature causes premature ripening of the coffee beans and negatively affecting the quality of the coffee and unpredictable rains cause coffee to flower at various times throughout the year leading to continuous harvesting of small quantities of coffee (Jassogne, *et al.*, 2013). And also, rising temperatures and erratic rainfall are threatening sustainable coffee production by enabling outbreak of diseases and infestations of insect pests that decrease the quality and yield of coffee berries (Avelino *et al*, 2015; Belachew and Teferi, 2015). In addition to direct impacts, climate change will likely alter the areas suitable for coffee production.

Unless action is taken to slow down climate change or find alternative ways to keep coffee plants alive, Ethiopia will be in danger due to the importance of coffee production for their economies. The Country faced that climate change will permanently destroy one of the most crucial aspects of their economies coffee production (Arabica coffee) as it needs specific requirements for growth, even slight changes to temperature and precipitation could kill the plant and as a result of climate change's impact so far, new threats have arisen in Ethiopia Coffee leaf rust and the coffee berry borer are now a much more significant threat to coffee production (Iscaro, 2014).

The key point is therefore, how coffee farmers in the study area perceived and they are responded to climate change? Identifying potential adaptation measures helps in defining factors that influence the choice decisions of farmers in the study area. In general, a few studies related to climate change and its effect on coffee crops are conducted in Ethiopia. However, the previous studies have limitation on perception of coffee farmers to climate change since most of studies consider Ethiopia's land and climate condition is suitable for coffee production and its sustainability is possible forever (Ovalle-Rivera *et al*, 2015). However, there is a chance and impend of climate change and variability affects and will likely change suitability of coffee production areas in our country. Second, there is limitation to identify climate change adaptations and factors affects to choice it, particularly for smallholder coffee farmer in the study area (Capitani *et al*, 2018), and there are limited empirical evidences in the study area and information on perception of climate change and local adaptation measures of coffee producer farmers. Therefore, the study aims to explore and fill the existing research gaps with respect to smallholder coffee farmer's perception, adaptation strategies and determinants to choice adaptation strategies in the study area.

1.3. Objective of the Study

1.3.1. General objective

The general objective of the study was to assess smallholder coffee producer's perception and adaptation strategies to climate change and variability in Mana district, Jimma zone, Southwest Ethiopia

1.3.2. Specific objectives

The specific objectives of the study were:

i. To assess coffee producer's perception towards climate change and variability in the study area
ii. To identify climate change and variability adaptation strategies of coffee producers in the study area
iii. To analyze determinants of adaptation strategies choices used by coffee producers to climate change and variability in the study area

Research question

i. What is a smallholder coffee producer farmer perceive climate change and variability in the study area?
ii. What are the adaptation strategies to climate change and variability employed by smallholder coffee farmers in the study area?
iii. What are determinants of smallholder coffee farmer's choice of adaptation strategies to climate change and variability in the study area?

1.4. Significance of the Study

Considering the effect of climate change and variability on smallholder farmers and developing appropriate adaptation strategies are critical issues in Ethiopia, a country where agriculture is central to economic development, food security, and local livelihoods. Therefore, the result from the study could provide the following major points for coffee producer farmers and other stakeholders.

a) It helps to know and document perception and adaptation measures employed by smallholder coffee producer to climate change

b) Knowing this helps for awareness creation and information for develop intervention by government or NGOs to overcome the constraints of smallholder coffee farmer household face in taking up adaptation strategies to climate change on identified adaptation in the study area.

c) Helps for those interested like development practitioners and other researchers as baseline information in initiate them to make further study about the issue.

1.5. Scope and Limitations of the Study

The study assesses smallholder coffee farmer's perception, adaptation strategies, and determinants in the choice of adaptation strategies to the changing climate particularly on temperature and rainfall changes. Likewise, the study is limited to Mana woreda, one of the district of Jimma Zone and, attempts to cover only three rural kebeles which limited the representativeness of the study to use at zonal level and beyond. In general, the previous enquires that this study tends to bridge their gaps have the following limitations.

The first limitation, the study considered only two element of climate(temperature and rainfall) which is not enough to assure climate change occurrence, and also focus only coffee, which is a single of crop production. Hence, didn't include the effects that may arise in other crop failure, prices fluctuations, household migration, food insecurity and effect of livestock due to climate change impacts elsewhere in the study area. The second limitation is that the study used cross-sectional data to assess households' choice of adaptation strategies which limits to contact the observation repeatedly across long-term changes of climate that cover the dry and wet seasons in the study area.

The third limitation, rather than assess perception coffee farmers and adaptation strategies to climate change and variability, and tried to see the effect of climate variability (temperature and rainfall) on coffee production for nine years (2010-2018) the study didn't included farther the impact of climate change on coffee productivity or yield (i.e. tonnes of coffee harvested per hectare) for long period of years due to restricted empirical evidences or time series data in the study area. The other limitation of the study was that the adaptation strategies identified was mainly traditional measures so that it is good if modern adaptation is developed through support of technology that adapt and mitigate climate change and variability and ensure coffee production and its sustainability in the study area.

1.6. Organization of the Thesis

This thesis report procedure was written and organized in to five chapters. The first chapter describes the introduction of the study that includes the background, problem statement and objectives, significance, scope and limitation of the study. Chapter two reviews important theoretical and empirical literatures related with climate change and variability, perception and adaptation strategies of smallholder of coffee farmers to climate change and variability. The approaches and methods of sampling techniques, data collection and analysis were presented in chapter three. In chapter four, discussions and results of the data analysis is presented in detail. In the last main chapter of the study or chapter five presents summaries, conclusions and recommendations of the study.

2. LITERATURE REVIEW

This chapter reviews literatures on the concepts of climate and climate change, perception and adaptation of climate change, smallholder farmers, adaptive capacity, theoretical framework, empirical literatures on smallholder farmer’s perception and adaptation strategies to climate change, and determinants to choices of adaptation strategies and conceptual framework on smallholder coffee producer’s choice of climate change adaptation strategies.

2.1. Definition of Concepts

2.1.1. Climate and climate change

Climate: is the average weather which is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years. Weather is conditions of the atmosphere are over a short period of time (WMO, 2016). Climate is simply the weather that is dominant or normal in a particular region; which includes temperature, rainfall and wind patterns. Geography, global air and sea currents, tree cover, global temperatures and other factors influence the climate of an area, which causes the local weather (James, 2008).

Climate change: refers a change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). Climate change is a scientifically proven phenomenon that includes any change in the climate, whether due to its natural variability or as a result of human activity (UNDP, 2010). Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years). It is characterized by increasing temperature and related climate phenomena, including an increase in the frequency and intensity of extreme weather events such as hot spells, droughts and floods, and an increase in climatic uncertainty (IPCC, 2011).

Climate variability: refers to variations in the mean state and other statistical measures (such as standard deviations and statistics of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events (IPCC, 2007).

2.1.2. Perception of climate change

According to Ban and Hawkins (2000), perception deals with the human senses that generate signals from the environment through sight, hearing, touch, smell and taste. Perception is the way one sees the world and experiences the world through both sensory and cognitive processes (McDonald, 2012). It is the process by which we receive information or stimuli from our environment and transform it into psychological awareness. In common terminology, perception is defined as the way you think about something and your idea of what it is like, the way that you notice things with your senses of sight, hearing etc., and the natural ability to understand or notice things (Qiong, 2017).

Perception strongly affects how farmers deal with climate induced risks and opportunities, and the precise nature of their behavioral responses to this perception will shape adaptation options, the process involved and adaptation outcomes (Pauw, 2013). Further, evaluating farmers' perceptions about the nature of microclimate behavior and its impact are crucial to design appropriate and effective policy interventions (Jems *et al*., 2013). Perception is therefore recognized to be the precondition for adaptation to climate change and variability. It is the one among the factors that can influence farmer's decision whether to adapt or not to climate change and variability as they determine decisions of the farmers in management of agricultural activities (Gbetibouo, 2009).

2.1.3. Adaptation of climate change

The concept of adaptation is defined by different scholars and organization in different time. For instance, IPCC (2007) and Eriksen and Selboe, (2012) define adaptation adjustments to practices, processes and systems to minimize current and/or future adverse effects of climate change and take advantage of available opportunities to maximize benefits, and IPCC (2014), defined adaptation to climate change as it refers to adjustments in environmental, social and economic systems in response to the actual and expected impacts of climate change," which "seeks to moderate or avoid harm or exploit beneficial opportunities" in human systems in general.

Adaptation strategies need to be diverse and specific to a particular location based on traditional roots and should benefit from modern science (Asfaw, 2010). Moreover, adaptation to climate change needs to be a continuous endeavor and adaptation decision is location-specific and influenced by key drivers such as socio-economic, environmental, and institutional circumstance. There are different types of adaptations that have been distinguished with different criteria. For example, IPCC, (2001) categorized adaptations strategies according to their purposefulness, timing, temporal scope and to their spatial scope. According to their purposefulness the IPCC group adaptations as either autonomous or planned. Autonomous adaptation is defined as a non-conscious response to a climatic stimulus and planned adaptation is the result of a conscious policy decision, based on climate change awareness and that action is needed to return to, maintain, or achieve a desired state (IPCC, 2007a). Skambraks (2014), explained that autonomous and planned adaptation is broadly interpreted as private and public adaption, respectively, where private decision makers include individuals, households, businesses, and corporations, whereas public decisions always are performed by governments at all levels, and consciousness is used as distinguishing parameter between autonomous and planned adaptations. And said that if a farmer changes his crop type because the crop is better suited to the new climatic conditions, the response can be defined as autonomous adaptation, since the response is initiated by the farmer himself and triggered by what the farmer incrementally perceives as climate variability or changes in growing season, and planned adaptation could be the government producing and distributing seeds of drought resistant varieties to the farmer, which is classified as a public act, triggered from a conscious awareness of climate change.

2.2. Climate Change and Agricultural Production

According to the Intergovernmental Panel on Climate Change (IPCC, 2013) states that the atmosphere and oceans have warmed, the amounts of snow and ice have diminished, the sea level has risen, and the concentrations of greenhouse gases have increased. FAO (2016), reveals agricultural production is already being adversely affected by rising temperatures, increased temperature variability, changes in levels and frequency of precipitation, a greater frequency of dry spells and droughts, the increasing intensity of extreme weather events, rising sea levels, and the salinization of arable land and freshwater in many regions and, Africa and Ethiopia’s climate has changed and it is expected will continue to change. As climate change impacts on agriculture intensify, it will become increasingly difficult to grow crops, raise animals, manage forests and catch fish.

2.2.1. Climate change and crop production

Various plants in the world, endemic to certain countries with different attributes, need special conditions and external additions to grow properly. Crops need specific conditions in order to thrive, including optimal temperature and water. Up to a certain point, warmer temperatures may benefit the growth of certain crops in some parts of the world. However, if temperatures exceed a crop's optimal level, or if sufficient water and nutrients are not available, yields are likely to fall. An increased frequency of extreme events, especially floods and droughts, also harms crops and reduces yields (FAO, 2016). More extreme temperatures, combined with decreasing rainfall, can prevent crops from growing at all.

Hatfield and Prueger (2015), using perennial fruits such as apples and cherries as examples, precise that climatic variations will have different impacts on plant development depending on the growth stage. Hatfield and Prueger (2015) also underline that a rise of 1°C to 4°C above the optimal temperature of certain plants has the potential to decrease the productivity between 2.5% and 10%. A rise in temperature above the common optimum level of 22°C for perennial fruits would disturb the pollination phase, causing a reduction in glucose, which would negatively affect the overall plant growth. Campbell *et al.* (2016) state that a one-degree increase in temperature is estimated to decrease variety of crops, including rice and maize, by 3 to 10 percent production.

2.2.2. Climate change and coffee production

Coffee is a perennial tropical crop grown both in humid lowlands and tropical humid/sub humid highlands. There are two coffee species, Arabica coffee (Coffea arabica) and Robusta coffee (Coffea robusta) almost entirely well-known and cultivated. Ethiopia is the origin of coffee Arabica (Ervine, 1969), and now a day it is grown in many parts of the country; most Ethiopian coffee is produced in the Oromia region (63.7%) and in the SNNPR (34.4%), with lesser amounts in the Gambela region and around the city of Dire Dawa (ECFF and Kew, 2017), and its production system is categorized into four areas i.e. forest coffee which is a wild coffee grown under the shade of natural forest trees and it does not have a defined owner, semi - forest coffee, where farmers thin and select forest trees to let sufficient sunlight to the coffee trees and to provide adequate shade garden coffee found in the near of a farmer's residence and plantation coffee which the government or private investors for export purposes (USAID, 2010).

Coffee grows requires very specific environmental conditions for successful production and grown well in a relatively narrow range of climatic conditions. Outside their optimum temperature ranges, both types decrease in photosynthesis, delays the development and ripening of cherries and yellowing and loss of leaves as a result coffee bean loose its quality and yield. Changing climate might also increase exposure and vulnerability of coffee to pests and diseases. The coffee berry borer, for example, is expected to spread into higher latitudes and altitudes under a warmer climate (Jaramillo *et al,* 2011). Arabica coffee can gives productive at temperatures of 15 to 24°C, but its optimum temperature to give best production is achieved at 18 to 22°C and extreme temperatures reaching 30°C can limit growth and can dry at 34°C (Magrach and Ghazoul, 2015). And annual rainfall of 1,500 to 3,000 mm is ideal for most Arabica varieties (International Coffee Association, 2015), but some varieties require less rain as too much can be harmful and rainfall needs also change with soil type, level of humidity, cloud cover, and overall management practices.

2.3. Review of Empirical Studies

2.3.1. Perception of coffee producer farmer's to climate change and variability

According to different studies point out, both in formulating and designing adaptation strategies and mitigation policies, community perception or view regarding climate change and variability is essential. If the public perception differs from policy makers perception, implementation will be misunderstood neglected or even opposed (Maharjan *et al,* 2011). Climate change is a long-term phenomenon difficult to detect, but people may shape their perception based on personal experience of increased climate variability (Weber, 2016). Many studies regarding to farmers' perception towards climate change were carried out in different world countries including Ethiopia.

According to Zuluaga, et al, (2015) conducted a study in Nicaraguan coffee growers' perceptions on long term changes in climate, almost all of the interviewed households have perceived changes in climate during the last 10 years, which majority of them have observed changes in temperature, in the frequency of rains, on the seasonality of rains and in the frequency and intensity of extreme events like drought or flooding. Similarly, Mugagga (2017) conducted a study in Uganda on perceptions and response actions of smallholder coffee farmers to climate variability reveals that farmers generally perceived decreasing trends in annual rainfall and moderately increased in temperature and. The authors said that such variations significantly affected coffee production with early rainfall onsets perceived to cause early ripening of coffee berries, while short rainy seasons resulted into reduced yields and longer dry seasons led to drying of coffee berries and ultimately reduced crop yield.

According Legesse (2013) conducted a study in Tole district of southwest Showa Zone of Oromia Regional State with the objective of assessing climate change perception and identifying factors affecting adaptation strategy choice of smallholder farmers to climate change, using likert rating scale, to examine smallholder farmers' perception to climate change. The result of the study depicted that households perceived precipitation and temperature change over the past 20years as decreased and increased respectively in the study area. In response to this, most households were using different adaptation strategies to minimize the adverse effect of climate change. Similarly, Yimam and Mohammed (2016) conducted a study on local perceptions and adaptations to climate change and variability in compare with meteorological records of temperature and rainfall data in southern Ethiopia, there were increasing trend of temperature, unpredictable or erratic and decreasing trends of rainfall were perceived by sample respondents and annual rainfall anomalies showed that more than 50% of the annual rainfall was below the average annual rainfall record in the stations of Dilla, Yabello, Konso and Wolayta Sodo, and they concluded as it indicated the occurrences of several worst meteorological droughts in various years.

According to Tsegamariam (2018), a study conducted in the case of coffee producer farmers at Abeshege woreda in Ethiopia, perceptions of farmers with respect to changes in temperature and rainfall variability in line with empirical analysis of temperature and rainfall trends of metrological data station were indicated that majority of the farmers in the study area were perceived a decrease in the level of the rainfall and an increase in the level of temperature and, the results of linear regression show that the amount of rainfall received and temperature significantly affect coffee production in the study area.

2.3.2. Adaptation strategies of coffee farmer's to climate change and variability

Farmers' respond to climate change stimuli by undertaking activities that help them cope with adverse consequences, reduce vulnerability and potential damages from climate change, and help them to adjust to climate change and variability (IPCC, 2001). There are numerous literatures that different scholars conducted a study in different region and countries related to coffee production trends with change and variability of climate and its adaptation strategies. From that few literatures which support the empirical study of climate change and variability adaptation strategies were adopted and explained as follows.

