ADOPTION OF CLIMATE SMART AGRICULTURAL TECHNOLOGIES AND DETERMINANTS CHOICE OF ADAPTATION STRATEGIES TO CLIMATE VARIABILITY IN MIDHEGA TOLA DISTRICT, EASTERN ETHIOPIA

MSC THESIS

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ADOPTION OF CLIMATE SMART AGRICULTURAL TECHNOLOGIES SMALL BY HOLDER FARMERS AND DETERMINANTS CHOICE OF ADAPTATION STRATEGIES TO CLIMATE VARIABILITY IN MIDHEGA TOLA DISTRICT, EASTERN ETHIOPIA

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ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled "**Adoption of Climate Smart Agricultural Technologies and Determinants Choice of Adaptation Strategies to Climate Variability in Midhega** Tola District, Eastern Ethiopia" submitted in partial fulfillment of the requirements for the degree of Master of Science in **Climate Smart Agricultural Landscape Assessment**, Wondo Genet College of Forestry and Natural Resource, and is a record of original research carried out by **Ahmed Abdella** Id. No **MSc/CSAL/R002/10**, under our supervision; and no part of the thesis has been submitted for any other degree or diploma. Therefore, we recommend that the student has fulfilled the requirements and hence can submit the thesis to the Department.

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EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of examiners of the final open defense by **Ahmed Abdella** have read and evaluated his thesis entitled "**Adoption of Climate Smart Agricultural Technologies and Determinants Choice of Adaptation Strategies to Climate Variability in Midhega District, Eastern Ethiopia**'', and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfilment of the requirements for the Degree of Master of Science in Climate Smart Agricultural Landscape Assessment.

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DECLARATION

This is to declare that this thesis work entitled "Adoption of Climate Smart Agricultural Technologies and Smallholder Farmers' Determinants of Adaptation Strategies to Climate Variability in Midhega Tola District" submitted in partial fulfillment of the requirements for the award of the Degree of Master of Science in Climate Smart Agricultural Landscape Assessment to the Collage of Forestry and Natural Resources, Hawassa University, through the Department of Agroforestry is an authentic work carried out by me. All resources of material used for this thesis have been duly acknowledged.

Ahmed Abdella

Signature___________________

Date_______________________

LIST OF ABBREVIATION AND ACRONOMY

CRGE	Climate Resilience Green Economy
CSAP	Climate Smart Agriculture Practices
GDP	Growth Domestic Production
GHGs	Green House Gases
IIED	International Institute for Environment and Development
INDCs	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IRLI	International Livestock Research Institute
NGO	Non-Governmental Organization
NMA	National Meteorological Agency
PCI	Precipitation Concentration Index
SPSS	Statistical Package for Social Sciences
SRA	Standardized Rainfall Anomaly
UNDP	United Nations Development Program
UNFCCC	United Nations Forum for Climate Change Convention

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Abstract:

Title: **Adoption of Climate Smart Agricultural Technologies and Determinants Choice of Adaptation Strategies to Climate Variability in Midhega** *District, Eastern Ethiopia.*

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Agricultural productivity in Midhega Tola is constrained by climate-related risks to include prolonged dry seasons, more frequent and intense drought, increased incidence of pests and diseases. As agricultural adaptation strategies, Climate-smart agriculture technology (CSA) is proposed to transform and reorient agricultural systems to support mainly food security under climate change and variability. The current study assessed climate variability and trends, CSA technologies under adoption by smallholder farmers and the factors that influence their adoption decision in the study area. Primary data was collected through multistage sampling technique to select sample farm households and kebeles. Both quantitative and qualitative data were collected through household survey using semi-structured questionnaire, focus group discussion and key informant interview. Multinomial logit model was employed to identify factors that influence smallholder farmers' decisions on adoption of CSA technologies in the study area. Eighty percent of the sampled households made attempts to adapt at least one of CSA practices like agronomic practice, SWC, integrating crop with livestock, and rainwater harvest. Accordingly, the SWC and integrated crop with livestock practices were adopted dominantly in the area, while rainwater harvest was scant. The result of the MNL model indicated that ownership of livestock, income, access to weather information, and education level of household head have positive influence on the adoption of CSA practices, while the gender and age of household held showed significant and negative correlation with the adoption of CSA practices. Therefore, encouraging the practice-based education program (adult education) for local farmers, improving access to credit, market services and enhancing institutional linkages between Research, Extension and Meteorology service is critical for dissemination of weather information which would aid in decision-making as to when farm operations would be carried out for improved agriculture productivity and production in the study area are recommended issues to minimize the climate variability impact.

Keywords:Crop-Livestock Integration, Soil and Water Conservation, Multinomial Logit, & Smallholder Farmers

1. INTRODUCTION

1.1. Background

Agriculture is the backbone of the Ethiopian economy. The sector is the mainstay for sources of food, fiber, energy, export commodity, livelihood (income) as well as employment. In Ethiopia agriculture accounts for the majority of the People's employment (>73%), more than 40% country's GDP, about 80% export commodity (ATA, 2017; World Bank, 2017). According to (MoFED, 2010) the Ethiopian agricultural lead economy is subjugated by a rainfed and subsistence farming system that plays a central role in the economic development of the country.

The subsistence or rainfed agricultural production system in many developing countries including Ethiopia is constrained by multiple and complex biophysical challenges, like climate change and variability, low soil fertility, pest and disease prevalence (Bekele Shiferaw *et al*., 2014). The Climate change and weather variability have emerged as one of the greatest environmental issues the world facing today (Enete and Musa, 2010; Deepika, *et al*., 2018), particularly for the agriculture sector of developing nations. The agriculture sector is extremely vulnerable to climate change, and variability because of its dependency on local climate parameters like rainfall, temperature, wind storms and natural resources (Katunzi *et al*., 2016). For instance, the sector is sensitive to variations in temperature, precipitation, and occurrence of natural events and disasters such as droughts and floods (Perine, 2015; Pound *et al*., 2018). According to Abrham Belay *et al*. (2017) and Gbegbelegbe *et al*. (2017), the SSA agriculture is naturally vulnerable to climate change-induced risks due to its dependency on highly volatile rainfall in volume and distributions. Like most African countries, Ethiopia is frequently identified as a country that is highly vulnerable to climate variability and change because of the country's agriculture sector is rainfed Georgis (2015), which characterized by less inputs, low-output and subsistence production system EPCC (2015), that resulted in the sector to be affected by climate change (Adugna Tafesse *et al*., 2016; Abayineh Amare and Belay Simane, 2017). This is mainly due to the subsistence nature of Ethiopian agriculture, its mere dependence on rainfall Solomon Asfaw *et al.* (2015), and low level of technology adoption (Sisay Diriba, 2017).

The climatic impact on agriculture is manifested by increasing incidence of floods, droughts, unpredictable rainfall, temperature variability, as well as pest and diseases outbreaks that negatively influence agricultural production, productivity, and quality and resulted in food shortage and famine in the past and continue to pose a serious threat to economic development of developing nations (Abayineh Amare and Belay Simane, 2017; Khanal, 2018; Wakjira Tesfahun, 2018). Drought is one of the most significant climate-related natural hazard which periodically affects Ethiopia and greatly menacing the agricultural sector and livelihoods of rural households as well as the economic growth of the country (FAO, 2010; Lautze *et al*., 2003).

Due to less institutional, low income (low level of economic and social development), low adaptive capacity, limited infrastructure, less technologies availabilities which intermingled with fragile ecosystem in high land NMA (2007), UNDP (2011) as well as highly degraded land in semi-arid and arid part of the country Temesgen Tadesse *et al*. (2009), Ethiopia is highly vulnerable to changing climate. However, nature and magnitude of the impacts are vary depending on the local socio-economic, geographic factors, and on how well individuals and communities prepared and their ability to adapt to climate variability and change (Andrieu *et al*., 2017).

Patently, in the absence of effective adaptation, serious climatic events will consequence in the welfare loss of a large number of people in the developing world (Nelson *et al*., 2009; Yibekal Abebe *et al*., 2018). Therefore, agricultural adaptation is an essential strategy to enable smallholder farmers to cope with the adverse effect of climate change and variability which in turn increases the agricultural production of the farm households (Mahmud Yesuf *et al*., 2008). **Adaptation is** defined as "a process of adjustment to actual or expected climate and its effects" (IPCC, 2014). An adjustment here is interpreted as any change carried out by households, communities, governments or NGOs in managing resources to respond to climate change and reduce the impacts (Smit and Pilifosova, 2003; IPCC, 2011). Henceforth, to lessen the challenge posed by climate change and variability, agriculture has to become "climate-smart", which sustainably increase agricultural productivity (farm incomes), adaptive capacity and build resilience to climate change, as well as reduce or remove greenhouse gases (GHG) emissions (Raghuvanshi *et al*., 2018). Recently, Climate-smart agriculture is emerging as a solution to transform and reorient agricultural systems to support food security in changing climate (Andrieu *et al*., 2017).

As adaptation option to climate variability, smallholder farmers were practicing different CSA based adaptation strategies to reduce the impact of climate-related risks in the study area and Ethiopia generally either of traditional and modern ways (Melaku Jirata *et al*., 2016). There are anumber of CSA practices and technologies excuting by smallholders farmes as adaptation to climate change and variability in Midhega Tola area. This traditional knowledge-based CSA practice needs to be documented and tapped in order to develop sustainable and appropriate CSA technologies for the study area and country generally (Menale Kassie *et al.*, 2010; Melaku Jirata *et al*., 2016). There is limited empirical evidence of smallholder farmers' perception toward climate-smart agriculture technologies from the climate change point of view, agroecology specific adopted CSA practices, and factors affecting the adoption of technologies in Ethiopia and study area in general. Therefore, this paper was to generate empirical evidence on farmers' perception toward climate change and climate-smart technologies, CSA practices adopted in Midhega Tola as adaptation strategies to climatic variability as well as factors that hinder the adoption of CSA practices.

1.2. Statement of the Problem

Agriculture is one of the basic pillars in economic development especially for the developing world including Ethiopia. The agriculture contribution to the Ethiopian national economies through the food supply, employment creation, export earnings, are enormous (CSA, 2005; FAO, 2006), but it is predominantly rainfed and subsistence forms which highly vulnerable to climate variability. Accordingly, due to current unstable weather conditions (climate variability), many smallholder farmers have suffered from frequent drought or too much rain (floods) which leads to crop damages, and consequently affects agricultural productivity (Zighe, 2016; Khanal, 2018). Many Ethiopian's smallholder farmers are vulnerable to climate change Andrieu *et al*. (2017) disproportionally, it is acute in the dry lands where land degradation, depleted soil fertility, water stress, high climate variability, and expanding weeds outbreak that contribute to low crop yields (Zougmoré *et al*., 2014). Therefore, local farmers, policymakers and development practitioners must continually strive to find local specific appropriate technologies that provide households with greater resilience and the ability to adapt to changing climatic conditions (Tachie *et al*., 2013).

According to information obtained from MTANRO (2017) in district agricultural production is frequently influenced by climate-related shocks particularly concurrent drought, Striga and Perthinium weeds prevalence, and crop-livestock disease outbreak.

Adoption of adaptation strategies therefore, remains an imperative option to mitigate against the effect of climate change and also address its challenges prevailing on agriculture production (Temesgen Tadesse *et al.*, 2008; Di Faclo *et al*., 2011).

Despite Midhega Tola Woreda highly experienced with climate variability such as late-onset and early termination, less amount of precipitation and erratic pattern of precipitation, high intensity of heat for prolonged period of time, and extreme climatic shocks like droughts and adoption of potential CSA practices; the integrating farmers' perceptions of climate change and variability with the observed meteorological data has not been studied in the area. In addition to this, there is no empirical data that substantiate about the local farmers' perception toward CSA practices as adaptation strategies, site-specific adopted CSA technologies, factors that hinder or accelerate the use of a set of potentially risk-reducing climate-smart agricultural practices in Ethiopia and the Midhega Tola area (Melaku Jirata *et al*., 2016). Therefore, this paper was to generate empirical evidence on farmers' perception toward climate change and climate-smart technologies, CSA practices adopted in Midhega Tola as adaptation strategies to climatic variability as well as factors that hinder the adoption of CSA practices. It also fulfills evidence limitation exist at the district level, and similar agro-ecological area on relative topics and identify ground-based factors that holding back the smallholder farmers from implementing practices as well as generate additional information relevant to policy and interventions to address the challenge of climate change and variability in light of variable and uncertain environments.

1.3. Objectives of the Study

1.3.1 General Objective

The general objective of the study is to investigate adoption climate smart agricultural practices and determinants Choice of adaptation strategies to climate variability by smallholder farmers in Midhega Tola District.

1.3.2. Specific Objectives

- To explore farmers' perception on climate variability integrating with observed rainfall and temperature metrological data in MidhegaTola district;
- To assess smallholder farmers' perception toward CSA technologies in the study area;
- To identify the CSA technologies adopted as adaptation strategies to climate variability in the MidhegaTola district ;
- To determine the factors influencing the Choice of adaptation strategies in the study area.

1.4. Research Questions

The study attempted to address the following questions:

- How local farmers' perceived about climate variability and it effects?
- How local farmers perceived CSA technologies with changing climate?
- What kind of CSA technologies are adopted by farmers in the study area in response to climate variability and change?
- What are the determinant factors that influence adoption of CSA practices pursued by farmers in response to climate variability and change in the study area?

1.5. Significance of the Study

The study investigated the smallholder farmers' perception toward climate variability and CSA technologies, locally adopted CSA technologies, and determinate factors as adaptation strategies in Midhega Tola District. It was also attempted to analyze the 35 years temperature and rainfall trends in the area, and climate-smart agriculture practices based on climate change adaptation options and recommending that better attention needs to be given to this issue in the future. Hence, the findings of the study were significantly contributed to understanding the local specific climate trends, adoption status of CSA practices to cope with climate variability in the study area and similar agro-ecologies. As a result, researchers, policymakers, private organizations, local people, government sectors and NGOs which participating in promoting the CSA technologies as adaptation and mitigation strategies, in general, were benefited from the study. The study also listed out the barriers to promote climate-smart agriculture practices (CSA) in the study area. Also, it was used as reference material for similar and related studies concerning the role of climate-smart technologies in climate change adaptation at similar agro-ecologies.

1.6. Scope of the study

Nowadays, the CSA concept has received great attention to addressing climate-induced risks. Because of this, it has been disseminated all over the world especially, in sub-Sahara African countries including Ethiopia with less rate of adoption; where the agriculture sector is highly vulnerable to climate change. In traditional based and modern ways the Midhega Tola woreda farmers have been carrying out different CSA technologies to overcome climate change risks. In addition to this, there is an attempt by NGOs and governments in introducing and implementing CSA practices in the study area. Therefore, this study mainly focused on assessments of the local farmers’ perception toward CSA, the adoption level of the technologies, factors affecting the adoption process as well as analyzed the temperature and precipitation trends of 35 years in the study area.

1.7. Limitations of the Study

The first and most challenging event was the limitation of time and money. The other challenge was the obstacle of meteorological data in the study area because it is not available at Midhega Tola woreda. Thus, the researcher forced to travel about 661 km of distance from the study area to Addis Ababa, NMA two times. The other problems that the researcher faced were a clash of programs held with developmental agents (DAs) and kebele managers to use the enumerators and key informants with that of woredas seasonal training and works. However, it adjusted by postponing the held program to appropriate days. In all these ups and downs, the aforementioned money constraint played a great role in traveling and buying stationaries even the regular salary in the study area stayed for more than a month (up to 33/34 days) due to budget deficit in the District. Even though there are an unmentioned lot of challenges, to be fruitful in the work, the researcher tried to overcome it using different means.

2. Literature Review

2.1. Definition, Concept and terms

This part provided with a wide and deep knowledge of the theoretical, empirical and methodological as well as definitions and review of conceptual terms and issues related to my thesis topic. So this chapter leading to introduce the reader with the ideas Climate Smart Agriculture technologies, factors influencing adoption and its role in coping with climate variability as well as its implication to agriculture-based climate change adaptation similar to other views and practice different parts of our country Ethiopia as well as the world.

2.1.1. Concepts and Terms

Climate change: It refers to a change in the state of the climate that can be identified by changes in the mean, the variability of the properties or regular occurrence of its properties that persists for an extended period, typically decades or longer (IPCC, 2007). While, climate variability: Is defined as differences in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. It could result from natural internal processes within the climate system (internal variability) or from variations in natural or anthropogenic external forcing (external variability) (IPCC, 2001).

2.1.2. Adoption, coping and adaptation to climate change and variability

In most agricultural technologies adoption used when given practices are accepted and continuously practiced in a particular area. Kessler (2006) described adoption as a decision process. He indicated that technology is adopted only when it is implemented continuously in the farmers‘ field and fully integrated into the household farming system. De Graaff *et* *al*. (2008) characterized the process of adoption into three phases, namely: acceptance, actual adoption and continued use.

The coping and adaptation to climate change and variability are closely related and interchangeably used in the context of disaster response except that they have different periods. Accordingly, coping strategies are autonomous, short-term, location-specific actions and adjustments targeted against a certain hazard and activities that take place within existing structures Ashton (2002) and Ashraf and Routray (2013) whereas, the adaptation defined as “the process of adjustment to actual or expected climate and its effects from short to long terms (IPCC, 2014). According to UNDP (2005), it is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented. An adjustment here is inferred as any change carried out by an individual, households, communities, governments or NGOs in managing resources to respond to climate change and reduce the impacts (Smit and Pilifosova, 2003; IPCC, 2011).

Mitigation: IPCC (2001) defined mitigation as a process of curbing greenhouse gas emissions from human activities, for example emissions from fossil fuels as well as deforestation, with a view to stabilizing greenhouse gas concentration at a safe level.

2.1.3. Climate change Vulnerabilities and Resilience

The net impact of a shock depends not only on the intensity of the shock itself but also on the vulnerability of the system to this particular type of shock. Vulnerability is the propensity or predisposition of a system to be adversely affected by a given shock including climate change (IPCC, 2012; Grist, 2015). It contains different ideas and elements including sensitivity or susceptibility to harm and a lack of capacity to cope and adapt (Grist, 2015).

Resilience: Turner *et al*. (2003) defined resilience as the degree to which an impacted system rebounds or recovers from a perturbation. Climate change impacts necessitate responses and adjustments to the biophysical and social conditions which together determine exposure to climate hazards. These responses may occur in the form of autonomous action or through public as well as private planned, individual and institutional mechanisms.

2.1.4. Concept of Climate-Smart Agriculture Technologies

Climate-Smart Agriculture (CSA) is an approach to guide the management of agriculture with the aim of climate change. The concept was proposed in 2009 and reorganized through inputs and interactions among multiple stakeholders involved in developing and implementing the idea (Lipper and Zilberman, 2018). In response to current and future climate risk, the concept of climate-smart agriculture (CSA) has been developed, acknowledging the need to adapt current farming systems to the impacts of climate-related stresses (Campbell *et al*., 2014; Lipper *et al*., 2014). The CSA concept is emerged as a new approach to ensure food security, increase agricultural productivity and incomes that build resilience to climate change, as well as reduce emissions from agricultural activities (Chandra, 2017).

2.2. Impacts of climate change and variability on agriculture and Livelhoods in Ethiopia

It is bothersome that Africa is especially vulnerable to climate change and variability because large numbers of the population are poor and depend on agricultural activities, which is highly sensitive to climate parameter (rainfall variability and change in temperature) (World Bank Group, 2010). Climate-related pest and disease outbreaks, extreme weather events (droughts, flood, heat stress, storm etc.,) and altered crops growing seasons are already undermining many farming communities; particularly, subsistence farmers in the tropics are front lines for climate change risks, with limited resources access to mitigate the disruptions(Khan and Akhtar. 2015). Some of the adverse impacts of climate variability and change in agriculture include loss of crop and livestock production through a reduction in crop and livestock yield and productivity is already occurred (Traore *et al.*, 2013). Accordingly, changing in the one climatic parameters has negative impacts on agricultural production and allied sectors (Deepika, *et al*., 2018), for instance, changes in precipitation patterns Barnard, *et al*. (2015) and Nelson, *et al*. (2009) increase the crop failures, production declines and favor for the growth of weeds and the proliferation of crop pests. Rising temperature, declining and erratic rainfall, more recurrent extreme weather events and complex severity of pests and diseases are among the drastic changes that influencing food production (Parry *et al.*, 2007; Kotschi 2007; Morton 2007; Brown and Funk, 2008; Lobell *et al.*, 2008).