Msuya (2013) conducted a study on impact of climate variability on coffee production and farmers coping and adaptation strategies in highlands of kigoma district, Tanzania. The result shows that, both rainfall and coffee production were decreased trend and the author concluded that, coffee production was also influenced by other factors like shortage of agricultural inputs such as fertilizers and pesticides the study area. From the same source, rain water harvesting, mulching, terracing, planting hedge and shading trees to mitigate increased solar brilliance, reducing temperature variations and helping retain moisture were the adaptation strategies practiced in the study area. Similarly, a study conducted on perceptions and response actions of smallholder coffee farmers to climate variability in montane ecosystems of Uganda, show that the common response actions were agronomic practices such as, planting shade trees, pruning, replacement, planting drought-resistant varieties and application of organic fertilizers (Mugagga, 2017). And also, Tesfaye (2016) was conducts a study on determinants of smallholder farmers' adoption of climate change and variability adaptation strategies using Logit regression. The result of the model shows that crop diversification, planting different crop varieties, changing planting and harvesting dates to correspond to the changing pattern of precipitation, irrigation, planting tree crops, water and soil conservation techniques, and switching to non-farm income activities were the significant adaptation strategies of farmers have adopted and practiced.

Mesfin and Bekele (2018) were conducts a study to examine farmer adaptation strategies to climate change in Benishangul-Gumuz Regional State of Ethiopia, using multivariate discrete choice model. The result conclude that, the important adaptation options being used by farmers were crop diversification, using different improved crop varieties, changing planting and harvesting dates, increased use of irrigation, increased use of water and soil conservation techniques and changing planting dates.

According to Amogne *et al.* (2018) conducted a study on analyzing the determinants in the adoption of climate change adaptation strategies of smallholder farmers in north central Ethiopia, using multinomial regression model and triangulated with thematic analysis. The result showed around more of the respondents had perceived a change in climate and employed adaptation measures. Stone/soil bund, changing the farming calendar and switching to short maturing varieties were the most widely practiced adaptations strategies. Similarly, Tsegamariam (2018) conducted a study on adaptation strategies to climate variability used by farmers in abeshege woreda, Ethiopia. The result indicated that soil and water conservation were highly preferred climate variability adaptation strategy whereas, small scale irrigation, changing planting date, improved crop and livestock variety and off-farm employment were also used as climate variability adaptation strategy by the respondents.

2.3.3. Determinant of adaptation strategies of coffee farmer to climate change and variability

A study conducted in on adaptation to climate change, the case of Nicaraguan Coffee Sector Victor in Nicaraguan coffee growers' perceptions on long term changes in climate, the adaptation strategies implemented and its determinants, using probabilistic models. The results suggested that household age and years of education, number of household members, level of wealth, having received technical assistance, participation in farmer groups, off farm work, perceptions about changes in climate and exposure to climate change, affect the coffee growers' decision to adapt to climate change (Zuluaga, et al, 2015). Similarly, Mugagga (2017) conducted a study of perceptions and response actions of smallholder coffee farmers to climate variability in montane ecosystems of Uganda. The author concluded that, several socio-economic factors were influence response actions with the most significant being access to climate change information, level of education, and access to credit.

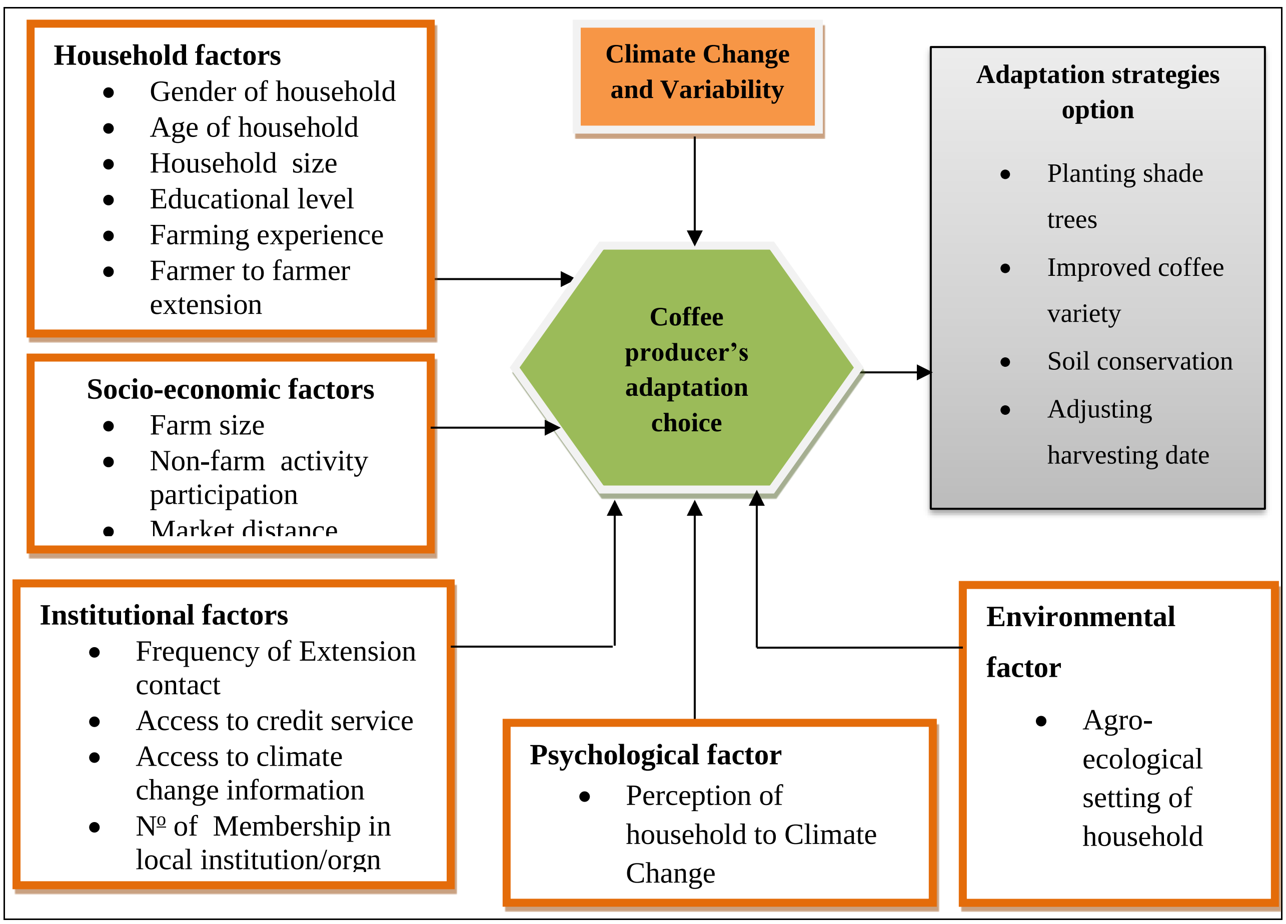
According to a study conducted in Vietnam on determinants of farmers' adaptation to climate change in agricultural production, Using binary logit model and multivariate probit model, training attendance, farm size, educational level, farming experience, access to credit, and gender were the factors that influenced significantly the probability that farmers would adapt to climate change (Thoai et al, 2018)., and also Otitoju (2013) was conducts a study aimed at the effects of climate change adaptation strategies on food crop production efficiency in Southwestern Nigeria. The result of the multinomial logit (MNL) model indicated that household size, age of the household head, years of education of household head, sex of the household head, and years of climate change awareness, farmsize and average distance, extension contact, and access to credit were affect the farmers' choice of the main farm-level climate change adaptation strategies in food crop production in study area.

According to a study conducted by Tsegamariam (2018), to examine climate variability and determinants of its adaptation strategies; the case of coffee producer farmers at Abeshege Woreda in Ethiopia using logit regression model, the result shows that perception, education level, farm size, access to credit service and total family size are among the factors which are positively and significantly affecting the farmers' adaptation decision. Also, Asfaw, *et al.,* (2019) conducted a study on analyzing the determinants in the adoption of climate change adaptation strategies of smallholder farmers in north central Ethiopia using MNL model to investigate the factors guiding household choices of climate change adaptation methods. The MNL regression model outcome reveals that age and education level of the head, family size, herd size, having a training, access to information, microfinance as well as extension services, agro-ecology, having a family member who needs daily care, perceiving that climate change can be adapted and experienced crop failure were found to be the determinants factors.

A study conducted in Geze Gofa District, Gamo Gofa Zone of Southern Ethiopia on determinants of smallholder farmers' adoption of climate change and variability adaptation strategies using Logit regression. The result of the logit model showed that annual farm income, farming experience, knowledge of climate information, education and extension access variables were significant determinants of climate change adaptation strategies (Tesfaye, 2016). Asrat and and Simane (2018) conduct a study aimed at analyzing farmers' perception and adaptation to climate change in the Dabus watershed, North-West Ethiopia, using Heckman sample selection model. The model result conclude that educational attainment, the age of the head of the household, the number of crop failures in the past, changes in temperature and precipitation, farming experience, climate information and, duration of food shortage, were significantly influence farmers' perception of climate change of the study area,

2.4. Conceptual Framework of the Study

The study focuses on assessing smallholder coffee producer's perception, adaptation strategies and factors affecting smallholder coffee producer's choice of adaptation strategies to climate change and variability. Coffee producer farmers have climate change and variability related stresses such as unpredictability and heavy of rainfall, increase of temperature, warmer days and nights and their effects on coffee production. In order to overcome the problem and respond to climate change and variability, Coffee producer farmers can do effort through adoption of different adaptation strategies. However, their choice of adaptation strategies to make decisions were affected by different factors such as factors related to household, socioeconomic, institutional, natural and etc. In general, the study was examined the relationship between these factors and smallholder coffee farmer's choice of adaptation strategy to climate change and variability which is presented as follow.



Source: Adopted from legesse (2013) and Ahmed (2017)

Figure 1: Conceptual framework of the study

3. RESEARCH METHODOLOGY

This chapter describes the research methods and process of the study. It includes study area, research design, sampling method or technique, source and type of data, method of data collection and data analysis. Finally, it was presents the specification of multivariate probit model, variables and research hypothesis.

3.1. Description of the Study Area

3.1.1. Location and population

The study area, Mana district, is found in central parts of Jimma zone, Oromia regional state of Ethiopia. It is located between 7° 44' 59.99" N latitude and 36° 44' 59.99" E longitude and 1820 m.a.s.l elevation in the southwest of Addis Ababa (capital of Ethiopia) at a distance of 368 km and in the west of Jimma town at 10 km (PHSE, 2007).

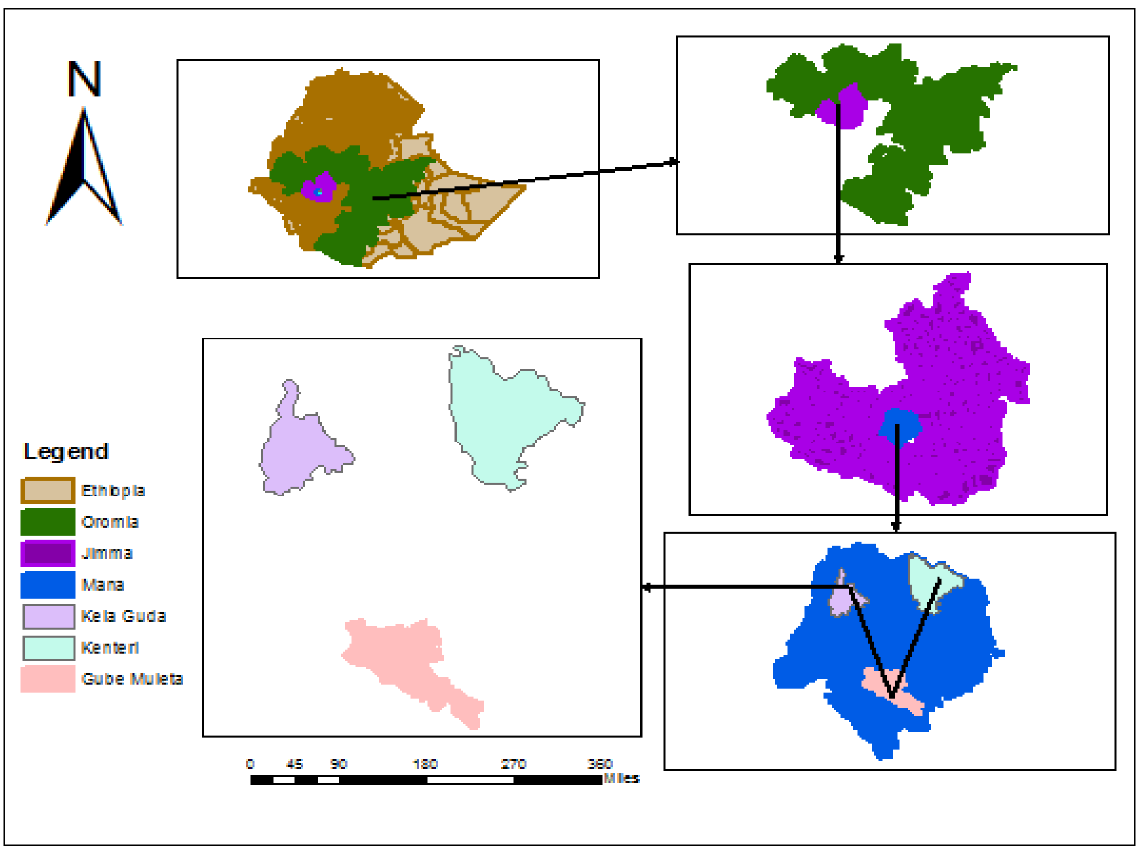


Figure 2: Map of the study area

Mana district is bordered by Seka Chekorsa, Gomma , Limmu Kosa and Kersa districts in the south , west, north and in the east respectively. It has 24 rural kebeles and 'Yebu town' is it's central capital and also now a day ‘Bilida town’ is it’s additional municipal town. Mana has a high population density and smaller size and relatively better access to infrastructure and services in Jimma zone. Now a day it’s a total population is 196,503, of whom 96,438 were women and 100,065 were men. In addition it has 22,596 total households and majority of its residents were Muslim (90.23%), while 8.44% of the population practiced Orthodox and, 1.15% were protestant (Mana District Administration office, 2019).

3.1.2. Climate and farming system

Based on agro-ecological characteristics including the rainfall, soil, and topography, Manna district is classified in to dega (12%), woinadega (63%) and kolla (25%) agro-climatic zones. It has 1290 mms an annual average precipitation and mean minimum and maximum temperatures of 13 and 25˚C, respectively (ARDO, 2008). According to Hurni (1998), *Dega* refers an altitude between 2300 and 3200 m asl, with mean annual temperature between 6 and 16 ^{0}C and mean annual rainfall above 900mm, *Woyina Dega* refers an altitude ranging 21 between 1500 and 2300 m asl, with mean annual temperature 16 and 20 ^{0}C and annual rainfall above 900 mm; and *Kolla* refers to an area with an altitude ranging between 500 and 1500 m asl, with mean annual temperature between 20 and 28^{0}C and annual rainfall between 600 and 900 mm. The landscape of Mana includes mountains, high forests and plain divided by valleys. Mountains include Weshi and Bebella. Rivers include Aniso, Doha Wanja, Yebu and Sogibo. It occupies loamy soils with production of coffee, cereals and vegetables (ARDO, 2008).

Mana is one of the major coffee producing woredas in Jimma zone. More than 85% of farmers are practice crop-livestock mixed farming which is predominantly rain-fed and coffee production (80%) an important cash crop of this district. The other cash crop commodities which are cultivated in the district include chat, fruits like mango, avocado, papaya, banana, orange, pineapple and spices mainly ginger and Ethiopian cardamom. Among cereals, maize, teff, wheat, barley and sorghum are grown in the area. Livestock commodities include cattle, small ruminants (sheep and goat), apiculture, poultry and equines and honey production and some horticultural activities are take place (IPMS, 2007).

3.2. Research Design and Method

The study focus on assess the perception of smallholder coffee farmer’s households on climate change and adaptation strategies employed in the study area. In order to capture relevant data from household survey, cross-sectional research design that enhance the researcher to contacts households at a single point of time was used for the study, and to balance and hinders the arguments of finding from quantitative and qualitative data the study was used mixed research approach that requires both type of data.

3.3. Sampling Design and Sample Size

In the study multistage sampling technique was employed to select the sample for the study which involved both purposive and random sampling. In the first stage, Mana district was purposively chosen based on its predominant of coffee production in Jimma zone and affordable of data collection properly in inexpensive finance and short period of time as a result of proximity of the areas. Manna district has twenty four rural Kebeles (the lowest level administrative units under the Federal Democratic Government of Ethiopia) and two administrative towns. In the second stage, the district was classified in to three strata based on its agro ecological zone in order to group kebeles' having the same features and characteristics in to one category; Since, farmers living in different agro-ecological settings have their own choice of adaptation strategy methods (Tessema, *et al*. 2013 and Legesse *et al*. 2013). In the third stage, coffee production was identified in consultation with the district's agricultural experts. Accordingly, Gube Muleta, Kela Guda and kenteri kebele from highland, midland and lowland were randomly selected respectively. Finally, a total 377 sample of respondents were selected using simple random sampling technique on the basis of probability proportional to size (PPS) of each kebele's households. The sampling frame of the study was the listed of coffee farmer households and obtained from the respective kebele's administration center.

Determination of an appropriate sample size is very essential in any research in order to samples represent the population in appropriate way as samples that are too small may scarcely represent the population and lead to invalid findings and recommendations. Although there are a number of factors like the purpose of the study, population size, the sampling error and etc., are influence to determine an adequate sample size, the level of precision, the level of confidence, and the degree of variability in the attributes being measured are the most criteria often used and to be specified to determine the appropriate sample (Miaoulis & Michener, 1976). In bearing this concept, total sample size of the study was determined in employing the following Kothari (2004) formula.

$$n = \frac{z^2.p.q.N}{e^2\ (N-1)+z^2.p.q} \qquad (1)$$

where n is the desired sample size; Z is the upper points of standard normal distribution at 95% confidence level, which is equal to 1.96; ***e*** is acceptable error at a given precision rate; ***p*** is the proportion of population (which is taken as 0.5 or 50%), ***q*** is *1-p;* and ***N*** is the total household. Accordingly, the total household of the study area during the survey conducted were 22596 (Mana District Administration office, 2019), which provide 377 total sample by using 0.05 level of precision at 95% of confidence interval.

Table 1: Sample household distribution

Sample kebele	Kebele's households			Sampled household heads		
	Male	Female	Sub-total	Male	Female	Sub-total
Gube Muleta	980	378	1358	88	34	122
Kenteri	955	511	1466	86	46	132
Kela Guda	902	467	1369	81	42	123
Total	2837	1356	4193	255	122	377

Source: Own survey, 20120

3.4. Sources and Types of Data

The study was used primary and secondary source of data, and qualitative and quantitative data type. Quantitative and qualitative data focused on household characteristics, socio-economic factors, institutional factors and perception of climate change particularly on rainfall and temperature and its effect on coffee production and, local adaptation strategies employed in the area were collected from households. Secondary data from different literatures, journals, Books, and articles were included for the study.

3.5. Method of Data Collection

1. Primary data collection methods

i. Interview schedule: Semi structured questionnaire with both open-ended and close-ended questions were typed in a definite order on a set of stated objectives and research questions were prepared and households were interviewed. Before the actual survey accompanied, pre-test was conducted and after that the survey was conducted by trained and qualified enumerators in the study area and the researcher was supervising them and giving direction with necessary modification in order to collect relevant and necessary data and to avoid unnecessary mistake.

The questions were deals with demographic and socioeconomic characteristics of the respondent such as age, marital status, family size, education level, institutional factors livelihood activities, perception of climate change, effect of climate change on coffee production, local adaptation strategies of climate change and variability were included.

ii. Focus Group Discussions (FGD)

In order to collect necessary qualitative data which required for the study, in depth focus group discussions were conducted with purposively selected group of men and women farmers who have experience and common characteristics in living in the study area for quite long period to memorize well the trend of climate with the help of sample households and community leaders. To triangulate and take essential information three FGD group per kebele, which contain seven-nine members were organized and the discussion were held at the places they choose with open ended questions with facilitated by a researcher during discussion to direct and clarify the issue.

iii. Key Informant Interviews (KII)

In addition to household survey and focus group discussion, nine Key informants or knowledgeable and professional individuals those knows about climate change and variability condition and able to articulate problems with related to coffee production and also raise about solving direction in the study area were conducted. The individuals were included three Mana district's agriculture expertise, three development agents and three community leaders.

2. Secondary data collection method

Relevant secondary data needed for the study were gathered through review of different documents and literatures, journals, books, articles and reports and records related to coffee production, household population and characteristics which maintained at Development Agents centers and district's agricultural office were collected. In addition, in order to assess the trend of climate variability and change in the study area, the two key climate elements namely rainfall and temperature recorded for thirty (30) years started from 1988 to 2018 were obtained from Western Oromia Metrology Service Center of Ethiopia Meteorological Agency.

3.6. Method of Data Analysis

3.6.1. Qualitative method

Qualitative data collected from focus group discussion and checklists of key informants were analyzed by using transcription of record information and images and then the results were written in narration and quote form. In addition, Farmer's perception to climate change and variability were assessed with five Likert scale (strongly agree, agree, neutral, disagree, and strongly disagree) in increase, decrease, unpredictable, no change of temperature and rainfall trend and it were displayed by bar graph using frequency and percentage using SPSS software version 23 and excel program Microsoft word. And also its effects on coffee production were interpreted and then the findings were also written in the form of narration and quotes.

3.6.2. Quantitative methods

In the study quantitative data were analyzed with descriptive statistics and multivariate probit (MVP) econometric model. Descript statistics like mean, standard deviation, minimum and maximum, and percentage and frequency; were applied to characterize the various aspects of sample households in the study area with STATA version 13. In order to assess the progressive of climate change, temperature and rainfall data were critically analyzed by trends analysis and then the finding was presented and explained with line graph.

3.6.2.1. Econometric model

In order to regresses the effect of explanatory variables on the outcome of dependent variable Economic models has the major role. When there are dependent variables with more than two alternatives that the decision maker can choose among them, the appropriate econometric model would be either multinomial logit model or multivariate probit model. Both models estimate the effect of independent variables on a dependent variable involving multiple choices with unordered multiple categories. Even though multinomial logit can be used to measure the set of dependent choices, its limitation is that individuals can choose only one outcome (mutually exclusive) from the set of alternatives and, it is difficult to make interpretations simultaneously influences of explanatory variables on each outcome variable (Abebe, et *al.*, 2016). In the study, when dependent variable were climate change and variability adaptation strategies while independent variables were socio-economic characteristics of households, including institutions and environments factors.

Therefore, a multivariate probit (MVP) econometric technique is preferred in this study because farmers can adopt more than one adaptation strategy at a time either substitutive one another or in combined (Tessema *et al.,* 2013; Feleke *et al*. 2016 and Kidanu *et al.,* 2016), and it allows simultaneously the influence of the set of explanatory variables on each adaptation choices and the unobserved and/or unmeasured factors (error terms) to be freely correlated complementary (positive correlation) and substitutability (negative correlation) between different adaptations options (Belderbos *et al.* 2004; Lin *et al.* 2005). Farther, Tabet (2007) concluded multivariate Probit model has several attractive features which make it particularly suitable for the analysis of correlated binary data. It relaxes the independence of the irrelevant alternatives (IIA) property assumed by the logistic model and moreover, it is a natural choice in situations where an interpretation for threshold continuous data is possible. It allows for flexible modeling of the association structure underlying the latent data and automatically accounts for over dispersion and under dispersion.

i. Multivariate probit model specification

The multivariate probit **(**MVP) model assumes that given a set of explanatory variables, the multivariate response is an indicator of the event that some unobserved latent variable (Z), assumed to arise froma multivariate normal distribution falls within a certain interval. According to Piya et al. (2012a), the MVP model assumes that each subject has J distinct binary responses. Let i=1 . . . , n be the independent observations, j = 1,. . . , J be the available options of binary responses, and Xi be a matrix of covariates composed of any discrete or continuous variables.

Let $Y_{ij} = (Y_{i1} \ldots, Y_{ij})$ denote the j-dimensional vector of observed binary responses taking values {0,1} on the i^{th} household and $Z_{ij} = (Z_{i1}, \ldots, Z_{ij})$ denote a j-variate normal vector of latent variables such that:

- $Z_{ij} = Xi\beta + \varepsilon_i$; i=1 . . . , n (2)

Where $\beta = (\beta_{1,\ldots}\ \beta_J)$, a matrix of unknown regression coefficient, ε_i is a vector of residual error distributed as multivariate normal distribution with zero means and unitary variance; $\varepsilon i \sim N(0,\sum)$ where Σ is the variance-covariance matrix. The off-diagonal elements in the correlation matrix $\rho_{kj}=\rho_{jk}$ represent the unobserved correlation between the stochastic components of k^{th} and J^{th} options (Cappellari & Jenkins, 2003).

The relationship between Zij and Yij is:

- *Yij=1 if Zij* > 0; 0 otherwise i=1,. . ., n and j=1, . . . ,J. (3)

The likelihood of the observed discrete data is then obtained by integrating over the latent variables

$$Z: P(Yij = 1|Xi, \beta, \sum) \int Ai1\Phi T \ (Zij = 1|Xi, \beta, \sum) dZij \quad (4)$$

Where, A_{i1} is the interval $(0, \infty)$ if Yij=1 and the interval $(-\infty, 1)$ otherwise and $Ai1\Phi T \ (Zij = 1|Xi, \beta, \sum) dZij$ is the probability density function of the standard normal distribution.

ii. Coefficients interpretation

The MVP coefficients are difficult to interpret, and associating with the j^{th} outcome is tempting and misleading. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as:

$$\delta ij = \frac{\partial pij}{\partial xi} = \partial Pij\left[\beta j - \sum_{k=0}^{j} Pik \ \beta k\right] = Pij[\beta j - \beta] \quad (5)$$

Where, δij-denotes the marginal effect, of the explanatory variable on the probability that alternative j is chosen. The marginal effects measure the expected change in probability of a particular choice with respect to a unit change in an explanatory variable (Amdu; Ayehu and Deressa, 2012 and Mihiretu et al, 2019). MVP model fitness was tested the null hypothesis that the identified adaptation choices were independent with likelihood ($\chi 2$) ratio statistics tests joint success or failure probability of adapting among adaptation strategies options.

The existence of multicollinearity affects the parameter estimates. If linear regression exists among the explanatory variables then this will result in large value of at least one of the test regressions. To detect the problem of multicollinearity among the continuous variable and dummy variables, Variance Inflation Factor (VIF) and Contingent Coefficient (CC) was used for the study respectively. VIF for continuous variables value > 10, and CC value >0.75 for dummy variables indicate multicollinearity (Gujarati 2004; Rabe-Hesketh and Everitt 2004).

3.7. Definitions of Variables and Research Hypothesis

3.7.1. Dependent variable

The dependent variable of the study was choice of climate change adaptation strategy options. In the study four alternatives adaptation strategies that coffee producer farmers would be adopted were identified from different literatures and preliminary study in the study area and then the actual study was conducted. Those were planting shade trees, using improved coffee variety, soil conservation, adjusting harvesting date.

3.7.2. Independent variables

Based on the review of different empirical literatures related to the study, the following potential explanatory variables were considered as it could be affect smallholder coffee producer farmers in choice of adaptation strategy to climate change and variability in the study area.

1. Gender of household head: It is dummy variable taking value 1, if the household head is male and 0, otherwise. Most studies concluded as male headed sample households were more likely to use more strategies as compared to female headed households. For example, Belaineh *et al*. (2013) and Temesgen (2014) reported that male headed sample households are more likely to select and use a combination of diversified crop and soil and water conservation, as compared to female headed households. Therefore, it was hypothesized that being male-headed households positively affects adoption of climate change adaptations strategies.

2. Age of the household head: It is continuous variable and expressed in years. According to Gbetibouo (2009), age of household head negatively affects the adaptation to climate change, as older farmers are more conservative and more risk averse compared to younger farmers, resulting in a lower likelihood of adopting new technologies and in addition, Mulwa *et al*. (2015) said that aged farmers lack to perform agriculture conservation and manure application such as soil and water conserving mechanisms which are labor intensive activities due to being aged. Therefore, it was hypothesized that age of household head negatively affect adoption of climate change and variability options.

3. Educational level of household head: It is continuous variable measured in years of schooling that the household head attended. Higher level of education is believed to be associated with access to information on improved technologies which increase productivity. Aschalew (2014); Hadgu, *et al (*2015); Mengistu and Haji (2015) explained that farmers with higher level of education were more likely to adopt with different adaptation options to the change of climate. Therefore, in the study education was hypothesized positively affect household to adopt adaptation strategies in the case of climate change and variability.

4. Household size: Household size refers the number of family members lived a house and measured in number. It is continuous variable and assumed to represent the labor input to the farming activities. Deressa, *et al.* (2009) reported that large household size increases the probability of taking up of adaptation strategies to climate change. In addition, Seid*et al*. (2016) stated that large family size is normally associated with a higher labor endowment, which enables household to accomplish various agricultural tasks. Therefore, this variable was hypothesized to influence household's choice of climate change adaptation strategies positively.

5. Farm size of household: Farm size is the total landholding of farming household measured in hectares. It is a continuous variable. Farmland size was assumed to encourage adoption of most adaptation strategies. Tessema et al (2013) explained that farmers with large farm size have adopted one or a combination of climate change adaptation options as compared to the farmers with small land holdings. Therefore, it was hypothesized to influence household's choice of climate change adaptation strategies positively.

6. Farming experience of household head: Farming experience refers to the number of years of experience in farming activities of household. It is a continuous variable and measured in years. Belay *et al,* (2017) said that farming experience has a positive effect on climate change adaptation strategies. Accordingly, in the study this variable was hypothesized to influence household's choice of climate change adaptation strategies positively.

7. Agro-ecological setting: It is a categorical variable takes the value 1 for highland 2, for midland, and 3 for lowland. It is recognized that there are three agro-ecology zones (highland, midland and lowland) in Ethiopia and also those are known in the study area. Different study's revealed that farmers living in different agro-ecological settings have their own choice of adaptation options. For example, Amare and Simane (2017) said that small-scale irrigation, and livelihood diversification strategies were widely considered adaptation options in both midland and highland and on the other hand, farming in midland and highland zone significantly reduces the probability of using soil and water conservation measures as compared with farming in lowland. Thus, agro ecology was hypothesized to have a positive or negative effect on household's adoption decision on climate change adaptation options.

8. Perception of household to climate change: This is if farmer households perceived the change in climate over the last decades. It is a dummy variable and takes a value of 1 if a farmer household perceives the change and 0, otherwise. Noticing the long- term change in the rainfall enhances the chances of adapting to climate change using irrigation, soil conservation, changing planting dates (Meseret, 2009). Similarly, Asayehegn *et al*, (2017) said that farmers who aware of climate changes and variability more willing to explore adaptation strategies than those not perceived or aware. Therefore, perception to climate change was hypothesized to influence climate adaptation of smallholder farmer positively.

9. Frequency of extension contact household: This variable is the frequency of agricultural extension agent visits smallholder coffee producer farmer household. It is categorical variable and take a value '0' if the household didn't visited at all, '1' if visited occasionally, '2' if visited mostly, '3' if the household was visited regularly by extension agent. Access to extension services provide to farmers aware of changing climatic conditions, and knowledge of various management practices that they can use to adapt to changes in climatic conditions. Farmer access to extension service increases the probability of adapting to climate change (Gbegeh & Akubuilo, 2012). Accordingly, in the study frequency of extension agent contacts household was hypothesized that influences household's choice of climate change adaptation strategies positively.

10. Farmer to farmer extension: This variable indicates the communication and contacts of farmer household with his neighboring and other model farmer. It is dummy variable that 1, if household practice farmer-to-farmer and 0, if not. Having access to farmer-to-farmer extension service increases the likelihood of using different agricultural technologies. It also helps to increase adoption of most of the adaptation methods. Therefore, this variable was hypothesized to influence farmers' climate change adaptation positively.

11. Access to climate information: It is a dummy variable, which takes a value of '1' if household has access to information and, '0' otherwise. Access to climate information has effect on adaptation to climate change. Debalke, (2013) found that access to information about climate change forecasting, adaptation options and other agriculture activities remain important factors determining use of various climate change adaptation option. Similarly, Belay *et al.* (2017)

showed that smallholder farmers who had access to weather information had a higher probability of implementing climate change adaptation strategies such as late and early planting, use of early maturing crops, planting food and fodder trees, and soil and water conservation measures. Therefore, in the study access to climate information household was positively hypothesized to adopt climate change and variability adaptation measures.

12. Number of Membership to local Institution/organization: This variable indicate the number or quantity of local institutions/organizations household being membership like cooperative, religious association, Ikueb (traditional saving), Dugda (reciprocal work group) and self-help group like Idir/afosha and Debo/jige. It is continuous variable, which measured in number. Membership to local institution or organization enables farmers to acquire information on agronomic practices, credits, and productive inputs at which stakeholders meet to attend training and workshops. Participation in community based institutions expected to increase awareness about climate change due to the farmer-to-farmer information sharing at their periodic gatherings. Tafa *et al.* (2009) and Tazeze et al., (2012) said that being a member of a social group increased the probability of adapting climate variability and change using conservation agriculture, drought-tolerant varieties, and irrigation. Thus, it was hypothesized that membership in local institution positively affects adoption of adaptation options in response to climate change and variability.