Like as other developing world, Ethiopia is a poor country and its economy is highly depending on agriculture which had failed to meet the growing food demand due to the negative effect of climate changes on agricultural sector (World Bank, 2007). According to Mahmud Yesuf *et al*. (2008), Ethiopia as one of the countries the most vulnerable to climate change with the least capacity to respond. Indeed, Ethiopia has experienced at least five major national droughts since 1980, along with literally dozens of local droughts. Moreover, According to Temesgen Tadesse (2007) Ethiopian agriculture sector is negatively affected by climatic related disasters like drought and flood being the major.

African development report (2010) indicate that, there is a strong relationship between weather condition and Ethiopia's economic growth performance. A change of 1% in average annual rainfall is linked with a change of 0.3% in real Gros Domestic product in the following year. This has a clear suggestion for the impacts of climate shocks on smallholder food security in the country. Mostly climate change has the possibility to challenge sustainable development, enhance poverty and delay the realization of the millennium development goals (IPCC, 2007).

2.3. Farmers perception on climate change and variability

Awareness or having knowledge about climate change is a pre-condition for mitigating or adapting to its adverse effects (Maddison, 2006; Juana *et al.*, 2013). Different empirical studies indicated farmers' perception about climate change. Gandure *et al.* (2012) revealed that farmers in South Africa have perceived increase in temperature, and indicated that summer temperatures were warmer while winter temperatures were colder. According to Juana *et al*. (2013) studied on farmers' perception and adaptation to climate change in sub-Saharan Africa using a survey date from farmers. The finding revealed that most of farmers in sub-Saharan Africa are aware that the continent is getting warmer, and precipitation or rainfall patterns have changed. Acquah-de Graft and Onumah (2011) also analyzed perceptions of climate change in western Ghana, the majority of the farmers in the study area perceived an increase in temperature and decrease in precipitation. Mandleni and Anim (2011) also pointed out that about 86% of pastoralist in the eastern cape of South Africa were aware of the increase in temperature pattern and that weather conditions in the province was dominated by drought. Moreover, a study conducted by taking samples from Benin, Burkina Faso, Ghana, Niger and Togo indicated that most of the respondents reported a decrease in rainfall, change in rainfall pattern with delayed rains and early cessation and a significant increase in temperature characterized by an increase in the number of hot days (Akponikpè *et al.*, 2010).

Apata *et al.* (2009) and Sofoluwe *et al. (*2011) also analyzed arable food crop farmers' perceptions about climate change and adaptation strategies in southwestern Nigeria and the results of the study indicated that about 89% of the farmers perceived a significant increase in temperature, 72% perceived higher evapotranspiration rates, 68% indicated that there has been violent rain and hailstorms and 65% experienced delayed rainfall and early cessation. Generally, the farmers have experienced increased pests and crop diseases, increased crop water requirements, leading to crop failures, reduced crop production in countries or regions where arable farming is predominant (Gbetibuou, 2007; Nzeadibe *et al.*, 2011; Gandure, 2012).

2.4. Farmers Perception on Adaptation Strategies

To enhance policy towards tackling the challenges that climate change poses to farmers, it is important to understand local farmers' perception on climate change, their potential adaptation measures, as well as factors which affecting adaptation to climate change. In developing countries farmers use different adaptation strategies to reduce the impact of climate change in different ways including changing crop variety, changing planting dates, mix crop and livestock production, decrease livestock, moving animals/temporary migration, change livestock feeds, soil and water management, planting trees, change from livestock to crop production, change animal breeds, planting short-season crop, and irrigation/water harvesting are among some of the several strategies available to enhance social resilience in the face of climate change (Bradshaw *et al.*, 2004).

As adaptation strategies to changing climate most farmers in sub-Sahara Africa, especially those in regions with reduced precipitation have perceived the switching from planting high water-requirement to low water-requirement crops to overcome drought occurrence (Nhemachena & Hassan Rashid, 2007; Mahmud Yesuf *et al.*, 2008; Temesgen Tadesse *et* *al.*, 2008; Gandure *et al.*, 2012). Likewise, farmers in many developing countries including Ethiopia have been recognized various CSA practices including switched to planting diversified crops, changed planting dates to correspond to the change in the precipitation pattern, planting tree crops, mixed cropping and livestock rearing as well as participate in off-farm income-generating activities to counterattack the climate events (Kurukulasuriya and Mendelson, 2006; Maddison, 2006; Temesgen Tadesse *et al.,* 2008; Mertz *et al.,* 2009; Fosu-Mensah *et al.,* 2010; Sofoluwe *et al.,* 2011; Gandure *et al.,* 2012; Seid Sani *et al*., 2016). Accordingly, farmers in southern Africa and parts of East Africa, where most countries are water-stressed, have developed water conservation methods such as water harvesting, wastewater re-use in agriculture and crop irrigation Gbetibuou (2009), Nyanga *et al. (*2011), and Gandure *et al. (*2012) while farmers in West Africa, where most countries experience short intensive rainy season plant short duration crops, practice upland farming (as opposed to swamp farming) and soil conservation methods (De Wit, 2006; Sofoluwe *et al.,* 2011). CSA water management practices perceived to achieve stability of crop production by maintaining soil conditions close to optimum for crop growth in SSA (Harvey *et al.*, 2014).

According to Temesgen Tadesse *et al*. (2009) and Nhemachena and Hassan Rashid (2007) there are different CSA practices adaptation strategies like changing crop variety, changing planting date, mixed crop and livestock production, planting trees, soil and water management, and irrigation/water harvesting perceived and implementing as response to climate variability in SSA including Ethiopia.

Yibekal Abebe *et al*. (2013) study examined smallholder farmers' about climate change, types of adaptation strategies, factors influencing adaptation choices and barriers to adaptation Eastern Hararghe Zone, Ethiopia. The result revealed that planting trees, early planting, terracing, irrigation and water harvesting CSA adaptation options were perceived and practicing as an adaptation to climate-induced risks in eastern parts of Ethiopia.

2.5. Adoption of Climate-Smart Agriculture Technologies as Adaptation Strategies

The climate change impacts on every developing nations particularly agriculture sectors needs the adaptation efforts. Empirical evidence recognizes that adaptation to climate change can potentially reduce its adverse effects, protect the livelihoods of poor farmers and reinforce any potential advantages it may bring (Gandure et al., 2013; Wheeler et al., 2013).

It improves farmer resilience through stabilizing yields and reducing exposure to the impact of climate-related risks (Schaafsma and Bell, 2018). CSA technology has three inter-related objectives, where the first two objectives are emphasized in low-income situations (1) Food security, sustainably increasing crop yields and productivity and improving farmer incomes (2) Improving adaptation and building farmers' resilience to climate change and (3) Improving mitigation (when and where possible): reducing and/or removing greenhouse gas emissions (FAO, 2013; Schaafsma and Bell, 2018).

Actually, climate-smart agriculture technologies seek to maximize benefits and minimize negative trade-offs across the multiple objectives that agriculture is being called on to address: food security, development, climate change adaptation, and mitigation (FAO, 2013). According to the World Bank's definition, 'climate-smart' refers to a transition to low-carbon growth, besides, to enhance development and reduces vulnerability (World Bank, 2009a). It is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change (FAO, 2013). In a broad terms the CSA practices involves the implementation of a wide array of technologies, practices or actions, including conservation agriculture

Branca *et al*. (2011b), Jat *et al*. (2014) and Sapkota *et al*. (2015), improved pastoral and grazing, and more resilient food crops and risk insurance Boto *et al*. (2012) and Nyengere (2017), diverse on-farm practices such as agronomy, agroforestry, livestock, water and soil management, drought and flood-tolerant varieties of crops, livestock breeds, weather forecasting and early warning systems, integrated crop-livestock management and renewable energy systems (Thorn *et al*. (2016), Bryan *et al*. (2013) and Taneja *et al*. (2014), use of improved seeds and agriculture insurances are considered as climate-smart because it help to cope with extreme climatic events (Vermeulen *et al*., 2012b; Altieri and Nicholls, 2013).

2.6. Factors constraining Farmers Choice of Adaptation Strategies

Understanding how farmers perceive changes in climate and what factors shape their adaptive behavior is useful for adaptation research (Mertz *et al*., 2009; Weber, 2010).

According to study conducted by Waithaka *et al*. (2007), Diale (2011) and Sanga *et al*. (2013) indicate several factors influence farmers' ability to adapt the CSA practices including; availability and access to resources such as land, labor and financial capital, biophysical environment, potential benefits to be accrued vis-à-vis other practices Campbell *et al*. (2012), skills and information they have to use it, ability to cope with challenges that might arise during or after using the practices and compatibility, attributes of new technologies with local social and cultural practices (Hassan *et al*., 2008; Temesgen Tadesse *et al*., 2009).

Not only this adoption of the CSA practices also affected by local policies, institutional and social structures and processes. For instance, according to a study conducted in Nepal, indicate most local governments and communities have limited knowledge and capacity to adapt to the impacts of climate change (Nyengere, 2017).

According to Aemro Tazeze *et al*. (2012) studied on identify the determinants of farmer's choice of adaptation strategies to climate change in the Babile district of Eastern Ethiopia. The multinomial logit analysis reveal that that sex of the household head, age of the household head and education of the household head, family size, livestock ownership, household farm income, off-farm income, access to credit, distance to the market center, access to farmer to farmer extension, agro-ecological zones, access to climate information, and extension contact have a significant impact on climate change adaptation strategies. Not only this but also access to credit is another important determinant enhancing the adoption of various technologies (Tizale Chilot, 2007). Distance from market favors planting different crop variety as an adaptation strategy possibly because households located far from market centers are likely to plant crops of different varieties (Bryan et al., 2011). According to Aemro Tazeze et al. (2012) and Wondimagegn Tesfaye, and Lemma Seifu (2016), male-headed households are more likely to plant different crop varieties as a climate change adaptation strategy. Many studies have confirmed that having better access to extension services increases the probability of adopting different adaptation measures (Aymone, 2009; Temesgen Tadesse *et al*., 2009).