13. Accesses to credit service: It is dummy variable, which takes a value of 1 if household is access to credit service and 0 otherwise. Dawit and Habtamu (2011) indicated that access to credit allows higher chances of adapting to changing climatic conditions, increases financial resources of farmers and their ability to meet transaction costs associated with adaptation strategies. Legese (2013) showed that accesses to credit services increases the probability of using improved crop variety, changing planting date and planting trees and soil and water conservation as climate adaptation strategy. Therefore, access to credit was positively hypothesized in influence of farmer’s choice of adaptation strategy.

14. Market distance: It is the distance between farmers household’s house and the central (woreda’s) market in km. It is a continuous variable. Accessibility to market is another important factor affecting adoption of agricultural technologies. Seid*et al.* (2016) explained that when farmers are far from market center, the transaction cost for acquiring input and output will be high and this will in turn, reduces the relative advantage of adopting new technologies. In other way, Kelelew *et al.*, (2017) concluded that households nearer to the market use improved varieties as opting strategy because they may access information on improved varieties to use it as an adaptation strategy against climate change stresses. Therefore, it was negatively hypothesized households to adopt climate change and variability adaptation measures.

15. Nonfarm activity participation: This variable is participation of households in nonfarm activities to drive additional income that are not associated with farming. It is a dummy variable which takes a value of 1 if the farmer household involved and earns income from non/off-farm activities or 0, otherwise. Responses to climate change through adaptation require sufficient financial wellbeing and hence increased income will encourage the investment capacity on adaptation options. For instance, Sani *et al*, (2016) explained that off/non-farm income increases uptake of irrigation and improved crop varieties as adaptation strategies to climate change. Thus, this variable was hypothesized to have a positive influence on smallholder farmer’s choice of climate change adaptation options.

Table 2: Summary of variables used in empirical model and hypothesis

Code	Dependent variables	Values and unit of measure	Expected sign
ICV	Improved coffee variety	Each adaptation option is dummy (1, if adopted, 0, if not adopted)	
SC	Soil conservation		
PST	Planting shade trees		
AHD	Adjusting harvesting date		
Code	**Explanatory variables**		
1. GENHH	Gender of household head	It is dummy (1, male 0, female)	+ve
2. AGEHH	Age of household head	It is continuous, measured in year	-ve
3. EDUHH	Educational level of household head.	It is continuous , measured in years of schooling attended	+ve
4. HSIZ	Household size	It is continuous, measured in number	+ve
5. FARSIZ	Farm size of household	It is continuous, measured in(ha)	+ve
6. FAREXP	Farming experience of household	It is continuous, measured in years	+ve
7. AGRECO	Agro-ecological set of household	It is categorical (1, highland 2, midland, and 3, lowland)	+/-ve
8. PERHHCC	Perception of household to climate change	It is dummy (1 if household perceives climate change and 0, otherwise)	+ve
9. FREXNCON	Frequency extension agent contacts household head	It categorical ('0' didn't contacted, '1' contacted occasionally, '2' contacted mostly, '3' contacted regularly)	+ve
10. FARTOFAR	Farmer to farmer extension of household	It is dummy (1, if farmer to farmer extension 0, if not)	+ve
11. ACCINFO	Access to climate information	It is a dummy (1, if access to climate information, and 0 otherwise)	+ve
12. NOINSMEM	Number of local institution household's membership	It is continuous, measured in number	+ve
13. MARDIS	Market distance of household home	It is a continuous variable measured in (km)	-ve
14. ACCRD	Access to credit service of household	It is dummy (1,if access to credit service and 0 otherwise)	+ve
15. NONFARM	Nonfarm activities participation of household	It is dummy (1, participates or 0, otherwise)	+ve

4. RESULT AND DISCUSSION

This chapter focused on the result and discussion of sample household of coffee producer's perception to climate change, adaptation strategies and factors affected choice of adaptation strategy in Manna district. The chapter is divided in to three sections, the first section discusses about socio-economic characteristics of sample respondents. The second section discusses about coffee farmer's perception to climate change and its effects on coffee production and, identified adaptation strategies employed by them and the final section presents factors affect adaptation strategy choice of smallholder coffee farmers in the study area.

4.1. Socio-economic characteristics of households

In the study, different factors influence choices of climate change adaptation strategies were hypothesized. Gender of the respondent was one of the important variables considered. Survey result indicated that out of total sample size, 67.6% were male headed households and 32.4% were female headed households, and in addition, marital statuses of the respondents were 93.2% married, 2.5% single, 1.1% divorce, and 3.2% were widow. The mean age of respondent was 46.41years with 11.08 standard deviations, and 27 and 79 was the minimum and maximum age of years, respectively. The result indicated that educational level of sample household was 4.3 mean year of schooling with 3.3 standard deviation, which vary from 0-12 years in attending school, and the respondents had 2.2 mean of household size with 6.1 standard deviations.

The survey result referred that majority of the sample households 71.1% lived in Woinadega, and the rest 9.0% and 19.9% lived in Dega and Kolla agro-ecological setting, respectively. 80.4% of respondents have perceived climate change in their local area but 19.6% have not perceived. Farther, the result showed that even though there were variations in size, all respondents had their own land which varies from 0.13 to 3.0 hector and 1.22 mean hector with 0.75 hector of standard deviation, and in addition respondents had 26.14 mean of year in farming experience with 9.7 standard deviations. Their livelihoods were mainly depended on crop production and mixed farming (crop and livestock) production. In addition, when 65.8% of respondents were participated on nonfarm/off farm activities for additional income, but 34.2% of them were not participated in such activities.

Table 3: Description of categorical variables

Categorical Variables		**Frequency**	**Percent**
Gender of Household head	Female	122	32.4
	Male	255	67.6
Agro-ecological set of household	Dega	34	9.0
	Woinadega	268	71.1
	Kola	75	19.9
Perception of household to climate change	No	74	19.6
	Yes	303	80.4
Frequency of Extension agent contact household	No contact	57	15.1
	Sometimes	84	22.3
	Mostly	116	30.8
	Regularly	120	31.8
Farmer to farmer extension of household	No	165	43.8
	Yes	212	56.2
Access to climate information	No	115	30.5
	Yes	262	69.5
Access to credit service	No	178	47.2
	Yes	199	52.8
Non/Off farm participation of household	No	129	34.2
	Yes	248	65.8

Source: own survey result, 2020

The other variables hypothesized in the study were factors related to institutional services such as frequency of extension agent visit/contact household, access to climate change information, access to credit service, and market distance from the home stead of households. The survey result showed that 15.1% of household was not contacted/visited by extension agent, 22.3% were contacted some times, 30.8% were contacted mostly, and 31.8% of households were contacted regularly by extension agent. And also when 69.5% of respondents were accessed to climate change information, 30.5% were not accessed to such information. Farther, from those households accessed in climate change information, 41.7% of respondents were got information from mass media (Radio and TV), 35.2% were from extension agent 2.3 % were from climate change forum, 12.4% were from other farmers, and 8.4% were guess climate change and variability from their indigenous knowledge or experience. And also, the survey result showed that when 52.8% of sample of households were access and usage of credit service, while 47.2% were not get credit service, and also the survey indicated that the market distance of respondent’s home from central market was 7.06km of mean with 1.16km standard deviation. In addition, 56.2% of sample households were exchange innovate information, knowledge and experience with each other through farmer to farmer extension, but 43.8% were didn't participate farmer to farmer extension. Similarly, sample household had 3.6 mean of the number of membership to local institution/organization with 1.3 standard deviations.

Table 4: Description of continues variables

Continuous variables	Min	Max	Mean	SD
Age of household	27	79	46.1	11.1
Household size	2	12	6.1	2.2
Farm size	0.13	3.0	1.2	0.7
Farming experience	6	45	26.2	8.3
No of membership to institution	0	6	3.6	1.3
Educational level	0	12	4.3	3.3
Market distance	3.0	13.0	7.1	1.2

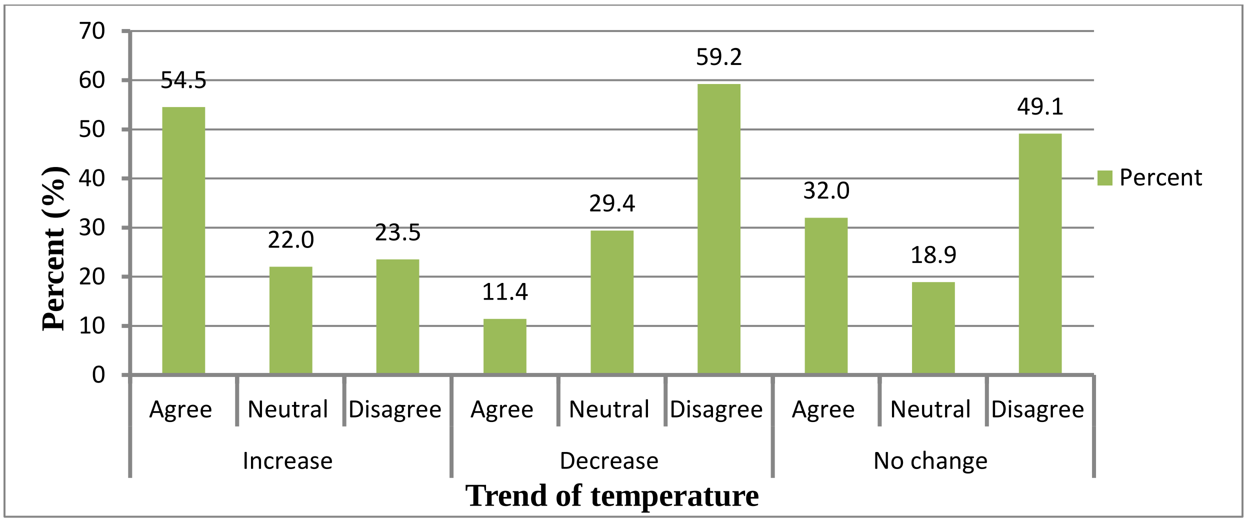
Source: Own survey result, 2020

4.2. Smallholder Coffee Farmer's Perception to Climate Change

In the study of adaptation measures to climate change, respondent's perception to the trend of climate is the important and preliminary request. Thus, in the study smallholder coffee farmers were asked whether they were perceived or not climate change. As it was described in the above section, 80.4% of sample households were perceived climate change and 19.6% were not perceived change of climate in their local area. Following their perception to change of climate, sample household was asked in order to they give their insight to progress of climate change elements particularly towards temperature and rainfall in the past 10-15 years were analyzed in the study.

Accordingly, their perception was assessed with five items likert scale (strongly agree, agree, neutral or neither agree or disagree, disagree, and strongly disagree) in increase, decrease, the same progress/no change of temperature. The end result was presented in three scale in adding the percent of households strongly agree and agree (agree), strongly disagree and disagree (disagree), and neutral (neither agree or dis agree) on each perception trends of temperature. Before the analysis employed, reliability of internal consistence of the scales were tested with Cronbach's alpha standard which describe inter-relatedness of the items to ensure validity of the study. Accordingly, the result of the reliability was good (α=.84) in the study which indicates all items in the study was internally consistence and reliable to asses perception of households (Namdeo and Rout, 2016).

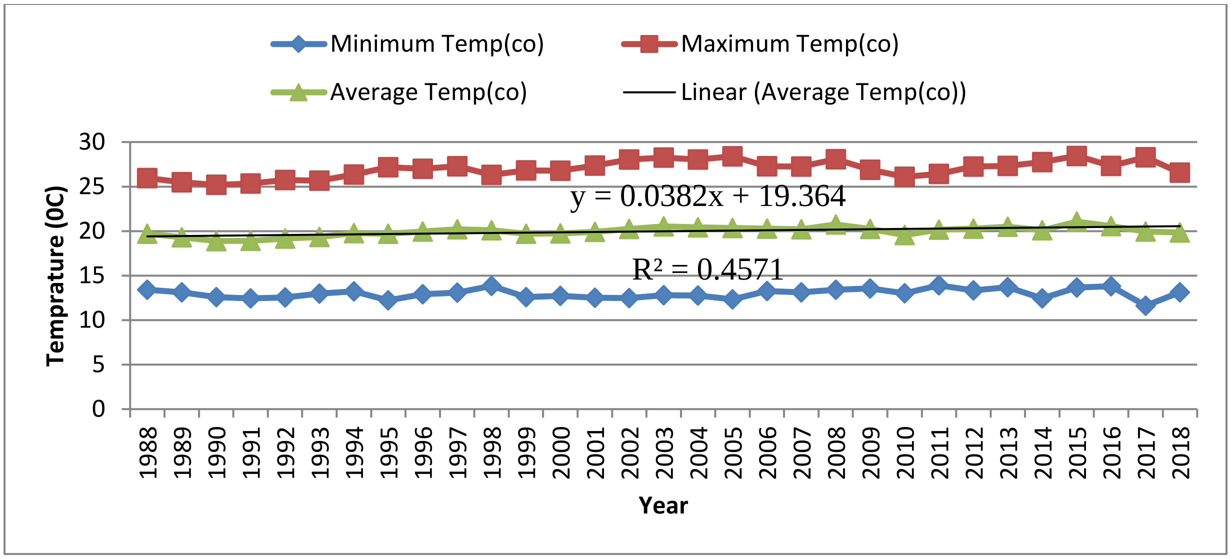
The result showed that when most of the respondents (54.5%) were agree to increase of temperature, but a few of household (23.5%) were disagree and about (22.0%) households were neutral (neither agree nor disagree). Similarly, when about (59.2%) of households were disagree to decrease of temperature, while (11.4%) and (29.4%) of households were agreed and neutral to decrease of temperature. And in other way about when about (49.1%) of households were disagree to no change of temperature, (32.0%) and (18.9%) of households were agreed and neutral to no change of temperature. The result indicated that smallholder coffee producer were perceived change of temperature in terms of increase in their local area.



Source: Own survey result, 2020

Figure 4: Perception of households to trend of temperature

Since perception based on subjective view of individuals and difficult to generalize change of climate in particular area, the study used climatic data of the study area recorded at national metrology agency to verify coffee producer household's perception on the progress of climate. Accordingly, monthly meteorological data of temperature (maximum and minimum) recorded for thirty years (1988-2018) were collected (Appendix Id, Table 2 and Table 3), and analyzed with trend analysis. The result showed that the average temperature of the study area was became slightly raised up during the last thirty years. The regression coefficient indicated that throughout one year the average temperature increased by 0.038C^{o} (Figure5). The result referred that progress of average temperature data recorded at national metrological service center was became increased trend in the study area which is inconsistence with the sample household's perception to the change of temperature.

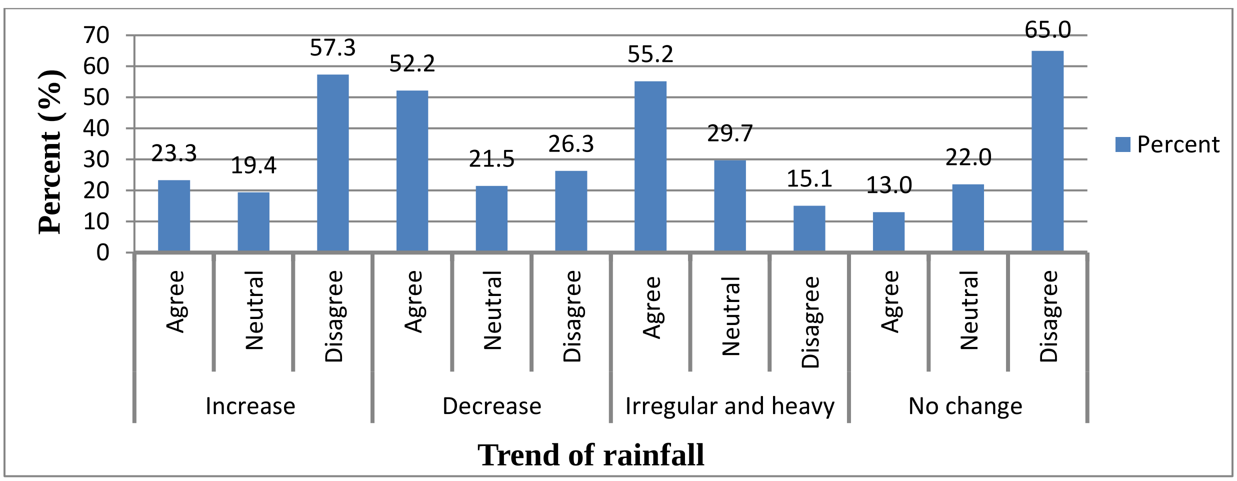


Source: Ethiopia Metrology Agency, Western Oromia Metrology Service Center, 2019

Figure 3: Trend of average temperature over 30 years in the study area

However, even though temperature trend in the study area was not as much increased, different studies were recommended climate change adaptation practice is important. For instance, Technoserv, (2011) and Agegnehu, et al, (2015) concluded that rising temperature is threatening the nation's coffee crops by enabling infestations of insect pests that decrease the quality and yield of coffee berries which before 1984, temperatures in the Ethiopian's coffee growing regions were cool enough to keep the coffee berry borer in check but now frequency and severity of climatic extremes are increasing so that making adaptation an absolute necessity through using current information on climate variability to develop long term plans for managing coffee berry borer via reducing the vulnerability of Ethiopian coffee growers to continued changes in temperature and rainfall. And also the study conducted in Jimma area was referred frequency and severity of climatic extremes and rising temperatures are expected to disrupt traditional coffee production as a resulting in the loss of coffee are increasing which make adaptation is an absolute necessary (Amsalu and Ludi, 2010 and Capitani *et al*, (2018).

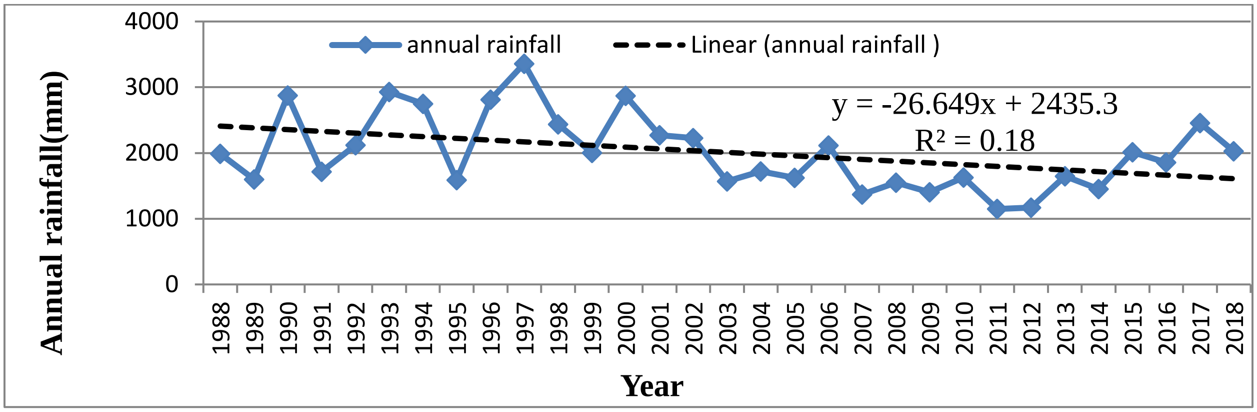
In assessing perception of coffee farmers to climate change, the second element of climate considered in the study was rainfall since it is easily examined by farmers in giving their awareness. Accordingly, in the study sample household of coffee producer was asked their perception to the trend of precipitation in relative to its raining season and crop productivities in their area over the past 10-15 years. The survey result indicated that when approximately more than half of the sample households (57.3%) were disagrees to increase of rainfall but about (23.3%) and (19.4%) of households were agree and neutral to increase of rainfall respectively. Likewise, (52.2%) of households were agrees to decrease of rainfall and 26.3% and 21.5% of households were disagree and neutral to decrease of rainfall respectively. And most of households (55.2%) were agrees to irregular and heavy rainfall in the study area, but (15.1%) and (29.7%) households were disagrees and neutral to irregular and heavy rainfall. In addition when (65%) of households were dis agree to no change of rainfall, but (13.0%) and (22.0%) of households were agree and neutral to no change of rainfall in their local area. Moreover, they said that unpredictable or erratic and heavy rainfall during flowering and harvesting stage is the great change them in break the coffee branches and drop coffee flowers before it changed to fruit and matured coffee berries before we harvest it in addition to soil erosion effects. The result indicated that small holder coffee farmers were perceived change and variability of rainfall in terms of decrease, unpredictable or erratic and heavy rainfall in the study area.



Source: Own survey result, 2020

Figure 6: Perception of households to trend of rainfall in the study area

Similarly, in order to validate smallholder coffee producer's perception to the progress of rainfall in their area, metrological data of monthly rainfall which recorded for thirty years (1988-2018) were collected (Appendix Id, Table 4) and analyzed. Accordingly, the trend analysis of rainfall indicated that rainfall was became decreased from year to year. As it showed in the below figure (figure 8), the regression of annual rainfall indicated that an increase of the time in one year, the annual rainfall of the study area was decreased by 26.649mm. The result of recorded rainfall data at metrological agency was in line with perception of sample households to the trend of rainfall in their local area.



Source: Ethiopia Metrology Agency, Western Oromia Metrology Service Center, 2019

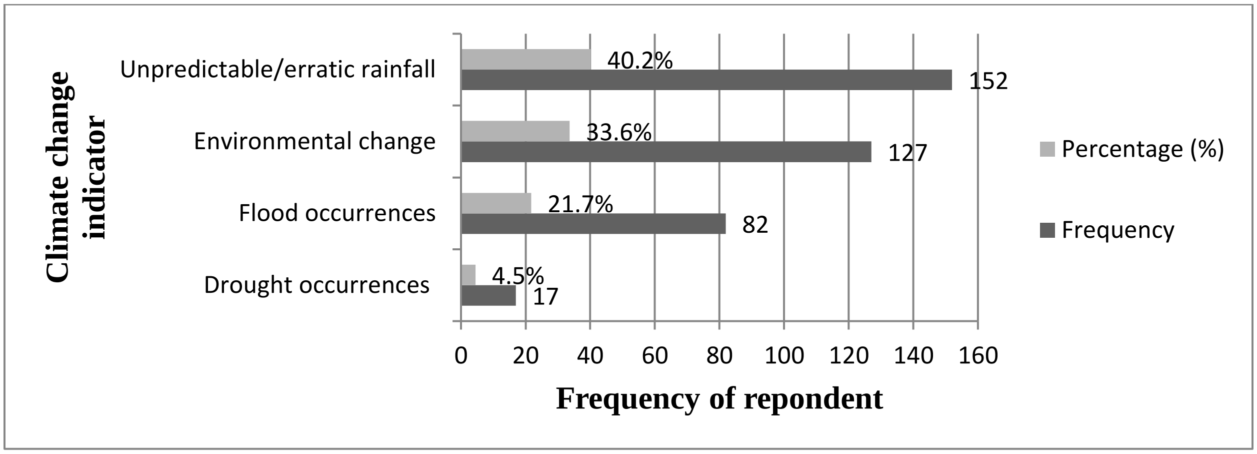
Figure 4: Trend of annual rainfall over 30 years in the study area

In sum up, the trend analysis of the two basic element of climate (temperature and rainfall) of thirty years revealed that when the average temperature was increased, the annual rainfall of the study area was decreased in the study area. Hence, from the progress of the temperature and rainfall of the three decades confirmed that climate change was takes placed in the study area and smallholder coffee producer farmers were perceived climate change.

4.2.1. Indicator of climate change in the study area

During the study, respondents were asked about climate change indicators which used analysis the effect of climate change on coffee production. Accordingly, 40.2% were respondents revealed that unpredictable or erratic rainfall, 33.6% were said environmental change in terms of plant and animal type production which are not well known yet in the area, agricultural activities, loss of biodiversity and shortage of fresh water flood occurrences (21.7%), drought occurrences (4.5%) were recognized and identified in the study area those used as a sign to notice the changing nature of climate condition in the study area.

The result of the study was triangulated and checked by focus group discussant responses and key informants. They were asked the trend of temperature over their life and they were argued that temperature of the area was became increased from year to year and there was variation in intensity and time of hot days and nights and there were high rainfall variability and sometimes flood occurrences. During the discussion, they were also asked why temperature became changed in their area and they responded that the major cause was the human activities. According to focus group discussant raised their idea, before 10-15 years the majority of their area was covered with dense forests of plants and their livelihoods were also depend on that, particularly for coffee production. And also they argued that due to the increment of human population and their desire to the expand of the land for different agricultural production and for other purpose like house materials and different furniture, charcoal and wood, the forest coverage in their area was became decreased and decreased.

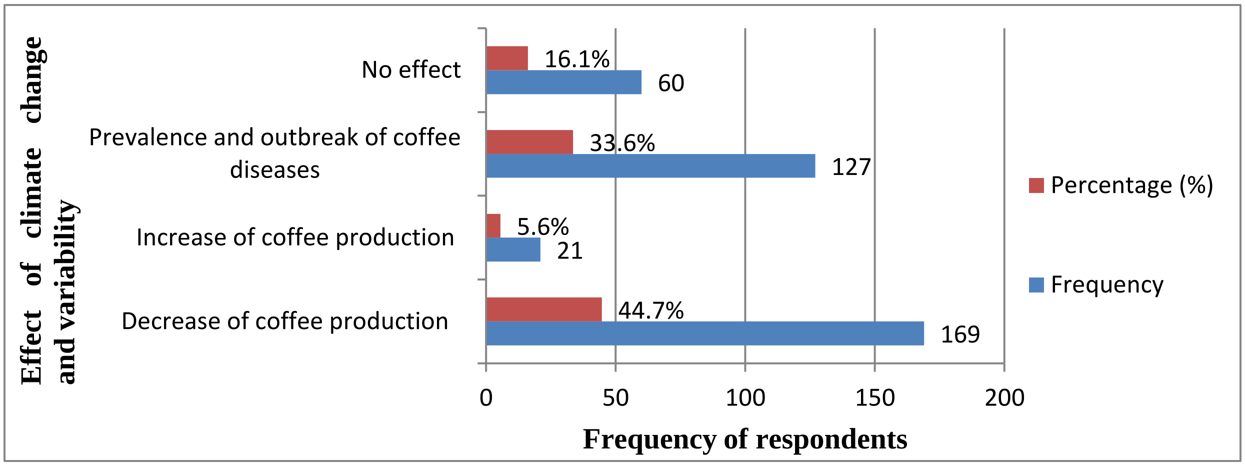


Source: Own survey result, 2020

Figure 5: Indicators of climate change in the study area

4.2.2. Effect of climate change on coffee productivity in the study area

Likewise, sample households were asked about the effect takes placed in their area due to climate change and variability. Accordingly, the survey result revealed that 44.7% of respondents were said decrease of coffee production in quantity and quality, and 33.6% of households were expressed prevalence and outbreak of coffee diseases like wilt disease, coffee berry disease, leaf rust, leaf blight, head and leaf smut and seedling blight diseases were the most severe diseases that affect coffee production and coffee quality in the study area, and in addition, there were also pests that affect coffee production and quality like stem borer that followed by berry bore and some of farmers were tried to control by applying hot ash and killing the larvae by clogging the hole with a stick while none of the respondents were reported the use of in organic fertilizer and chemicals rather than adoption of improved coffee variety. In other side about 5.6% of households were said increase of coffee production due to climate change and variability, particularly as a result of increasing in temperature coffee production was started in highland areas which is not well known before 15-20 years ago, and 16.1% of respondents were responded as no effect was takes placed on coffee productivity due to climate change and variability in the study area.



Source**:** own survey result, 2020

Figure 6: Effect of climate change on coffee production in the study area

During FGD conducted, they were also asked to compare the trend of climate change with their coffee productivities. Accordingly, they said that production yields were became decreased from year to year particularly as a result of high rainfall variability. For instance, from focus group discussions (FGD) conducted in kenteri kebele, one man of the group member said that *"I remember what the before was, when I was young it was good condition. Rainfall came in time and stopped when its time or season is past and it was not as variable as much. But now a day, when I compare with past decades, the amount of rain is decreased, and in addition to that in this time the great challenging of coffee producer farmer is the high variability of rainfall which now highly affecting coffee production in qualities and quantities due to it expands and raises coffee disease which affects coffee plants in changes of coffee leave's color to yellow and can go up to drying and killing coffee plants and we are reported it to the district experts* (62 years old man of FGD member, 13.01.2020).

In addition, key informants included the district's agricultural expert, development agents, kebele leaders, experienced men and women were interviewed. During the interview, they were requested about climate condition in view of experienced and knowledgeable person in terms of rainfall and temperature in the study area. Similarly, key informants were confirmed that change of climate in the area was affecting production of smallholder farmers. They said that temperature became hotter and hotter from year to year and rainfall was highly variable which cause to takes place of coffee diseases that affect production (coffee productivity) in quantity and quality. For instance, key informant man in Kela Guda kebekle said that *“Before, particularly in the early 1990s according to Ethiopian calendar, I got 10-15 kesha (quintal) of coffee per hector. But now a day, my production is decreased by more than half percent from what I had got before. For Example if I tell you the truth, in 2018/2019 year of production I got only 6 kesha (quintal) from the same size of land. Because of highly irregular rainfall at harvesting stage the production was affected. Unpredictable rainfall came at the matured of coffee bean and threw down it from its braches on the earth, then coffee beans were rooted and planted within its coat and as well as the colour of the left were changed into green and black, for the reason that I couldn’t collect on time since I do not have labor. In such away it was been out of use and the income what I would be get from it was left”* (Key informant man who was 56 years old, 28.02.2020).

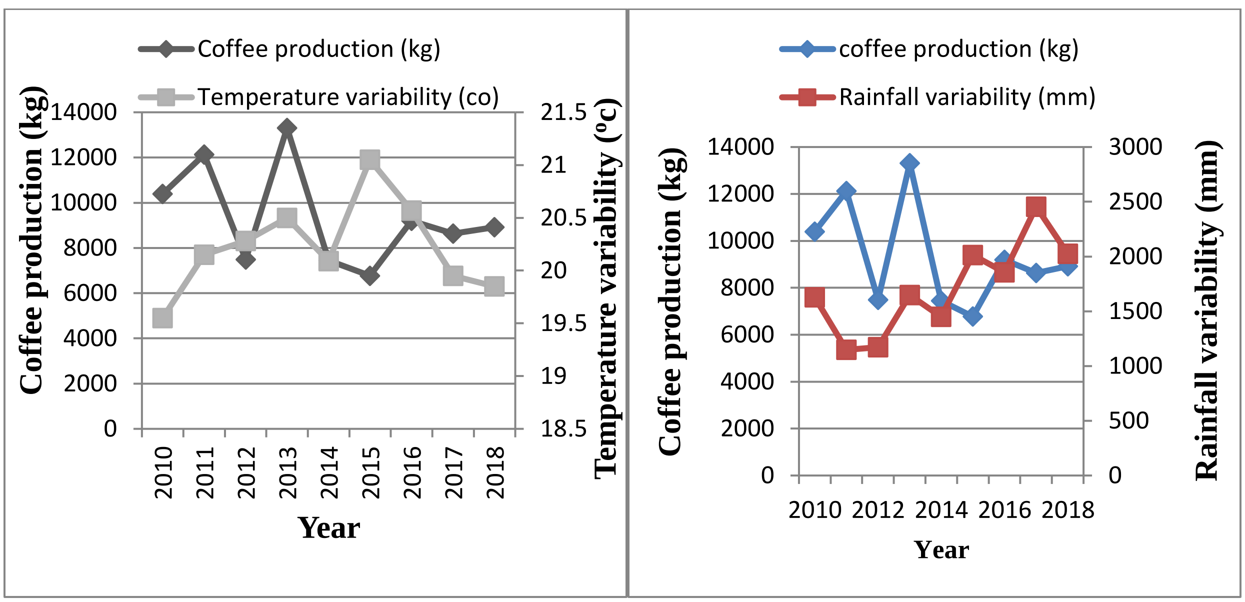
Figure (10) below was the image captured by researcher during key informant conducted which show affected coffee beans as a result of unpredictable rain at harvesting stage. Really, when the researcher looked it well, the collected coffee beans were planted and rooted in its seed coat and as well as the lefts were shirked and changed to black color. In addition, key informant man said that such type of coffee didn’t have weight and well taste, and as a result they couldn’t sell their production to market in balanced price due to the productions loose its qualities in such away.

Source: Photo captured during the survey by Researcher, 2020

Figure 7: Image shows destroyed coffee beans due to unpredictable rainfall

In addition, the status of coffee productivity for nine years were collected (Appendix Id, Table1), from the report of Agriculture and Natural Recourse Office of Mana district and analyzed with temperature and annual rainfall data recorded in the respective years. The production of coffee over nine years were indicated that when it was increased at 2011and became decreased at 2012 and reached high production at 2013 and similarly temperature was became slightly increased starting from 2010 to 2013. However after 2013 when coffee production was became decreased and reached lower production at 2015 while temperature was became reached highest and then as temperature became decreased coffee production was became increased. This revealed that even though temperature is important for coffee production it should optimum otherwise it influence coffee production adversely when it became over the necessary point (fig 11 a).