Aemro Tazeze *et al.,* (2012) showed that the sex of the household head, age of the household head, education of the household head, family size, livestock ownership, household farm income, off-farm income, access to credit, distance to the market center, access to farmer-to-farmer extension, agro ecological zones, access to climate information, and extension contact have a significant impact on choices of climate change. In addition, Belaineh Legesse *et al.,* (2013) identified that sex, plot size and frequency of extension contacts have a significant and positive impact on crop-based diversification coupled with soil and water conservation practices while family size, off-farm income and training have significant negative impacts.

Generally, drawing on existing literature the limiting factors of adoption of the CSA practices and technologies' summarized as socio-demographic, institutional factors, farm characteristics, economic factors, characteristics of the technology and system of information transmission (FAO, 2017; El Bilali and Allahyari, 2018; Taylor, 2018).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

Midhega Tola district, shown in Figure 1, is one of administrative unit in East Hararge Zone of Oromia regional state and it located 56 km to the South of Harer town and 611 km distance from Addis Ababa. It is divided in to 18 rural kebeles and one urban kebele (the smallest administration unity in Ethiopia) administrations and is located in the range of $8^0$30'0'' to 9^0'0'0''N latitude and $42^0$0'0' to $42^0$30'0'' E longitudes. The district borders with Fedis district in the North, with Babile district in the northeast, with Gurawa district in the West, with Meyu Muluke in southwest, and with Somali regional state in the East and southeast.

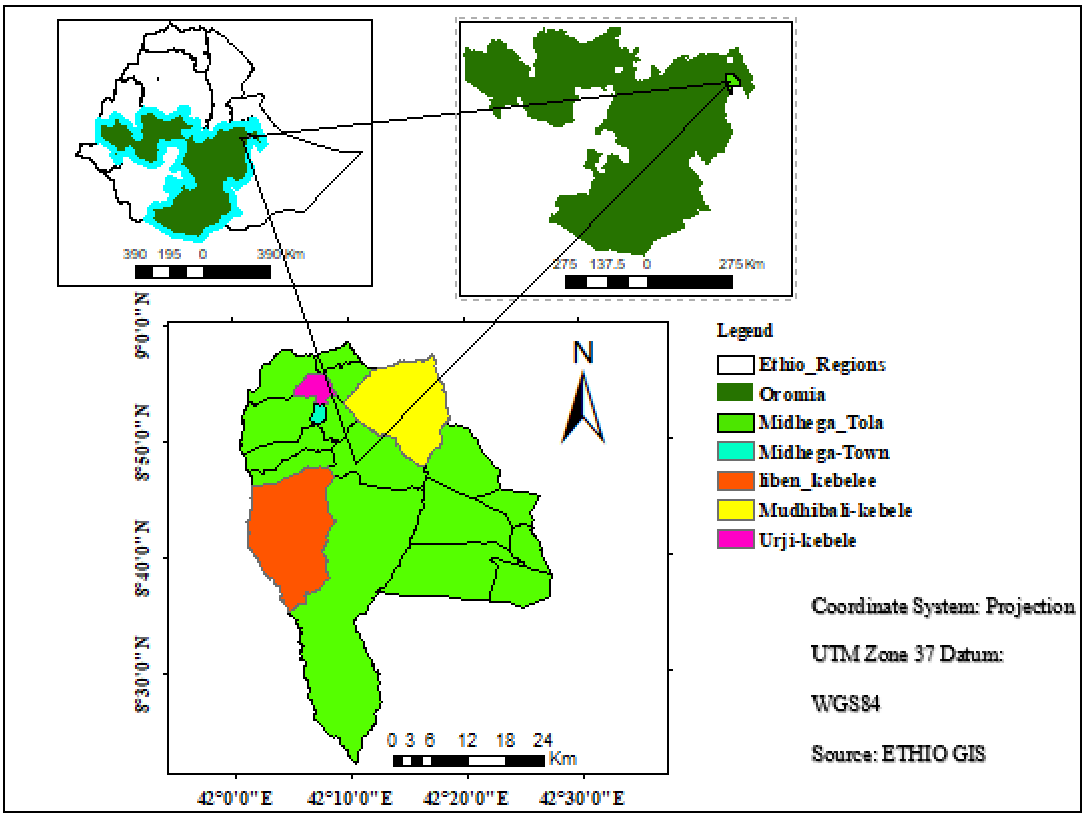

Figure 1: Map of Midhega Tola District.

3.1.2. Climate, topography and soils

The district's temperature ranges between 15.5 and 32°C, while annual rainfall varies between 500 and 800 mm. The area has four distinct seasons including the dry season (locally known as Bona) (December to February), the short rainy season (locally known as Badhessa) (March to May), the main rainy season (locally known as Ganna) (June to of September), and the autumn season (locally known as Birra) (September to November) (MTANRO, 2017). Topographically, the district is slightly undulating especially in the midland and almost flat in the lowlands area that account for about 85% of total land cover whereby the total land area falls within altitudinal ranges of 870 to 1535 m.a.s.l whereas 15% of total land cover is midland (Woinadega) 1536-1856 m.a.s.l (MTLAO, 2016). Some parts of the low land in the district are slightly covered by natural bush and shrub. The type and texture of the soils of the study area vary to a great extent across agro ecologies. Those kebeles that are located in Kolla agro-ecology are dominated by Regosols and Regosols Arenosols association, Lithosols, Vertic Luvisols, Ranker while, those in the Woinadega (mid-altitude) are dominated by Regosols, Acrisols, Cambisols, Lluvisols, Nitosols are the major soil types found in Mdhega Tola woreda (MTANRO, 2017).

3.1.3. Demography

The total population of the District was 103453 out of which 51.4% were males and 48.6% were females. 15,574 men-headed and 2814 female-headed summed to 18,388 households reside in Midhega Tola. The average family size is 5 per household. The annual population growth rate is estimated at 2.85% (MTFEDO, 2017) while the national average is 3%. The age distribution of the woreda is characterized by a higher proportion of young (0-14) and a low proportion of old age (above 65), reflecting a higher fertility rate. Regarding religious composition, 99.75% of the populations are Muslims and 0.25% of the populations are others. The Major ethnic group of the woreda is Oromo, which represents 98.5% of the population and 1.5% are others (MTFEDO, 2017).

3.1.4. Livelihood strategies and socioeconomics

The main income sources of the community in the district are from of crops and livestock productions. Crop production is 100% dependent on the rain-fed system. Sorghum, finger millet, groundnut, sweet potato, in lowland area and maize, sorghum, chickpeas , haricot beans, chat are major crop grown in study area . Households have also been found to pursue additional livelihood options whereby 2.6% sell firewood, 3% involve in manual labor, and 1.3% work on petty trading. The average landholding in Midhega Tola woreda is 1.5 hectares per household. 37.4% of HHs own 0.51 to 1 ha, 26.7% own 1.51 to 2.5 ha, 21.3% own 1.1 to 1.5 ha and 14.6% own 0.26 to 0.5 ha of land (MTANRO, 2017).

3.2. Sample Size and Sampling Design

Data collection was conducted following a multi-stage stratified random sampling procedure in order to increase the reliability and validity of the data; where a combination of purposive and random sampling procedures used to select districts, Kebeles, and household samples respectively. At the first stage Midega Tola District is purposively selected taking into consideration the fact that the district suffers from frequent drought, climate-induced risk and researcher interest. In the Second stage, Woreda's kebeles were stratified into two agro-ecological zones namely dry Woinadega (mildand) and Kolla (lowland) based on the agricultural production system, potential of CSA practices, climatic condition (temperature and moisture concerns), soil condition, latitude, and socio-physical setting. Then three kebeles (Urji) from Woinadega, (Mudhibali and Liben) from Kolla were selected. These kebeles were selected randomly using lottery method. The purpose of analysis in relation to agro-ecological differentiation is to investigate how farmers living in different agro-ecologies perceive, and adapt climate change via CSA practices and how different agro-ecologies are affected by climate change and variability. The researcher has adopts Yemane Formula, (1967) for determining sample size as follows.

$$n = \frac{N}{1+N(e^2)} \text{ ……………………………Equation (1),}$$

Here, n designates the sample size the research uses; *N* designates total number of households heads; *e* designates maximum variability or margin of error **7**%; 1 designates the probability of the event occurring. Because of heterogeneous population existence in rural area farmers in each kebele further categozed as better-off, medium, and poor with the help of key informants based on wealth status, household profile in terms of their potential adaptation strategies on their farm, experiences, assets and income levels, thus related to capabilities, resilience to shocks, land size and other socio-economic parameters. Finally**,** based on the sampling estimation made 179 farm households were selected by simple random sampling technique out of the total 1505, proportion to population size to each kebele. A list of household heads were used to frame out sample household of each kebele was taken from woreda agricultural office.

3.3. Method of Data Collection

For this study, both primary and secondary data were collected from various sources. The primary data was collected through a household survey using semi-structured questionnaire survey, focus group discussions (FGDs), and key informant interviews; while secondary data were collected through review of official archived documents (reports) of the various government offices and NGOs working in the district, and other published and unpublished materials. Rainfall and temperature Gridded data of 35 years

(1983 to 2017) was obtained from the National Metrological Agency (NMA) based on data collected through the metrological stations found in neighboring districts of Fedis and Babile (Bisidimo), that are 24 and 17km far from the study area respectively.

3.3.1.Household survey

The data was gathered at the household level on socio-economic, household characteristics, types of CSA adopted, sources of income and livelihoods, agriculture production, HHs perceptions toward climate variability and CSA technologies as climate change adaptation strategies as well as major constraints in the study area. Interviews and discussions were based on a checklist of topics or questions prepared in English and then were translated to the local language. Before the actual survey, the questionnaires were tested in none selected kebele (Lenca kebele) on five farmers and then for data collection, enumerators were trained on the ways they approach the respondents and execute the interviews. The interviews and discussions were held in Afaan Oromo directly by the investigator and thus data were gathered technically by speaking to the participants and accessible informants on an informal base to maximize the source of information.

3.3.2. Focus Group Discussion (FGD)

Focus group discussion (FGD) is a group discussion that provides an opportunity to discuss thoroughly on the desired topics (Kothari, 2010). The goal of the FGD was to gather insights on aspects of research themes that cannot be addressed by household surveys; and also to triangulate the information generated through households' survey. Accordingly, the researcher purposively identified women association leaders, elders, and DAs from each of the selected kebeles for FGD with the help of kebele managers. A total of six FGDs and two per kebele comprising 18 participants were conducted. The participants of the FGD were long-time resident of kebeles of the study area and well-informed about local climate variability and CSA practices with represents both men and women.