Figure 11: Trend of coffee production with relative to temperature and rainfall variability



a. Coffee production versus temperature

b. Coffee production versus rainfall

Source: Agriculture and Natural resource office of Mana district and national metrology agency, 2020

In other hand, as rainfall became decreased starting from 2010 up to 2012 coffee production was became decreased and similarly when rainfall became increased from 2012 to 2013 coffee production also increased. However, as rainfall became slightly increased starting from 2013 up to 2017 while coffee production was became decreased and reached the lowest production at

2015 and after that became increased at 2016 and again became decreased as rainfall became researched the highest at 2017, and wile became increased as rainfall became decreased at 2018 (fig 11b). Similarly, this indicated that even if rainfall is compulsory for production coffee it should optimum with otherwise it affects negatively. Farther, pairwise correlation of coffee production with temperature and rainfall variability was analyzed (Appendix, table 5). The result indicated that even though it was not significant, coffee production was negatively relationship between both coffee production and temperature and coffee production and rainfall variability. The result was in line with the finding of Tsegamariam (2018) who revealed that the amounts of rainfall received and temperature significantly affects coffee production. Moreover, Yalew *et al*, (2018) in the study climate change, agriculture, and economic development in Ethiopia, concluded that climate change reduced agricultural output, increased agricultural price, altered the international trade mix, and profoundly affected households' welfare.

4.3. Coffee farmer's adaptation strategy choices to climate change

As it was explained in the above sections, smallholder coffee farmers were perceived climate change and variability. Thus, in order to copy with and reduces the risk of climate change sampled households in the study area were took different responsive measures to climate change and variability, and those were arranged in to four major adaptation options according to their close relation with each other in their functions.

Table 5: Summary of adaptation strategies used by sample households

Adaptation strategies		Multiple choice sets (n=377)	
		Frequency	Percent
Improved coffee variety	No	196	51.99
	Yes	181	48.01
Soil conservation	No	131	34.75
	Yes	246	65.25
Planting shade trees	No	67	17.77
	Yes	310	82.23
Adjusting harvesting date	No	92	24.40
	Yes	285	75.60

Source: Own survey result, 2020.

Accordingly, soil conservation, planting shade trees, adjusting planting date and improved coffee variety were the major of adaptation options employed in the study area. Then, respondents were asked whether they adopted or didn't adopt with binary responsive (yes/no) answer for each category of adaptation measure. The study revealed that household was employed multiple adaptation in which households those adopted one adaptation option was the least adopter of climate change and variability in the study area. The study indicated that when planting shade trees was the most implemented while improved coffee variety was the less implemented by coffee farmers in the study.

i. Planting shade trees: Production of coffee under the shade of trees is obvious and the traditional way that enables coffee to adapt climate change and variability. However, households were used shade trees in planting and managing inside or surrounding their farms and houses. In order to reduce risks related to climate change and variability in the study area. The result of the survey showed that out of the total sample households, 82.2% of respondents were employed planting shade tree. In the study area, smallholder coffee producer were used different planting species which provide shade for coffee plants. These plants include those useful for home and market in yielding fruit, fuel, and medicinal quality and many of the shade tree species specifically like orange, avocado and mango, timber trees, in addition to natural forest which provide excellent bee forage and honey production as additional household income source. The preferred shade trees species by farmers tree that have intermediate height (10-15m) which provide good shading to coffee shrubs and easy to manage in pruning and those have spread crows and deciduous lifespan and have considerable leaf size (small) in order light easily filter through them and fast composition rate in improve soil fertility, particularly *Albizia gummifera, A.schimperiana, Millettia ferruginea, A cacia abyssinica, Croton macrostachyus, Olea welwitschii, Schefflera abyssinica and Syzygium guineense* tree species were preferred in the study area and they managed and used for timber and fuel the trees too old in replace by eitherplanting new ones or by managing the natural regeneration.

Even though now a day climate change and variability adaptation particularly temperature tolerant coffee have been developed in response to fungal disease and higher production rates (Perfecto *et al*, 1996), open planting or full-sun coffee planting which represents a modern system influence coffee bushes exposed to direct sunlight which require high inputs of chemical fertilizers and pesticides as well as an intensive yearly workforce and in addition, it has negative impact on the environment (Takahashi, *et al*, 2013). According to Teshale (2017) coffee grown in the open sun fields exposed to the biennial bearing problem that yields immature coffee, which is not good to get sustainable quality coffee. Moreover, Rice and Robert, (2010) and USAD and NRCS (2012) explained that coffee shrubs require certain environmental and ecological conditions to perform at their best in terms of vigor, growth and berry production so that in order to maintain ideal coffee-growing temperatures planting and managing shade trees is essential in coffee plantation, and in addition, these scholars referred that as trees provide valuable soil erosion control, formation of a secondary forest by shade grown coffee helps increase water retention in the soil profile, reduces wind speed in the coffee groves, benefiting pollinators and wildlife and favorable condition in providing a better working environment for farm laborers.

ii. Soil conservation strategies: Likewise, the other adaptation strategies smallholder coffee farmers mostly employed in the study area was soil conservation. The survey result referred that out of sample households about 74.6% of households were adopted soil conservation practices. Most of the time coffee grown by smallholders characterized by land fragmentation and many small plots scattered on hillsides which easily eroded by rainfall. To adapt climate change and variability households were implemented different soil conservation activities like terraces, soil and stone bunds, sloping or progressive terraces, and ditches, check dam and mulching in coffee farms. However, these soil conservation measures executed by smallholder farmers in the study area were not uniform due to lack of awareness, knowledge and skill, and lack of sufficient materials and labor force.

iii. Adjusting harvesting date: Adjusting harvesting date was one of the essential adaptation strategies used by smallholder coffee farmers to climate change and variability, particularly in order to keep the quality of coffee in the study area. The study indicated that 75.6% of households were adopted adjusting harvesting date. Smallholder coffee farmers said that coffee cherries mostly harvested once a year which would start from the early October up to the last December which depending on the rainfall received and temperature variability and other like management activities and soil fertilities the time and the way of harvesting coffee was varied due to climate change and variability in the in the study area. They said that before almost two decades ago they harvested coffee cherries strip picking in a way whole coffee cherries harvested at one time which the harvested coffee may not achieve the desired quality due to the mixture of under repine and over repine coffee cherries. But now a day in order to keep specially its qualities coffee farmers were harvested coffee cherries by selective picking in which the only repined coffee cherries harvested by hand from coffee plant braches in keeping the time of maturity of coffee cherries meet by looking the red color which indicates maturity status of the coffee. Jassogne, *et al.,* (2013) revealed that increase in temperature causes premature ripening of the coffee and unpredictable rains cause coffee to flower at various times throughout the year leading to continuous harvesting of small quantities of coffee. Moreover, Duguma (2017) said that in order to harvest matured coffee cherries that give good quality coffee needs a suitable time for repine of coffee fruit's chemical that are responsible for aroma and flavor properties of the coffee.

iv. Improved coffee variety: The other adaptation strategy used by coffee farmers to climate change and variability in the study area was improved coffee variety. Smallholder coffee farmers were adopted improved coffee varieties and employed different practices like change of the old coffee plants which give a low both in the quality and amount of products. The study showed that about 48.01 % of households were adopted improved coffee variety. The different studies revealed improved coffee has the adapt climate change and variability since it has the capability resist high temperature and deficiency and erratic rainfall risks and provide high production outputs per hector and maintain the inherent quality of the coffee produced than unimproved coffee. Currently, improved coffee varieties about 37 varieties along with its agronomic practices were released by Jimma research center, and from those the top ten leading coffee variety like 74110, 74112, 741, 74140, 74158, 75227, 74148, 744, 7440 and 74165 were used by households in the study area and all over the country (Taye et al, 2011). For example, According Nimona (2019) from the released improved coffee varieties, particularly 74440, F59 and 74110 were give highest clean coffee yields respectively and more adaptive capability to climate change and variability than the rest of coffee varieties.

The result was also cross checked with focus group discussion (FGD). They said that now a day every farmer has use adaptation measures in order to reduce the effect of climate change and variability. Focus group discussants in respective kebele's were pointed out the following expression in general: *"We are using different adaptation measures to reduce the risk of climate change, based on our capability like financial capital, knowledge, experience, household* *members, and farm land size. We are using agroforestry practice like planting and management of shade trees, soil conservation by constructing stone bund, soil bund and mulching, change planting date, and changing the date of harvesting that means collection coffee beans as soon as it matured in one by one rather than keep until all beans should be matured simultaneously. In addition, as development agent advising us, improved coffee variety give high yields per hector and have ability to resist coffee disease and drought in the case of climate change and variability. Now, use of improved coffee variety has being expanded and we are adopting it"* (Smallholder Coffee farmers in FGD, 2020).

4. 4. Determinants of adaptation choices strategies coffee farmers to climate change

To analysis determinants of adaptation choices, multivariate probit model was used to identify and estimate variables affect smallholder coffee farmers to adopt soil conservation, planting shade tree, adjusting harvesting date, and improved coffee variety in the study area. Before running the model, multicollinarity of explanatory variables were tested, and the values of contingency coefficient among all discrete/categorical variables were <0.75 (Appendix II, table1), and the values of variance inflation factor for all continuous variables were < 10 (Appendix II, table2). This showed that there wasn't series problem which affect the result of the model in the study. And then, MVP model was run and analyzed the responses of 377 total observations with 100 draws. The Log likelihood test was (-431.03) and Wald chi2 (60) was 433.42 at less than 1% of significant.

Table 5: Overall fitness, probabilities and correlation matrix of adaptation choices from multivariate probit model (MVP) regression

	ICV	SC	PST	AHD
ICV	1.0000			
SC	0.6009***(0.0000)	1.0000		
PST	0.0995*(0.0535)	-0.0915*(0.0759)	1.0000	
AHD	-0.2080***(0.0000)	-0.2071***(0.0000)	0.2205***(0.0000)	1.0000

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0:
chi2(6)=44.0524
Prob > chi2=0.0000

Joint probability success or failure: *Joint probability (success)=28%*
Jointly probability(failure)=1.1%

Note: *** and * represent significance level at less than 1% and 10% respectively
ICV-Improved coffee variety, SC-Soil conservation, PST- Planting shade trees, ADH-Adjusting harvesting date

The result of the study showed that there were positive and negative relationships among the pairwise correlation matrix of adaptation options. This indicated that smallholder coffee farmers were undertake adaptation strategies jointly (+ve) and interchange/substitution (-ve) of one another to copy with climate change and variability in the study area. The relationship between improved coffee variety and soil conservation was positive and significant at less than 1%, improved coffee variety and planting shade trees was positive and significant at less than 10%, and improved coffee variety and adjusting harvesting date was negative and significant at less than 1% significant level. In other way, the relationship between soil conservation and planting shade trees was negative and significant at less than 1%, and soil conservation and adjusting harvesting date was negative and significant at less than 1% of significant level. In addition, there was positive relationship between planting shade trees and adjusting harvesting date at less than 1% of significant level.

The joint probability of success or failure of sample household in adoption of adaptation strategies was predicted. The likelihood ratio test of independence of error terms of each adaptation was 0 and chi2 (6) and Wald chi2 (60) was 44.05 and 433.42 respectively at less than 1% of level of significance. The model result was justified that the joint probability of success of sample household adopts climate change adaptation strategies was about 28.3% while the probability to jointly failure was 1.2%. This indicated that the null hypothesis that the four adaptation strategies are independent was rejected. Hence smallholder coffee farmer households were used improved coffee variety, soil conservation, planting shade trees, and adjusting harvesting date in altogether rather than use one adaptation at a time. The result was support the finding of Belayineh *et al.,* (2012) who revealed that use of more than one adaptation strategy at a time is more likely effective since a single adaptation strategy is inadequate in reduction of climate change and variability risk.

4.4.1. Discussion of the model results

1. Gender of household head: The result indicated that being male headed household was statistically significant and positively influenced adoption of improved coffee variety at less than 1% of significant level. The probable reason could be male headed households have the chance of get advanced information and new innovation due to they have freedom in social movement and have power to decision than female headed household. Female households affected due to different gender constraints like inequality of male and female over resource control and decision making, unequal access to services and the burden in house activities due to role division in social life. The result was in line with the previous scholars finding like Legesse *et al* (2017); Mulwa, *et al* (2017); Enimu and Onome (2018) and Gc and Yeo (2019).

2. Age of coffee producer household head: The study revealed that age of coffee producer was significant and negatively affected implementation of soil conservation at less than 1% of probability level. However, in contradict to this age of coffee producer was significant and positively influenced planting shade trees at less than 1% of significant level. The result disclosed that when household age increase the probability to implement soil conservation become decreased, and while the probability to employ planting shade become increased. This may due to when household going to aged, he/she become going to tired and weak to employ labor intensive adaptation strategies like soil conservation, instead they more likely to plant shade trees which is implemented for one time for ever except managing and pruning its branches to reduce its canopy in order to coffee plant get sun light. The result is in consistent with the previous finding like Madison (2006) and Atinkut and Mebrat (2016).

3. Educational level of household head: The result indicated that educational level of household head was significant and positively affected both improved coffee variety and soil conservation at less than 1%, and planting shade trees at 10% of significant level. This referred that households who have more spent his/her years in school of education, more adopt improved coffee variety, soil conservation, and planting shade trees than those who less spent his/her years in school of education. The probable reason could be more educate farmers have better knowledge and advanced information that help them to understand climate change risk, and easily identify advantages of adaptation strategies and practice them in order to copy with climate change. The finding is inconsistence with the results of previous studies. Like Tesfaye (2016); Asfaw *et al*., (2018; Gc and Yeo, (2019) were some of the scholars.

4. Household size: This variable was significant and positively influenced soil conservation at less 1%, and planting shade trees at less than 10% of significant level. This referred that farmer who has more household size more adopt soil conservation and planting shade trees than farmer who has less household size. The probable reason would be the enlargements of household sizes provide labor force for that family which enhances the achievement of different agricultural practices and adoption of adaptation strategies which need human forces. The result is inconsistence with the previous finding of different scholars like Abid *et al.*, (2015); Ali and Erenstein (2016); Ojo and Baiyegunhi (2018); (Menberu and Yohannes, (2014) and Marie *et al*, (2020).

5. Farm size of household head: The result of the study implied that farm size of household head was statistically significant and positively influenced planting shade trees at less than 1% of significance level. This showed that household who has more farm size more adopt planting shade trees than household who have less farm size. The reason could be household those have more farm land size have a chance to planting different shade trees in his farming activities as well as around it without any fear of his farmland or farm plot to be decrease for production than those have small farm land size. The result is inconsistent with the finding of the previous studies, for instance, Gebrehiwot and Van der veen, (2013) and Belay *et al.* (2017).

6. Farming experience of household head: The result showed that farming experience of household head was significant and positively affected adjusting harvesting date at less than 1% of significant level. The finding implied that more experienced household head more adopt adjusting harvesting date than less experienced household head. The probable reason could be during farmers practice farming activities from year to year he/she can develop his/her knowledge and come to well understand of success and failure of crop productivities with the trend of climate change and variability. The result confirm with the finding of scholars in the previous studies, like Onyekuru (2017) Enimu and Onome (2018).

7. Perception to climate change of household: This variable was statistically significant and positively affected adjusting harvesting date at less than 1% level of significant. The finding showed that household who perceive climate change more employed adjusting harvesting date than household who do not perceive climate change. The possible reason could be households who insight and recognize as climate is changed more stimulate to practice adjust harvesting date than household who do not seems climate change. The finding is in line with the previous studies, for instance, Atinkut and Mebrat (2016); Bagagnan et al., (2019) and Regasa and Akirso (2019).

8. Frequency of extension agent contacts household: The result of the study indicated that frequency of extension agent contacts household was statistically significant and positively influenced improved coffee variety at less than 5%, both soil conservation and planting shade trees at less than 1%, and adjust harvesting date at less than 10% of significant level. This referred that as extension agent contacts and follow households repeatedly, households become to more adopt the identified adaptation strategies altogether as much as possible than households who less contact with extension agent. The probable reason could be frequently contacted household with extension agent he/she will get update information about climate situations, knowledge and innovations, and different practices that help them how to adapt climate change and increase their production. The result was in line with the finding of many studies done in the previous, like Otitoju and Enete (2016); Ahmed (2017); Belay *et al.* (2017); Atinkut and Mebrat (2016) and Ojo and Baiyegunhi (2018).

9. Farmer-to-farmer extension of household: Farmer-to-farmer extension was significant and positively influenced planting shade trees at less than 1% level. The result of the study referred that households who communicated and with his neighboring farmers more adapted planting shade trees than who didn't participate in farmer-to-farmer extension. The probable reason could be when smallholder coffee farmers communicate and exchange experience through farmer-to-farmer extension they exchange experience and observe or visit t heir neighboring practice in planting shade trees and as a result their production (coffee) is adapt climate change and variability, they easily adopt it and practice in their farm accordingly rather than those who do not communicate and visit their neighboring farmers. The result support the finding of Apata (2011), farmer-to-farmer extension increases the likelihood of climate change adaptation due to play an important role in the availability and flow of information and practices and experiences.