3.3.3. Key Informants Interview (KII)

In order to explore farmers local knowledge on adoption and perception of CSA practices, a key informants (KII) were identified and interviewed in each kebele based on prepared open ended questionnaires. The selected individual farmers and experts who could identified key informants (KIIs) were used by snow ball method were employed (Bernard, 2002). As the sampling method used was an adaptation of snowball sampling which was defined as a technique for key informant fined for research subjects in which one subject gives the researcher the name of another subject who in turn gave the name of another (Vogt 1999). For this study local elders (Abba Gadaa), woreda agriculture office experts, and local NGO practitioners were selected for key informant's interview (KII) in order to get reliable data on local farmers' perception toward climate variability, adoption level of CSA, smallholders farmers' perception on climate change effects and CSA technologies as adaptation strategies with climate variability in the study area with the help of selected kebele managers and member of FGD. This interview was conducted with those who are knowledgeable (well know about socioeconomic background of interviewed HHs, local climate pattern), and lived in the community for a long period of time as well as experienced about the locally adopted CSA practices. Accordingly, a total of six persons for key informants' interview, and three from kebele and three from woreda's agriculture office (two senior experts) and a local NGO practitioner were selected. It was used as a method for triangulation, validation and verification of data collected through aforementioned methods.

3.4. Method of Data Analysis

In this study, both qualitative and quantitative techniques were used. In order to analyze and present the quantitative data collected from sampled households, and national metrological agency, the descriptive statistics, inferential tests such as Chi-square test and independent T-test were used. Furthermore, in order to compare the differences among groups for different socioeconomic and demographic variables. Indeed, the qualitative categorical types of data generated from focus group discussion and key informant interviews were analyzed using frequency and Chi-square test, while quantitative continuous types of variables were analyzed using independent T-test.

The Coefficient of Variation (CV), the Precipitation Concentration Index (PCI), and the Standardized Rainfall anomaly (SRA) was used as statistical descriptors of rainfall variability (Bewket and Conway, 2007; Dereje Ayalew *et al*., 2012; Hadgu *et al*., 2013). The coefficient of variation allows us to detect the degree of rainfall and temperature variability. It was calculated as follow:

$$CV=\frac{\sigma}{\mu} \text{ .... (Equation 2)}$$

Where: σ=Standard deviation over the observation period and μ=long term mean over the observation period.

According to Hare (1983), CV is used to classify the degree of variability of rainfall events as less, moderate and high. When CV<20% it is less variable, CV between 20% and 30% is moderately variable, and CV>30% is highly variable. In order to study distribution of rainfall of annual rainfall amount in the study area, Precipitation Concentration Index (PCI) was used (Luis *et al*., 2000), which is a modified version of (Oliver, 1980). This index was described as:

$$PCI_{Annual} = \sum_{i=1}^{12} P_i^{\,2} / \left(\sum_i^{12} P_i\right)^2 \quad X\ 100 \text{ .... (Equation 3)}$$

Where, Pi is the rainfall amount of the ith month and Σ = summation over the 12 months of the annual PCI. PCI values of <10 indicate uniform annual distribution of rainfall in the year, values between 11 and 20 indicate high concentration that denote annually in rainfall distribution, and values above 20 indicate very high concentration or variability (Oliver, 1980). Inter-annual variability was assessed using Standardized Rainfall Anomalies (SRA) for rainfall with respect to the long-term normal conditions for a specific time scale. The SRA were calculated and graphically presented to examine the nature of rainfall trend and also to determine dry and wet years in the study area over the period of observation (Agnew and Chappel, 1999). It is described as:

$$Z = (Pt - Pm)/\sigma \quad \textbf{(Equation 4)}$$

Where, Z is standardized rainfall anomaly, Pt=annual rainfall in year t, Pm=long-term mean rainfall over the observation period (1983-2017) and $\sigma =$ standard deviation of rainfall over the period of observation.

To analyze trends of rainfall and temperature over the past 35 years (1983-2017), MAKESENS Version 1 Mann-Kendall trend test software was used. The basic principle of Mann-Kendall (Mann, 1945; Kendall, 1975) test for trend involves the examination of the sign of all pair-wise differences of observed values. The Mann-Kendall test is based on the statistic S. Each pair of observed values xj, xk (k> j) of the random variable is inspected to find out whether xk>xj or xk<xj. The test statistic for the Mann-Kendall test is given as:

$$S=\sum_{k-1}^{n-1}\sum_{j}^{n} = k + 1 \ \text{sign}\,(x_j - x_k) \quad \text{(Equation 5)}$$

Where xj and xk are the sequential data values and j <k, n is the length of the data set and

$$\text{Sign}\,(xj - xk) = \begin{cases} 1 \text{ if } Xj\text{-}Xk>0 \\ 0 \text{ if } xj\text{-}xk=0 \\ -1 \text{ if } Xj\text{-}Xk<0 \end{cases} \quad \text{(Equation 6)}$$

The Mann-Kendall test has two parameters that are important for trend detection. These parameters are the significance level that indicates the strength of the test and the slope magnitude estimate that indicates the direction as well as the magnitude of the trend. Given the null hypothesis that xj are independent and randomly ordered, the statistic S is approximately normally distributed when $n \geq 8$, with zero mean and variance (Capodici *et al*., 2008). After computing the descriptive statistics and inferential tests, a multinomial logistic regression model was used to identify determinants of Household's adoption of climate smart agriculture technologies where the dependent variable was found to be unordered a multi-outcome. The data analysis was conducted using Statistical Package for Social Sciences (SPSS) version 22, Stata 15, XLSTAT16, and MAKESENS.1.0.

Econometric data analysis

Multinomial logit (MNL) model was used to analyze the choices the farmers make climate smart agriculture strategies and what factors determine their choices of the technologies. This model suits such type of analysis as it permits the analysis of decisions across more than two unordered categories variables (Wooldridge, 2002). However, the model requires that households are associated with only their most preferred option from a given set of climate smart practices.

The model is specified as follows.

Let Y denote a random variable with values $\{1, 2 \ldots J\}$ for a positive integer J and X set of variables. In this study, Y is a dependent variable and represents the adaptation alternatives (strategies) from the set of adaptation measures, whereas the X represents the factors that influence choice of the adaptation strategies which contains household characteristics as described in Table 1, and $P1$, $P2 \ldots Pj$ as associated probabilities, such that $P1 + P2 + \ldots + Pj = 1$. This tells as how a certain change in X affects the response probabilities $P(y = j/x)$, j

= 1, 2 …*J*. Since the probabilities must sum to unity, *P*(*y* = *j*/*x*) is determined once the probabilities for *j* = 2…*J* are known.

$$P\ y = 1/x = 1 - \ P2 + P3 + \ldots\ldots\ Pj$$ -------------------------------- (**Equation 7**)

The estimation of MNL model for this study was conducted by normalizing one category which is named as “base category” or “reference estate”. The theoretical explanation of the model is that in all cases, the estimated coefficient should be compared with the base group or reference category (Gujarati, 2004). The choice of the reference category was based on empirical, literature and theoretically motivated. The generalized form of probabilities for an outcome variable with *j* categories is:

$$\boldsymbol{p\left(y = \frac{j}{x}\right) = \frac{exp(x\beta j)}{\left[1+\sum_{h-1}^{j} exp(x\beta h), j=1\ .\ ...J\right]}}$$ ------------------------ (**Equation 8)**

Where P stands for probability, J stands for CSA practice options, X for explanatory variables and βj = K x 1 is coefficients, j = 1, 2. . , J. The parameter estimates of the MNL model only provide the direction of the effect of the independent variables on the dependent (response) variable; estimates represent neither the actual magnitude of change nor the probabilities (Green, 2012). Differentiating Eq. (8) with respect to the explanatory variables provides the marginal effect of the independent variable which is given as;

$$\frac{\alpha pi}{\alpha xp} = \boldsymbol{pj[\beta jk - \textstyle\sum_{j=1}^{j=1} pj\beta jk]}$$ …………………………………….. (Equation 9)

Marginal effect of marginal probabilities is the function of probabilities and measures the expected change in probabilities where the choice of particular CSA practice is being made by a unit change of the independent variable from the mean (Greene,2000). The problem of multicollinearity among the explanatory variables was tested using variance inflection factor and Contingency Coefficient for continuous and dummy explanatory variables, respectively. In both cases, no problem of multicollinearity was detected (the value of VIF(less than 10) and contingency coefficient was (less than 0.75). The results of the test indicate the presence of no problem of multicollinearity among the explanatory variables. Since, the VIF for each continuous explanatory variable is less than 2 with mean of 1.51 (appendix Ia). Breusch-Pagan test (hettest of STATA) was conducted to assess the presence of heteroscedasticity in the model (appendix IV).

Then, before data analysis and presentation, the model was tested for the validity of the independence of irrelevant alternatives (IIA) using Suest test procedure that requires the probability of using a certain CSA technology by a given household is independent of the probability of choosing other CSA practices (appendix V). Tests failed to reject the null hypothesis of independence of the climate CSA options, suggesting that the multinomial logit (MNL) specification is appropriate to model climate smart agricultural practices adoption of smallholder farmers.

3.5. Definition of Variables and Hypothesis

Dependent variable: It represents the observable CSA technologies used to cope with the negative impact of climate changes and variability over the years in Midhega Tola Woreda. For the purpose of this analysis, varies CSA practices are combined into five categories including the ‘no adaptation’, category for the convenience of model analysis. In this study because of their close relation (in function), the CSA technologies namely stone bund, soil bund, minimum tillage and terrace are grouped into one single component of SWC measure. Similarly, the processes of collecting, storing and conserving surface runoff for agricultural production and domestic purposes or, use of an on-farm rain water harvesting, run off diverting to farm land and ponds are merged together into rain water harvesting. The use of drought-tolerant crop varieties, crop diversification, early mature crop, crop rotation, intercropping, using improved crop varieties and so on has combined together and categorized as an agronomic practice or management. Lastly, the range land management, improved fodder quality, herd management, livestock diversification, mix crop and livestock, diversifying livestock herds, the choice for animal types and breeds that are better adapted to heat stress and dry conditions that is changing livestock species composition in favor of browsers (e.g. goats and camel instead of cattle), grazing management were grouped as integrating crop with livestock technologies. Generally, no adaptation, agronomic practices, SWC, rain water harvest, and integrated crop livestock are the five CSA technologies options considered as dependent variable of this study. **Independent variable:** Is variable that is responsible for affecting the perception and adoption of certain CSA strategies. It was includes households' characteristic and demographic, environmental, institutional and economic factors which are expected to have associations with the households' adaptation strategies choices. Based on theory, empirical literature of previous findings, researcher's knowledge of the contextual setting and qualitative data were collected from surveys, the 12 explanatory variables were identified and used as determinants factors of the CSA technologies in Midhega Tola District.