10. Access to climate change information of household: In the study, access to climate change information was statistically significant and positively influenced both planting shade trees and adjusting planting date at 1% of significant level, and in addition, it was significant and positively influenced improved coffee variety at less than 10% of significant level. The result indicated that households those accessed climate change information more adopted planting shade trees, adjusting harvesting date, and improved coffee variety than those who didn't accessed information related to climate change. This may due to climate change information is more likely sensitive in order to households take an instant action like change of agricultural practices and to use climate change and variability tolerant of improved variety and more suspect them to think it for futurity and employ planting trees to overcome and handle the risks related to climate change from their production. The results were in line with the findings of various studies in the past like Otitoju and Enete (2016); Solomon and Edet (2018); Legesse (2013) and Ahmed (2017).

Table 7: Multivariate probit estimation for determinants of adaptation choices

Variables	Adaptation strategy employed by sample household							
Explanatory variables	Improved coffee variety		Soil conservation		Planting shade trees		Adjusting harvesting date	
	Coef.	St. Err	Coef.	St. Err	Coef.	St. Err	Coef.	St. Err
GENHH	.700***	.266	.129	.222	-.058	.241	.138	.245
AGEHH	.004	.018	-.038***	.014	.088***	.018	.022	.015
EDUHH	.363***	.061	.274***	.052	.095*	.052	.020	.057
HSIZ	.053	.055	.134***	.041	.089*	.054	.034	.048
FARSIZ	-.138	.175	-.150	.126	.741***	.146	.044	.134
FAREXP	-.003	.022	.028	.018	.005	.023	.089***	.018
AGRECO	-.108	.234	-.278	.172	-.213	.190	.047	.208
PECCHH	.202	.370	.054	.332	.079	.283	.780***	.245
FRQEXN	.320**	.131	.249***	.096	.284**	.124	.186 *	.126
FARTOFAR	.089	.249	.058	.203	.711***	.244	-.275	.253
ACCINFO	.519*	.274	-.191	.198	.763***	.209	.663***	.194
NOINSMEM	.022	.087	-.044	.066	.099	.089	.081	.082
ACCRD	.727***	.242	.205	.207	-.249	.252	-.061	.240
MARDIS	-.117	.119	.084	.071	-.118	.087	-.016	.089
NONFAR	.846***	.246	-.139	.190	-.252	.214	.215	.224
Constant	-3.792	1.185	-.641	.865	-5.001	1.082	-4.478	1.219
Multivariate probit (SML, # draws =100)				*Number of obs = 377*				
				Wald chi2(60) = 433.42				
Log likelihood = -431				*Prob > chi2 = 0.0000*				

Source: MVP outcome, 2020

*Note: ***, **and * are indict level of significant at less than 1%, 5 % and 10% respectively*

11. Access to credit services of household: Accessed to credit service was significant and positively influenced improved coffee variety at less than 1% significant of level. This indicated that households who got and used credit service more practice and adopt improved coffee variety than who didn't accessed credit service. This may due to credit access enables farmers to change their management practices in improving their financial problem in overcoming cost of new technologies and innovations. The result is inconsistence with the finding of many scholars, for instance, Berman (2014); Mihiretu *et al.*, (2019); Mmbando and Baiyegunhi (2016); (Enimu and Onome, 2018).

12. Nonfarm activity participation of household: Similarly in the study, household head participation on different nonfarm activity was significant and positively influenced improved coffee variety at less than 1% of significant level. The result indicated that household head who participate in nonfarm activity more likely use improved coffee variety than who didn't participate in such activities. The probable reason could be households who participate in different nonfarm activities in addition to farming, he/she can get additional income which enhance and cover transactional cost of new technologies than who do not participate in such activities. According to Tesso *et al*., (2012), farmers with strong financial capacity had capacity in adoption to climate change, and Sani *et al*, (2016) said that off/non-farm income increases uptake of improved crop varieties as adaptation strategies to climate change.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Climate change and variability like increase of temperature, and decrease and irregularity of rainfall affects crop production, particularly coffee is a sensitive crop to climate change and variability which needs optimum climate condition to give yields properly. The study examined smallholder coffee producer's perception and adaptation strategies to climate change and variability and factors affect them to choice adaptation options in Manna district, Jimma zone, Oromia region, Southwestern Ethiopia.

The study used mixed research approach which includes qualitative and quantitative data and cross-sectional research design. In order to achieve its objective household survey was conducted on 377 randomly selected household from three Kebele of the district. Necessary data were collected through household survey, focus group discussion and key informants. In addition, temperature and rainfall data for thirty years (1988-2018) were obtained from national metrology agency, and coffee productivities data over nine years were also obtained from Mana district agricultural and natural resource office.

The study was analyzed descriptive statistics like mean, standard deviation, minimum, maximum, frequency, percentage, and multivariate probit model. In addition, qualitative data collected through focus group discussion and key informants were analyzed by transcription and then the results were written in quotation and narration form and likert scale was also used in assess of household's perception to the trend of temperature and rainfall, and trend analysis was used in analysis of temperature and rainfall variability with coffee production over nine years.

The study showed that out of total sample households, 80.37% were perceived climate change and 19.63% of sample households were not perceived climate change. Meteorological data of the monthly average temperature and annual rainfall over the past thirty years of the study area indicated that temperature was raised by 0.038c^{o}, and annual rainfall was decreased by 26.65mm in a year. Unpredictable or erratic rainfall, environmental change, flood occurrences were the major climate change indicator used by sample households in the study area. Prevalence and outbreak of coffee diseases and decrease of coffee production in quantity and quality were the effect of climate change and variability in the study area.

In order to copy with and reduces the risk of climate change and variability, sampled households of the study area were took different responsive measures. Soil conservation, planting shade trees, adjusting harvesting date, and improved coffee variety were the major adaptation strategies employed in the study area. The result of the study showed that there were positive and negative relationships among these adaptation options. The study revealed that probability to adopt jointly success was about 28% while the probability to jointly failure was 1.1%. This referred that smallholder coffee farmer households in the study area were used adaptation strategies jointly or in substitute one another.

The result of the multivariate probit model indicated that gender of household being male, household size, farm size, farming experience, educational level, frequency of extension contact, access to climate change information, perception to climate change, farmer-to-farmer extension, access to credit service, and nonfarm activity participation of household were positively influenced, but age of household was negatively affected sample households to adopt climate change adaptations. However, agro-ecological setting of household, market distance and the number of household participate in local institutions or organizations were insignificant in the study.

Generally, the study refers that majority of smallholder coffee producers have perceived climate change and variability and they have being adopted adaptation strategies to reduce the risk related to climate change and variability on coffee production. In addition, factors influence them positively or negatively in implementation of adaptation options were identified in the study area.

5.2. Recommendations and Future Research

The study revealed that climate change and variability was affected production of coffee in the study area and households were implemented adaptation strategies. However, socio-economic of households and institutional factors were influenced them in adoption of adaption options. Therefore, based on the finding the following necessary recommendations are made.

- Extension workers should aware farmers about climate adaptation strategies in providing updated knowledge, innovations and information related to climate change and variability and motivate farmers to adopt adaptation strategies.

- Weather institute, broadcasting agency, research institute and universities should coordinately create more awareness to coffee farmers in disseminate weather information, conduct different climate change forums and workshops at household level how farmers respond to the adverse effects of climate change on coffee production.
- Farmers should be plant trees around his farm and manage the exiting forest and in addition what the government have started the agenda of planting trees at national level should be encouraged and enforce all community to plant trees in a year.
- Government should help and motivate the coffee farmers particularly aged and female headed households in providing agricultural inputs and give knowledge, skill and attitude training in coordinated with NGO's and foreign donors and investors, and making affordable policy and strategies of credit service accesses.
- Households should be participate in different nonfarm activities, expand their farming activities in contract land and share cropping, and develop their knowledge through adult education and information, and experience exchange through farmer to farmer extension.
- In overall, the study provided some necessary information about climate change and its effect on coffee production in the study area. But it didn't include wide area that includes all districts in the zone. Therefore it is good if farther study will be conducted with support of technology which can determine the sustainability of coffee production in the area.

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7. APPENDICES

I. Household survey questionnaire

a. Interview schedule

Jimma University

College of Agriculture and veterinary Medicine

Department of Rural Development and Agricultural Extension

Survey on Smallholder Coffee Producer's Perception and Adaptation Strategies to Climate Change and Variability in Manna district, South Western Ethiopia

Dear household head, my name is Alemu Tesfaye. I am MSc student at Jimma University, college of agriculture and veterinary medicine. Now am doing research on Smallholder Coffee Producer's Perception and Adaptation Strategies to Climate Change and Variability in Manna woreda. The object of this questionnaire is to collect the primary data on socio-economics, institutional, environmental, and related information that are required to analyze the study. Therefore, you are selected as one of coffee producer and kindly requested to give your response freely and accurately to the success of this work. You should be confident that the data/information which you give me required only for this study.

i. General information

Name of kebele: ________________________ Name of village: _____________________

Interview date: ________________________ Interview schedule number: __________________

ii: Household characteristics

1. Name of household head ________________________________

2. Age (in year) ___________________

3. Sex: A. Male B. Female

4. Educational status of the respondent's in number of years of formal schooling attained _________

5. Religion, Marital Status and Responsibility in the community of Household Head refer to the below table.

Religious of HH	**Marital status**	**Responsibility in the community**
A. Muslim	A. Married	A. Member of the community
B. Orthodox	B. Single	B. Religious leader
C. Protestant	C. Divorce	C. Coordinator of community development work
D. Wakefata	D. Widow	D. Kebele Administrator
		E. Abbaa Gadaa / Jaarsa Biyyaa

6. Family size

Age(year)	Number & sex of family member		
	M	F	**Sub total**
Below 15 years			
Between 15 and 65 years			
Above 6 5 years			
Total			

7. Do you have your own farm land? A. Yes B. No

7.1. If your answer for question yes, would you tell me landholding & farm characteristics of your land? (Farm land size)

No	Types of land use	Area (ha)
1	A. Cultivated (farm) land	
2	B. Forest land	
3	C. Homestead land	
4	D. Grazing land	
5	E. Unused land	
6	F. Irrigated land	
7	G. Other, specify___________________________	
Total		

8. What is your major livelihood activity?

A. Crop production B. Animal production C. Mixed farm D. Off-farm and non-farm activities

9. How many years' experience with farming do you have? ___________

10. In what agro ecological zone your local area is classified? A. Dega B. woina dega C. kolla

iii. Perception of coffee farmer to climate change and variability

11. For how long did you live here? ______________________

12. Have you perceive climate change in your local area? E.g. incase/decrease of temperature and rainfall? A. Yes B. No

12.1. If yes, what extent would you agree or disagree that the options indicated in the table below apply as possible reasons to the climate change trend in terms of temperature and rainfall in the past 10-15years?

No	Items considered	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
A	Changes in temperature	[ ]	[ ]	[ ]	[ ]	[ ]
1	Increased	[ ]	[ ]	[ ]	[ ]	[ ]
2	Decreased	[ ]	[ ]	[ ]	[ ]	[ ]
3	No change	[ ]	[ ]	[ ]	[ ]	[ ]
B	Changes in rainfall	[ ]	[ ]	[ ]	[ ]	[ ]
1	Increased	[ ]	[ ]	[ ]	[ ]	[ ]
2	Decreased	[ ]	[ ]	[ ]	[ ]	[ ]
3	No change	[ ]	[ ]	[ ]	[ ]	[ ]
4	Heavy and Irregular/erratic rainfall (eg. during planting, flowering and harvesting)	[ ]	[ ]	[ ]	[ ]	[ ]

13. What is/are indicator/s of climate change in your local area?

A. Drought occurrences B. Flood is frequently occurred

C. Environment is changed (in type of plant and animal production, forest coverage etc.)

D. Unpredictable/erratic rainfall is frequently occurred

14. What is/are the effect/s related climate change/variability in rainfall and temperature in the past 10-15 years on coffee production? (**Multiple choices are possible).**

A. Decrease of coffee production B. Increase of coffee production.

C. Prevalence and outbreak of coffee disease D. No effect

iv. Questions related to coffee farmer's adaptation strategies to climate change and variability

15. In response to climate change/variability, have you taken adaptation strategies? A. Yes B. No

15.1. If your answer is yes, indicate' ☑**'** mark the adaptation strategies you employ in your farm to cope with and decrease the adverse effects of climate change and variability **(Multiple choices are possible).**

No	**Adaptation strategies**	Mark (☑)	Reason
1	Improved coffee variety	[ ]	
2	Soil conservation	[ ]	
3	Planting shade trees	[ ]	
4	Adjusting harvesting date	[ ]	

v. Institutional related questions

16 Do you have access to extension services? A. Yes B. No

16.1. How many times development agent visits you last year?

A. No visit B. Occasionally C. Mostly D. Regularly

17. Do you communicate with your neighboring model farmers (farmer-to-farmer extension) to adopt climate change and variability adaptation measures and knowledge, information, new technologies and innovation that help you in coffee production? A. Yes B. No

18**.** Do you have an access to climate change information? A. Yes B. No

18.1. If yes, what is/are the source/s of your climate change/variability information? Multiple choices are possible (**Multiple choices are possible).**

A. Mass media (eg. Radio, TV, etc) B. Extension agent C. Climate change forum

D. Indigenous knowledge (experience) E. From other farmers

19. Do you membership to institutions/organizations in your local area? A. Yes B. No

19.1. If yes, mark ☑ the following local institution/organization which you membership and explain your role.

No	Institutions/ social relations	Member (☑)	Role in the group/ institution
1	Cooperative		
2	Idir/afosha		
3	Religious association		
4	Debo/ jige		
5	Ikueb (traditional saving)		
6	Dugda(reciprocal work group)		

20. Do you have access to credit services? A. Yes B. No

20.1. If yes, can you tell the purpose, source and amount of credit you received?

No	Purpose of credit	Yes/No	Source of credit	Yes/ No	Received (Birr)
1	For purchase fertilizer		Bank		
2	For purchase improved coffee seed		NGO		
3	For purchase weed management chemicals		Relatives		
4	For pay coffee bean harvest employments		Micro institutions		
5	For purchase farm implement equipment		Friends		
6	For land rent		Traders		
7	For other purpose (Specify).____________________		Saving and credit associations		

22. Do you have an access to market? A. Yes B. No

22.1. If yes, what is the average distance in order to buy coffee production inputs (improved coffee seed/ fertilizer/chemical? _______ km ______hours of walking?

23. Do you participate in non-farm and/or off-farm activities apart from crop production? A. Yes B. No

23.1. If yes, would you tell me about the types of activities, amount of income from the job, and the purpose for which you use the money?

No	Type of activity	Estimated annual income (in Cash)
1	Trade	
2	Wage work	
3	Land renting	
4	Remittance	
5	Government employee	
6	Tailor	
7	Selling wood, charcoal and other forest products	
8	Hand craft and clay work	

Thank you Very Much for Your Kind Responses!

b. Checklist for key informants interview (KII)

The objective of this interview is to gather information related to perception of smallholder coffee farmers towards climate change /variability and its adaptation strategies. Data to be collected from this interview will be used only for the study of raised issue. Your responses will be kept confidential. Therefore, I kindly request you to participate in this study voluntarily. The quality of this study depends on your genuine response. Thank you in advance for your time and kind cooperation!

Name ______________________ Position/profession _____________________

1. What do you think on the trend of climate change and variability?

2. Has the trend of rainfall changed or constant in the past 10-15 year?

3. Has the temperature been increased/decreased in the past 10-15 years?

4. What are the indicators of climate change/variability in your local area?

6. What is the effect of climate change/variability effects on coffee production in your local area?

Thank you Very Much for Your Kind Responses!

c. Check list to guiding Focused Group Discussion (FGD)

The objective of this Focused group discussion is to gather information related to perception of smallholder coffee farmers towards climate change /variability and its adaptation strategies in manna woreda. Data to be collected from this FGD will be used only for the study of raised issue. Your responses will be kept confidential. Therefore, I kindly request you to participate in this study voluntarily. Thank you in advance for your time and kind cooperation!

Kebele ___________________Place of discussion______________, Date of discussion _________________

Time of discussion ___________________ Number of Participants _______________________

1. How do you perceive climate change (Temperature, precipitation, Stream flow and vegetation cover and its type?)

2. What is /are the local indicator/s of the change of climate?

3. What are the effects of climate change on agriculture (coffee production)?

5. What about adaptation strategies are employed by coffee producer farmers?

6. Are there factors inhabit smallholder coffee farmers to adopt or practice of adaptation strategies?

7. Are there any factors contributing to low production of coffee rather than climate change/variability? If it is there explain.