Table 1: Variables hypothesized to affect adaptation decisions by farmers in the Study area

Variable label	**Description and measurement**	**Variable type**	**Expected sign**
Agroecology	Takes the value 1 for Woinadega and 2 for Kola	Dummy	+-
Gender	1 for male and 0, otherwise.	Dummy	+-
Age	Age of household head in years	Continuous	+-
Education	Year of schooling of HH's	Continuous	+
Income	HH's annual income in ET birr	Continuous	+
Farm land	Farm land size in Ha	Continuous	+
Extension	1 if access of extension services and 0 otherwise	Dummy	+
Credit	1 if access of Credit services and 0 otherwise	Dummy	+
Market access	1 if access of Market services and 0 otherwise	Dummy	+
Weather info	1 if access of weather information and 0 otherwise	Dummy	+
Family size	Number of people in the household, measured in number	Discrete	+
Livestock	Livestock holding in TLU	Continuous	+

4. Results and Discussion

4.1. Demographic and Socio-economic characteristics of the sample households

The minimum and maximum landholding in the study area was 0.25 and 5ha respectively (Table 2). The survey results in Table 2 showed that the mean year of schooling was 5. Moreover, the survey result revealed that the mean livestock holding of the sampled households in terms of tropical livestock unit (TLU) was 4, the maximum and minimum being 12.16 and 0.75 TLU, respectively (Table 2). An average farm income of the surveyed households was 20527.09 birr per annum. The results in Table 3 indicated that 80% of households were male headed while 20% is female headed. The survey results showed that 75.4 and 65.4% of the respondents were get extension and weather information services respectively Table 3. This shows that the majority of the farmers' share information on climate related issues and important agricultural inputs in the study area. Out of the total sample households surveyed, 41.9% reported that they received credit, whereas 58.1% reported that they did not get credit services (Table 3)

Table 2: Household characteristics of continuous variables

Variables	Minimum	Maximum	Mean	Std. Deviation
Age of household head (Years)	25	66	43.2682	10.13314
Family size	2	10	4.3575	3.07513
Land owned in Ha	0.25	5	1.6053	0.9277
Education status (year of schooling)	0	12+1	5.5642	4.6988
Livestock owned TLU	0.75	12.16	4.0169	2.42213
Income in ETBirr	7500	156200	20527.1	16265.23

Sources: survey data 2019.

Table 3: Household characteristics of categorical variables

Variables		Percentage
Gender of household head	Female	20.1
	Male	79.9
	Total	100
Access to extension	No	24.6
	Yes	75.4
	Total	100
Access to credit	No	58.1
	Yes	41.9
	Total	100
Access to market	No	40.2
	Yes	59.8
	Total	100
Access to weather info (%)	No	34.6
	Yes	65.4
	Total	100

Sources: survey data 2019.

4.2. Farmer's Perception on Climate variability and Its effects in Study Area

4.2.1. Local Farmer's Perception on climate variability

To explore the farmers' perception of climatic parameters over last 15-20 years, the respondents were asked for any observed changes in temperature, rainfall, drought and frequency of flood over the last 5-10 years. The results revealed that most sampled households perceived an increasing of annual temperature (85.5%) and 90% seasonal temperature over the past two decades (Table 4). The result agree with the finding of Hailay Tsigab *et al*. (2019) that report more than 92 and 87% of respondent perceive the rainfall and temperature was changed in Semiarid of Eastern Tigray, Northern Ethiopia. These results agree with finding of Temesgen Tadesse *et al*. (2011), and Taddesse Tesfamariam (2011) who reported that most of the farmers in Ethiopia are aware of the fact that temperature is increasing. According to the research carried out by Nega Debela *et al*. (2015) in relative agroecology of Borana zone of Oromia regional state, reported the majority of (>95%) smallholders agro-pastoralist perceived changes in temperature and rainfall, expressed mainly in terms of patterns in weather experienced; higher temperatures, below normal rainfalls and short rainy seasons, higher frequency and intensity of extreme weather events.

Table 4: Farmers' perception (%) on annual and seasonal temperature variability in Midhega Tola, Ethiopia (N = 179)

	Annual mean Temperature				Seasonal mean Temperature			
	Don't know	Decrease	No change	Increase	Don't know	Decrease	No change	Increase
Not perceived	3	1	5	7	2	1	4	9
Perceived	8	2	7	146	2	5	4	152
Total	11	3	12	153	4	6	8	161
%	6.15	1.7	6.7	82	2.23	3.4	4.5	89.9
Pearson X^2	26.106***				27.515***			
P-value	0.000				0.000			

***Statistical significance at 1% probability level.

Sources: survey data 2019.

Similarly, the result in Table 5 indicated that about 84.4 and 86.6% of the sampled farmers perceive a decreased in the amount and distribution of rainfall of annual and seasonal respectively over the last 10 to 20 years where as 2.2% of the respondents replied an increasing in seasonal precipitation in study area. This in line with the finding of the Yibekal Abebe *et al*. (2013), Alem Kidanu *et al.* (2016), and Hailay Tsigab *et al*. (2019) who reported that the majority of sampled farm households perceived the changed pattern of rainfall in amount and distribution in eastern Hararghe, and eastern Tigray re Ethiopia respectively.

Table 5: Farmers' perception (%) of annual and seasonal precipitation variability in Midhega Tola, Ethiopia (N = 179)

Farmers category	Annual Precipitation				Seasonal precipitation			
	Don't know	Decrease	No change	Increase	Don't know	Decrease	No chang	Increase
Not perceived	1	9	5	1	0	10	5	1
Perceived	5	142	15	1	4	145	11	3
Total	6	151	20	2	4	155	16	4
%	3.4	84.4	11.2	1.11	2.2	86.6	8.9	2.2
Pearson X^2	12.57***				12.623***			
P-value	0.006				0.000			

***Statistical significance at 1% probability level.

Table 6: Perceived effects of climate induced shocks in the study area.

Climate induced risks	Farmer's perception	Agro-ecology		Total	%	Pearson X^2	p-value
		Woinadega(n=64)	Kolla(n=115)				
Crop-Livestock disease	Don't know	1	4	5	3		
	Decrease	14	18	32	18	3.413	0.332
	No change	21	29	50	28		
	Increase	28	64	92	51		
Agricultural production	Don't know	0	1	1	1		
	Decrease	0	5	5	3	3.494	0.322
	No change	7	13	20	11		
	Increase	57	96	153	85		
Water availability	Don't know	2	0	2	1		
	Decrease	2	2	4	2		
	No change	6	11	17	9	4.07	0.258
	Increase	54	102	156	87		
Range land quality	Don't know	0	1	1	1		
	Decrease	1	3	4	2	2.87	0.412
	No change	8	7	15	8		
	Increase	55	104	159	89		

4.3. Observed Climate Variability and Change Trends

4.3.1 Temperature Trends

The accuracy of farmers' perceptions of climate variability was assessed by comparing their perceptions with 35 years observed trends in temperature and precipitation at nearby two meteorological stations of Fedis and Bisidimo. The historical analysis of temperature data (1983-2017) from two stations revealed that both annual and seasonal temperatures in the study areas showed an increasing trend (Table 7). The results in Table 7 indicated farmers' perception on trends of annual and summer temperature was agreed with observed data of both stations. However, it is not consistent with the temperature records during the winter season at Bisidimo station. According to the Mann-Kendall Test and Sen's Slope estimates for the trend of annual data, the mean annual temperature was significantly increased by 0.055 and 0.354°C per year at Bisidimo and Fedis stations respectively (Table 7). In general, an increasing trend in temperature has been observed both during summer and winter seasons in all stations. In Table 8 the Mann-Kendall trend test indicated a significant increasing trend of annual maximum temperature at the rate of 0.453 and 0.585°C in Fedis and Bisidimo station respectively. The annual minimum and maximum temperature showed increasing trends significantly at the rate of 0.228 and 0.45°C in at Fedis station per year respectively (Table 8). This is similar with the study of Solomon Gebrechorkos *et al*. (2019), who reported that the significant increasing trends of annual maximum and minimum temperature in eastern parts of Ethiopia. The result further in line with finding of Melaku Jirata et al. (2016) that was reported the mean annual temperature increased by 1.3°C from 1960 to 2006, in Ethiopia. Similar observations were reported by Belay Tseganeh *et al.* (2013), and Muluken Mekuyie (2017), who reported that an increasing trend of annual and seasonal temperatures in the central Rift Valley and Afar region of Ethiopia respectively. Furthermore, the studies by Daniel Mengistu *et al.* (2014)

in the Upper Blue Nile River Basin, Getamesay Behailu (2018) in Sekota, north-central part of Ethiopia reported a significant increasing trend of temperatures.

Table 7: Annual and seasonal temperatures' trends at Midhega Tola District (1983-2017).

Station name	Annual				Summer				Winter			
	Mean	Sen's Slope	Z	CV (%)	Mean	Sen's Slope	Z	CV (%)	Mean	Sen's Slope	Z	CV (%)
Fedis	98.6	0.354	2.67*	5	26.32	0.1	2.27*	10	22	0.0015	0.17	7
Bisidimo	107.7	0.055	4.8*	2	28	0.049	3.3*	11	20.3	-0.017	-1.48	7.3

*Statistical significance at 5% probability level.