Thank you Very Much for Your Kind Responses!

d. Report of recorded data from Mana district office and Metrology Service Center

Table1. Coffee production (ton) per year and farm land (ha) provide production in Mana district for nine years (2010-2018)

Year	Total coffee supplied for central market		Estimated local consumed/used (30%)	Total	Farm land (ha) provide coffee production
	Washed coffee	unwashed			
2010	1752.00	6244.00	2398.80	10394.80	19805
2011	3764.00	5565.00	2798.70	12127.70	20079
2012	2077.00	3680.00	1727.10	7484.10	20125
2013	3269.00	6969.00	3071.40	13309.40	21638
2014	2633.30	3094.20	1718.25	7445.75	22045
2015	3337.00	1873.00	1563.00	6773.00	22545
2016	4619.00	2454.00	2121.90	9194.90	22600
2017	4120.00	2520.61	1992.18	8632.79	26072
2018	3735.00	3128.40	2059.02	8922.42	31720

Source: Manna district, Agriculture and Natural Resource Management Office, 2019.

Table2: Monthly recorded mean minimum temperature (c^{o}) of Manna district for 30 years (1988-2018).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1988	13.03	13.52	14.02	13.95	13.99	13.47	13.47	13.37	13.48	13.69	12.30	12.65	**13.41**
1989	12.65	13.43	13.90	13.92	13.65	13.01	13.09	13.11	12.81	12.65	12.61	12.54	**13.11**
1990	12.12	12.40	12.28	12.66	12.75	12.70	12.67	12.77	12.64	12.70	12.78	12.59	**12.59**
1991	12.94	13.23	12.73	12.92	12.87	11.90	11.92	12.26	12.14	11.60	11.97	12.65	**12.43**
1992	12.32	12.35	12.52	12.53	12.50	12.15	13.15	12.89	12.61	12.45	12.49	12.67	**12.55**
1993	12.53	12.74	12.63	12.99	13.32	13.57	12.53	13.49	13.43	13.24	12.58	12.70	**12.98**
1994	12.81	13.10	13.78	14.26	13.78	13.59	13.40	13.69	12.36	12.61	13.14	12.01	**13.21**
1995	12.20	11.58	12.83	13.48	12.63	13.22	13.18	13.39	11.87	10.96	11.44	9.79	**12.21**
1996	9.49	14.06	13.45	14.00	13.53	13.45	13.43	13.41	12.89	12.51	12.38	12.45	**12.92**
1997	12.45	10.90	12.99	13.72	13.09	13.	13.71	13.41	13.30	13.49	13.45	13.74	**13.10**
1998	14.08	14.84	14.63	15.30	14.75	14.31	13.95	13.77	13.01	12.70	12.31	12.40	**13.84**
1999	12.82	13.39	13.45	13.55	12.79	13.06	12.29	11.96	12.59	11.48	11.60	12.02	**12.58**
2000	12.53	13.39	13.29	12.58	12.74	12.48	12.21	12.26	12.90	12.79	12.40	12.98	**12.71**
2001	12.46	12.86	13.04	12.64	13.04	12.12	12.50	12.31	12.74	12.20	11.85	12.44	**12.51**
2002	12.38	12.84	12.34	12.78	13.10	12.58	12.63	11.55	12.58	12.17	11.93	12.69	**12.46**
2003	12.49	13.19	13.69	13.67	13.16	12.19	12.54	12.53	12.55	12.38	12.85	12.37	**12.80**
2004	12.86	12.53	13.29	13.30	13.43	12.62	12.59	12.56	12.30	11.93	12.82	12.80	**12.75**
2005	12.76	14.54	13.73	13.81	13.77	13.25	13.67	13.67	12.75	1.53	12.28	12.31	**12.34**
2006	12.84	13.60	13.79	13.92	13.59	13.13	12.80	13.26	13.37	13.32	12.84	12.72	**13.26**
2007	13.35	13.34	13.77	13.63	13.90	13.71	13.13	13.42	12.14	11.96	12.32	12.68	**13.11**
2008	13.33	13.25	14.07	14.08	14.07	13.55	13.24	13.39	13.03	13.14	12.91	12.80	**13.41**
2009	13.50	13.15	14.38	14.51	14.24	13.40	13.35	13.37	13.13	13.35	12.95	13.16	**13.54**
2010	13.58	14.35	14.47	14.91	14.83	13.70	14.04	13.81	13.50	13.55	13.67	13.58	**13.00**
2011	13.36	14.20	14.63	14.14	14.74	14.11	13.95	13.81	13.88	13.34	13.31	13.37	**13.90**
2012	13.97	14.85	14.78	14.81	14.08	13.89	13.86	13.83	13.45	10.77	11.87	9.66	**13.32**
2013	14.20	14.58	14.63	14.80	13.25	13.34	13.49	14.23	13.61	13.43	13.18	11.42	**13.68**
2014	9.65	10.20	12.27	14.28	14.03	13.77	14.59	13.88	13.98	13.93	10.56	7.90	**12.42**
2015	13.29	14.45	14.30	13.77	13.27	13.65	13.66	13.04	13.00	13.69	13.97	13.73	**13.65**
2016	13.70	13.62	14.39	13.94	14.26	14.13	13.95	13.86	14.05	13.38	12.62	13.88	**13.82**
2017	2.71	11.66	13.73	13.92	13.40	13.90	13.38	13.96	14.18	13.60	10.37	4.63	**11.62**
2018	13.46	13.56	13.51	12.95	13.10	13.21	12.87	13.70	13.14	13.63	12.36	12.11	**13.13**

Source: Western Oromia Metrology Service Center, 2019.

Table3. Monthly recorded mean maximum temperature (c^{o}) of Manna district for 30 years (1988-2018).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1988	26.97	27.03	28.88	28.18	26.87	25.67	22.84	22.84	22.96	25.25	26.63	27.47	**25.97**
1989	27.26	27.07	26.92	25.98	26.37	24.71	23.45	23.86	23.93	25.35	26.06	24.85	**25.48**
1990	25.17	24.85	25.44	24.52	25.01	25.34	25.10	25.22	25.40	25.13	25.12	25.86	**25.18**
1991	25.68	25.91	25.94	25.72	25.78	24.90	23.96	23.55	24.39	25.68	26.33	26.36	**25.35**
1992	25.73	25.44	24.91	25.78	25.68	26.05	25.58	25.77	25.61	25.81	26.36	26.32	**25.75**
1993	25.84	26.25	25.67	25.62	25.60	24.51	25.36	25.12	25.54	25.55	26.40	26.63	**25.67**
1994	26.85	26.54	26.41	26.32	25.48	25.48	25.49	25.14	25.39	27.29	27.25	28.60	**26.35**
1995	28.15	29.67	29.94	28.36	26.60	25.33	25.20	23.60	24.41	27.68	28.68	28.52	**27.18**
1996	27.70	30.04	28.97	26.76	26.19	25.93	24.99	24.09	25.30	28.16	28.63	28.42	**27.00**
1997	28.46	30.99	29.40	27.97	27.83	26.75	25.66	24.65	26.11	26.01	26.08	27.63	**27.29**
1998	27.87	26.08	28.57	28.69	28.17	26.44	24.79	24.13	23.90	25.32	25.23	26.84	**26.33**
1999	27.68	30.38	29.62	29.59	26.87	26.07	24.15	24.35	25.29	24.61	26.24	26.98	**26.82**
2000	28.90	28.16	31.39	27.46	27.23	25.99	24.75	23.73	24.93	25.84	25.69	27.18	**26.77**
2001	27.83	30.06	28.01	28.19	27.45	25.36	24.99	25.18	26.65	28.12	27.50	28.73	**27.34**
2002	27.91	29.86	27.32	28.44	29.98	27.30	26.42	26.53	26.93	27.96	29.03	28.53	**28.02**
2003	29.26	27.81	29.55	28.29	30.92	26.88	25.93	26.66	26.47	28.65	28.90	29.59	**28.24**
2004	29.93	27.90	30.56	28.11	29.65	25.93	26.14	26.35	26.56	28.14	28.64	28.72	**28.05**
2005	29.25	32.65	30.67	30.44	27.71	27.47	23.85	27.17	26.75	27.36	28.72	28.56	**28.38**
2006	29.28	30.91	29.45	27.88	26.97	26.15	25.72	24.76	25.60	26.91	26.89	26.98	**27.29**
2007	27.63	28.37	29.57	28.21	27.32	25.83	24.50	26.22	26.13	26.75	27.80	28.86	**27.26**
2008	29.58	28.76	27.94	28.29	28.65	29.95	27.95	27.03	26.11	26.52	27.78	28.31	**28.07**
2009	28.66	27.68	28.11	28.47	27.65	24.50	24.56	25.32	26.09	26.28	27.75	27.76	**26.90**
2010	27.75	26.59	28.27	28.43	26.66	25.25	24.01	23.87	24.18	26.44	26.45	25.30	**26.10**
2011	25.79	29.43	28.78	29.05	26.35	24.39	24.18	23.84	25.14	26.36	27.10	26.53	**26.41**
2012	29.07	31.17	30.42	27.60	26.52	24.91	24.35	23.80	25.76	26.73	28.21	28.32	**27.24**
2013	29.24	29.39	30.42	30.42	26.04	25.08	24.93	24.59	25.59	26.04	27.49	28.68	**27.32**
2014	28.68	29.12	29.41	29.13	28.19	27.24	25.71	25.44	25.93	27.42	28.92	27.95	**27.76**
2015	29.88	31.51	31.56	28.40	28.43	28.05	27.10	26.82	26.48	27.46	27.95	27.74	**28.45**
2016	27.81	28.96	27.45	28.37	27.06	27.62	25.92	26.08	26.95	26.75	27.17	27.90	**27.33**
2017	30.31	29.73	29.63	28.89	27.34	34.12	25.59	25.45	26.05	27.19	27.14	27.95	**28.28**
2018	27.84	25.90	28.75	27.55	27.35	24.04	25.40	25.48	25.27	27.82	24.66	28.61	**26.56**

Source: Western Oromia Metrology Service Center, 2019).

Table 4: Monthly recorded rainfall (mm) of Manna district for 30 years (1988-2018)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual rainfall
1988	43.6	108.7	39.9	49.7	213.1	234.1	349.5	294.8	371.8	273.9	4.1	3.9	**1987.1**
1989	13.7	59.0	136.3	156.8	92.4	209.0	228.8	198.9	148.4	188.5	33.4	131.5	**1596.7**
1990	3.0	98.4	456.7	161.6	469.6	282.4	181	400.9	400.3	146.2	259.5	14.0	**2873.6**
1991	103.8	68.1	37.7	204.3	223.7	355.1	170.4	270.7	151.1	63.4	5.4	59.3	**1713.0**
1992	116.5	215.0	319.2	204.9	408.1	384.3	201.6	81.3	10.8	36.3	64.5	78.1	**2120.6**
1993	46.4	80.02	238.8	337.7	439.0	281.1	374.7	421.5	363.0	187.3	44.1	116.3	**2929.9**
1994	188.4	35.8	146.6	174.4	409.0	476.4	543.8	524.0	140.8	43.2	61.1	7.0	**2750.5**
1995	2.5	45.8	126.9	376.4	101.2	58.3	106.8	356.2	140.9	140.3	26.7	107.6	**1589.6**
1996	51.6	35.6	318.5	321.1	315.6	322.3	480.0	328.3	326.2	60.7	207.2	42.2	**2809.3**
1997	184.4	12.2	207.1	306.0	202.8	362.2	311.9	563.6	160.1	516.0	403.9	129.6	**3359.8**
1998	96.9	12.4	205.3	157.4	235.7	223.7	342.4	396.0	309.2	396.4	63.0	0.0	**2438.4**
1999	23.1	0.0	64.3	135.2	247.3	351.5	380.6	219.5	172.5	354.6	17.0	38.8	**2004.4**
2000	0.0	6.5	46.3	192.3	447.5	429.8	412.1	441.6	253.4	458.5	121.2	59.2	**2868.4**
2001	13.2	38.8	155.6	164.5	359.8	394.1	414.2	404.2	220.1	36.1	50.6	21.7	**2272.9**
2002	115.8	7.7	99.1	128.7	216.0	488.0	253.8	339.2	194.9	114.5	54.9	213.8	**2226.4**
2003	391.9	241.1	192.7	226.3	69.7	8.5	22.2	39.2	56.2	91.1	176.7	53.3	**1568.9**
2004	33.1	18.6	47.9	164.8	131.4	253.5	281.2	308.9	222.0	116.0	93.6	49.1	**1720.1**
2005	6.1	179.1	171.2	191.8	164.0	186.0	257.0	262.5	105.2	63.3	0.0	37.7	**1623.9**
2006	25.3	43.0	145.0	71.3	199.0	246.6	447.4	343.6	248.8	210.2	80.2	52.7	**2113.1**
2007	43.3	59.0	73.5	98.9	242.0	166.1	283.6	224.8	57.9	47.1	68.6	2.0	**1366.8**
2008	33.5	64.9	84.0	99.7	165.2	176.6	240.3	208.4	126.3	243.5	57.1	47.9	**1547.4**
2009	93.8	70.8	94.5	100.5	88.4	187.1	197.1	192.1	194.6	118.0	41.4	24.5	**1402.8**
2010	7.6	71.3	106.1	83.3	225.0	264.4	243.5	297.5	193.5	48.9	57.5	30.0	**1628.6**
2011	33.2	1.3	51.0	84.0	145.6	121.7	133.6	257.3	204.8	38.4	49.5	27.3	**1147.7**
2012	4.5	1.6	25.2	94.1	78.8	212.9	215.0	217.1	216.1	35.0	37.3	32.7	**1170.3**
2013	18.6	12.1	13.0	11.7	186.0	245.2	318.4	345.3	275.0	120.8	61.3	39.5	**1646.9**
2014	17.8	16.8	115.3	66.1	194.3	117.4	271.3	265.6	142.3	203.9	13.0	25.9	**1449.7**
2015	0.0	5.6	33.4	125.3	251.7	310.3	283.8	246.0	286.1	114.3	227.0	130.0	**2013.5**
2016	36.8	14.0	66.4	104.5	335.4	269.2	318.1	259.4	318.9	121.8	10.4	0.0	**1854.9**
2017	0.0	81.3	287.9	158.0	343.4	193.1	367.1	523.9	254.4	209.3	36.6	0.0	**2455.0**
2018	65.9	63.6	85.4	132.2	200.6	264.6	308.9	342.1	242.3	71.9	181.9	66.5	**2025.9**

Source: Western Oromia Metrology Service Center, 2019.

II. Result Tables

Table 1: Malticollinarity test of continuous variables

Continuous variables	**Collinarity statistics**	
	VIF	**1/VIF**
Age of household	1.458	.686
Educational level	1.568	.638
Household size	1.048	.954
Farm size	1.118	.894
Farming experience of household	1.319	.758
Number of institution or organization household's membership	1.069	.936
Market distance	1.033	.968

Table 2: Malticolinarity test of dummy/category variables

	gender	agroeco	percc	exnfrq	far2far	ccinfo	crdserv	nonoff
gender	1.0000							
agroeco	0.4012	1.0000						
percc	-0.1134	-0.0501	1.0000					
exnfrq	0.2254	0.1030	-0.1737	1.0000				
far2far	0.2355	0.1213	-0.2610	0.3862	1.0000			
ccinfo	0.0712	0.0274	0.2383	0.0066	0.0891	1.0000		
crdserv	0.2203	0.1146	-0.1731	0.5068	0.4187	0.0658	1.0000	
nonoff	0.0747	0.0534	-0.0749	0.3264	0.4005	-0.0164	0.3370	1.0000

Table 3: Correlation matrix of adaptation strategies

	ICV	SW	PST	AHD
ICV	1.0000			
SW	0.6009*	1.0000		
	0.0000			
PST	0.0995	-0.0915	1.0000	
	0.0535	0.0759		
AHD	-0.2080*	-0.2071*	0.2205*	1.0000
	0.0000	0.0001	0.0000	

Table 4: Joint probability of success or failure prediction of adaptation strategies

Variable	Obs	Mean	Std. Dev.	Min	Max
tecjpr1s	377	.2832744	.3487022	5.75e-14	.9969067
tecjpr0s	377	.0112089	.054936	4.98e-36	.7058759

Table 5: Liner prediction of adaptation strategies options

Variable	Obs	Mean	Std. Dev.	Min	Max
techpr1	377	.4819124	.4283569	.0000243	.9999972
techpr2	377	.6561494	.3315544	.0065271	.9998936
techpr3	377	.8184624	.2338227	.0295678	.999999
techpr4	377	.7611252	.2878514	.0292619	.9999221

Table 6: Correlation of coffee production with rainfall and temperature

		Coffee production (kg)	Rainfall variability (mm)	Temperature variability (^{o}c)
Coffee production	Pearson Correlation	1	-.248	-.191
	Sig. (2-tailed)		.520	.623
	N	9	9	9