Source: Computed from Data Obtained from NMA (1983-2017)

Table 8: Annual Maximum, Minimum Temperature Trends of Two Stations (1983-2017)

station	**Annual**	**Test Z**	**Sig**	Sen's Slope
Fedis	Minimum	1.73	+	0.228
	Maximum	4.147	***	0.4532
Bisidimo	Minimum	1.023		0.1241
	Maximum	5.87	***	0.585

+, *** =significant at 0.1 and 0.01 level of significances

Source: Computed from Data Obtained from NMA (1983-2017)

4.3.2. Annual and Seasonal Rainfall Variability and Trends

4.3.2.1. Annual and Seasonal Rainfall Variability

The annual rainfall in the study area ranged between 257.56 mm and 868.6mm, Fedis 193 and 871.8mm, with the mean of 607.787mm at Bisidimo and 594.43mm at Fedis, 145.796, and 182.66 standard deviation at Bisidimo and at Fedis station respectively over the study period of 1983 to 2017 (Table 9). Spring (Badhessa) season rainfall varied from 95.36 to 411.5mm at Bisidimo, 103.25 to 417.5mm at Fedis with the mean of 227.36 mm at Bisidimo, 236.32mm at Fedis and standard deviation of 100.34 at Bisidimo, 96.65 at Fedis station respectively. Whereas summer (Ganna) rainy season rainfall ranges between 103.865 and 511.2mm at Bisidimo and 146.9 to 547.8mm at Fedis station with the mean of 464.78 at Bisidimo, 218.8 Fedis and standard deviation of 90.5 and 101.77 at Bisidimo and Fedis respectively (Table 9). Furthermore, the analysis of the coefficient of variation revealed that rainfall in Midhega Tola has shown moderate inter-annual variability at Bisidimo and high at Fedis while high variability on the seasons at both stations (Table 9). Rainfall during Badhessa' season was highly variable (CV=40% at Bisidimo, 46% at Fedis) in the study area. The result also indicated that spring season rainfall has high variability than summer season, suggesting that the Badhessa season was least reliable for rain-fed agriculture. Similarly, PCI analysis has been carried out on annual and seasonal basis and the results showed that very high concentration (Table 9). According to Oliver (1980) and Zamani *et al.* (2018) PCI classification, annual and seasonal, rainfall indicated highly concentration in rainfall distribution in the India. The result was in line with the finds of Temesgen Tadesse *et al*. (2011) which indicated, the high variability in precipitation was observed in the Ethiopia over the last decade.

Table 9: Descriptive statistics of Annual and seasonal Rainfall

Descriptive Statistics	Annual and Seasonal Rainfall		
	Annual	Spring	Summer
Bisidimo Station			
Minimum (mm)	257.56	95.36	103.865
Maximum (mm)	868.6	411.5	511.2
Mean (mm)	607.787	227.36	464.78
Standard deviation	145.796	100.34	90.51
Coefficient of Variation (%)	24	40	34%
Mean PCI (%)	35.1	46.8	51.7
Fedis Station			
Minimum (mm)	193	103.25	146.85
Maximum (mm)	871.8	417.5	547.8
Mean (mm)	594.43	236.32	218.8
Standard deviation	182.66	96.65	101.77
Coefficient of Variation (%)	31	46	41
Mean PCI (%)	36.7	47.7	55.2

Source: Computed from Data Obtained from NMA (1983-2017)

4.3.2.2. *Annual and Seasonal rainfall Trend*

Here also, the analysis of historical precipitation data (1983-2017) from the two station revealed that both annual and seasonal precipitations in the study areas had trend significantly, except at Fedis station where the summer (Main rain season) precipitations were found to have a decreasing trend but not significant (Table 10). Farmers' perception on seasonal and mean annual precipitation was in line with the observed data at two stations (Table 10). The Mann-Kendall test results in Table 10 indicated the annually decreasing rainfall of study area at Bisidimo and Fedis station by 5.56 and 7.36 mm, with moderate variability respectively.

Table 10: Trends of annual and seasonal Rainfall from two stations around the Midhega Tola District

Station name	Annual		Summer		Spring	
	Sen's Slope	Z	Sen's Slope	Z	Sen's Slope	Z
Fedis	-7.36	-2.22*	-0.6	-0.23	-5.04	3.3*
Bisidimo	-5.56	-2.22*	-3.46	-2.56*	-3.51	-2.23

** =significant at 0.05 level of significance

Source: Computed from Data Obtained from NMA (1983-2017)

In Table 10 the Sen's slope estimator indicated that the summer rainfall decreased by 3.46 mm per season at the Bisidimo station with highly variability but, not significant at Fedis station. This result is in line with the findings of Solomon Gebrechorkos *et al*. (2019) that showed annual rainfall decreasing trend significantly in central and eastern parts of Ethiopia. Yilma Seleshi and zanke (2004), found an annual rainfall is highly variable, ranging from less than 200 mm in the southeast, east, and northeast borders to 1200 mm in the central and western highlands and there is no clear trend in the amount of rainfall over time. The result is also agree with Bewket and Conway (2007) and Dereje Ayalew *et al*.

(2012) who reported that the direction and magnitude of the trend in seasonal precipitation in Amhara regional state of Ethiopia varied from station to station.

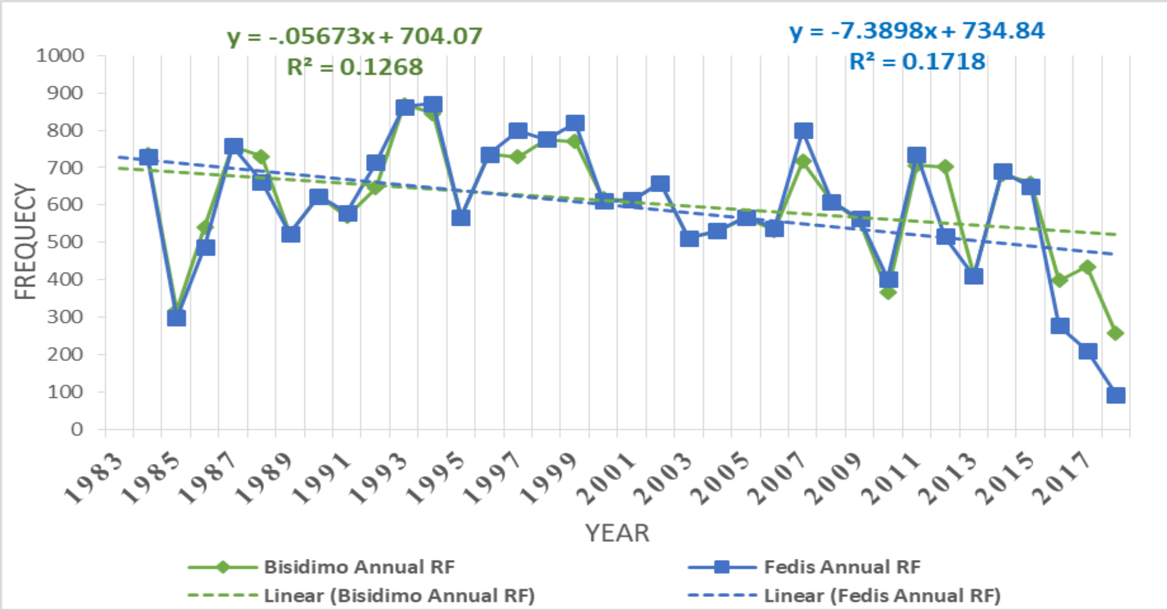

Figure 2: Annual precipitation of Midhega Tola area

Source: Computed from Data Obtained from NMA (1983-2017)

Similarly, the spring season rain fall was significantly declined by 5.04 per season at Fedis station with highly variability (Table 10). Evidence of decreasing trends of rainfall in the spring season in Ethiopia was also reported by Jury and Funk (2013) and as well as Muluken Mukeyie (2017). Generally, large areas of Ethiopia receive insufficient, and too variable, rainfall for adequate crop production, with the country frequently encountering droughts and famine (Dorosh and Rashid, 2015). Furthermore, the result of rainfall anomaly analysis for the annual rainfall generally indicated cyclic wet and dry conditions with negative anomalies for 42.9% at Bisidimo and 45.7% of the years (Fig 3, 4). This implies that rainfall in the study area exhibited high inter-annual variation during the study period (1983-2017). Based on Dereje Ayalew *et al.* (2012) drought classification system, six annual droughts occurred in the study area from 1983-2017. 1985, 2015and 2017 year was the extreme drought year with SRA -1.5 to -2.8 and the rest were moderate droughts

(Fig.3, 4). The high variability can be seen with a cluster of negative anomaly from 1984 to 1991 and from 2002 to 2017 at both station. Positive anomalies occurred between 1983 and 2001 and from 2006 to 2014. The result is in agreement with the study by Conway and Schipper (2011) and Abera Birhanu *et al.* (2011), who reported that rainfall anomaly, especially droughts, have been increasing and were the main reason for food insecurity and famine in Ethiopia. Generally, the time series analysis of anomalies of annual rainfall data showed an uneven rainfall distribution in Midhega Tola area; which leads to climate induced risks to subsistence rainfed agriculture of smallholder's livelihoods, where the majority of the people have been left susceptible to hunger and famine. These climate variability, particularly rainfall unpredictability and associated droughts have been the major causes of food insecurity and famine in Ethiopia (Conway and Schipper, 2011). The result is in agreement with the study by Yilma Seleshi and Zanke (2004), Conway and Schipper (2011) and Abera Birhanu *et al.* (2011), who reported that rainfall anomaly, especially droughts, have been increasing and were the main reason for food insecurity and famine in Ethiopia.

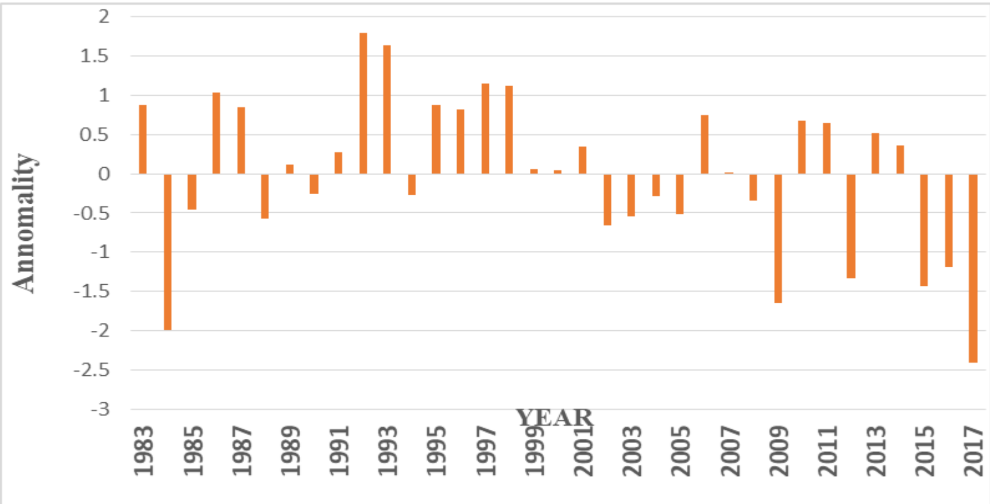

Figure 3: ***Anomalies of annual rainfall in the Bisidimo station for 1983-2017***

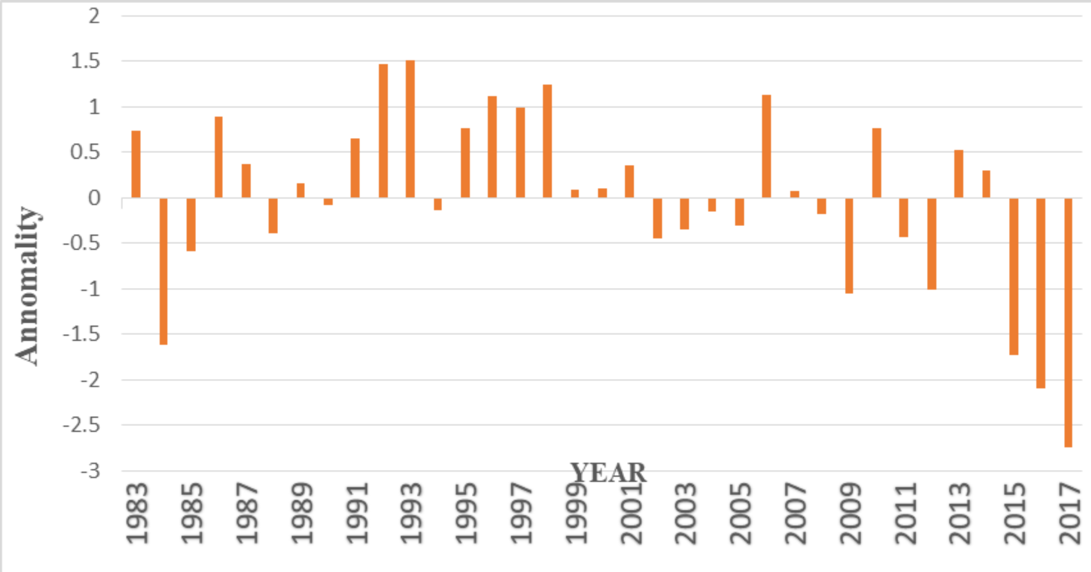

Figure 4: Anomalies of annual rainfall in the Fedis station for 1983-2017

Source: metrological data from 1983-2017.

4.3. Smallholder Farmers' Perception toward Climate Smart Agriculture Technologies

The results revealed out of total sample respondents 79.8% perceived that CSA practices are good in water management, erosion control, and sources of income while 20.11% were reported as not perceived (Table 11). The results in line with the finding of Nasir Siraj and Fekadu Beyene (2017), which reported 83.7% of total sampled households were positively perceived the importance of rainwater harvesting technology in decrease of the effect of drought and in mitigating the problems of rainfall shortage respectively in Gursum District of east Hararghe zone of Oromia regional state. Similarly, Yibekal Abebe *et al*. (2013) reported the eastern Hararghe farmers were perceived positively and executing various CSA technologies including planting trees, early planting, terracing, irrigation and water harvesting as erosion control, and sources of income. According to Dessalew Meseret (2015), reported the majority of interviewed household perceived that the different traditional and improved conservation measures of soil and water conservation practices on arable land could control erosion in Ankesha district Amhara regional state, North-Western Ethiopian. Further this finding is supported by the result of Kafula *et al*. (2017), who report that the majority of sampled household in conservation agriculture practices project were recognized the minimum tillage as adaptation strategies in Zambia. Furthermore, CSA water management practices are perceived to achieve stability of crop production by maintaining soil conditions close to optimum for crop growth in SSA (Harvey *et al.*, 2014). To enhance policy towards tackling the challenges that climate change poses to farm households and agriculture sector, it is important to understand local farmers' perception on different CSA practices before planning adaptation strategies (Temesgen Tadesse *et al*., 2011; Tambo and Abdoulaye, 2013).However, the smallholder farmers' perception on adaptation strategies depends on the knowledge they have about climate variability and its impacts, as well as benefit gained/expected from adoption of technology and innovations (Weber, 2010). Indeed, the results in Table 12 showed the household's perception on CSA practices is shaped by different factors including age, educational status , land size, understanding the impacts of climate change and methods they used to reduce the problem.

Table 11: Sampled household perception on CSAt in study area

HHs' Categories	CSA technologies adaption options				Total	%
	Agronomic practices	SWC	Integrated crop-livestock	RWH		
Not perceived	9	11	10	6	36	20.11
Perceived	30	34	55	24	143	79.87
Total	39	45	65	30	179	100

Source: Field data survey 2019.

The mean age of household head for perceived and non-perceived is 40.85 and 46.3years, respectively. An independent t-test was conducted to test if there was significant difference in the mean age of perceived and non-perceived. The T-value (t=4.284) showed statistically significant difference in the mean age of perceived and non-perceived. The non-perceived mean age was greater than that for the perceived and is significant at $P<0.05$and the result is provided in Table 12. This clearly indicates that as the farmers grow older, they become unwilling to practices the CSA technologies that they are not used before. The result agrees with the findings of (Mugo *et al*., 2013) who in their study on adoption of conservation agriculture in Kenya, found that age had a negative influence on adoption of conservation agriculture, but contradicts the findings of Gebre Hadgu *et al*. (2015) who reported a positive influence of age on adoption climate change adaptation options in Tigray, northern Ethiopia. Education is very important for the farmers to understand and interpret the agricultural information offering to them from different sources. A better educated farmer can easily understand and interpret the information transferred to them by a development agents and others. From the Table 12 the average mean year of school attainting of perceived and non-perceived is 6.955 and 3.273 respectively. The result was in line with the findings of Daniel Asfaw and Mulugeta Neka (2017) who found that more educated farmers has more likely chance be perceived the soil and water conservation practices than less educated in Wereillu District of South Wollo zone of Amhara regional state northern Ethiopia.

Livestock is vital element of the farming system in the study area. A majority of the sample households included in this survey own animals of a different kind. The average livestock holding for sample households in Tropical Livestock Unit (TLU) is found to be about 3.6. The result shows that the mean livestock owned in TLU was higher for the households who perceived technologies than their counterpart (Table12). The results independent sample T-test indicate that the average difference between the two groups with respect to livestock owned was statistically significant ($p<0.05$). It is argued that a household those had livestock can perceived more. This results in line with Temesgen

Tadesse (2011) that shows there is positive influence of livestock ownership on adoption of climate change adaptation options. Moreover, the independent sample t-test indicate that the average difference between the two group with respect to farm size, and household's income was statistically significant ($p<0.05$) respectively. The survey result indicates that from the total sample household heads about 60% of households have access to extension services. The result further indicates that from the total perceived of agronomic practices, 87.3% of the households have had access to extension services.

Table 12: Association between Sample households' characteristics and perception on CSA technologies for continuous variables (n=179)

Variables	perceived (good)		not perceived (bad)		t-test	sig
	Mean	SD	Mean	SD		
Mean age of HH(year)	40.85	8.2	46.3	8.3	4.284	0.000***
Income in ET.birr	21141.36	22550.96	21224	14560.42	-2.569	0.011**
TLU	3.5624	2.3384	2.8681	2.00654	-2.029	0.044**
Education (year)	6.955	4.423	3.273	3.394	-3.116	0.00***
Farm land size (ha)	1.6089	0.84905	1.2025	0.78594	-3.191	0.12
family size	5.2909	1.58748	4.9118	1.26651	-1.758	0.181

***, **,* Significant at 1, 5, and 10% probability level, respectively

Source: Calculated by author based on survey data in 2019.

The Chi-square analysis reveals that difference among perceived and non-perceived of different adaptation options is found to be significant at least 1% significance level. The chi-square test was conducted to compare the percentage scores of households who perceived about climate smart practices and who did not perceive with regard to the market access. The results showed that, there was statistically significant ($p<0.05$) difference between the two groups (Table 13). The results was similar with study conducted by Gutu Tesso *et al*. (2012) on econometric analysis of local level perception, adaptation and coping strategies to climate change induced shocks in North Shewa Ethiopia, that noted market service is one of the most important factors affecting the perception of farmers to climate change and their adaptation options. The results also call for provision of adequate information to ensure that farmers receive up to date weather forecasts. This is important for decision making to either use early and late planting as an adaptation strategy by farmers.

Table 13: Sample Household's characteristic for categorical explanatory variables on perception toward CSAt

Variables		Not perceived	perceived	Total	X^2	Sig
Agroecology	Woinadega	18	46	64		
	Kolla	15	100	115	6.219	0.013**
Gender	Female	10	26	36		
	Male	23	120	143	2.615	0.106
Market access	No	8	64	72		
	Yes	25	82	107	4.297	0.038**
Weather info	No	16	46	62		
	Yes	17	100	117	3.427	0.064*
Extension Service	No	12	32	44		
	Yes	21	114	135	3.03	0.082*
Credit service	No	19	85	104		
	Yes	14	61	75	0.05	0.946

**, * Significant at 5% and 1% probability level

Source: Calculated by author based on survey data in 2019.

4.4. CSA Technologies adopted as Adaptation Strategies to Climate Variability in Study Area

In order to adapt to changing climate conditions and its challenges, farmers in study area have been making adjusts to their agricultural practices. In this survey, farmers were asked questions about what climate smart measures and practices they have typically used in order to cope with the negative impact of climate changes and variability over the years. The survey result show about 25, and 11.3% of sampled households were adopts agronomic practices including drought-tolerant crop varieties (mungbean, sorghum, maze), crop diversification, early mature crop, crop rotation, intercropping, using improved crop varieties, change planting date, switching crops in Woinadega and kolla agroecologies respectively (Table 14). The reason behind the more adoption of agronomic practices in the Woinadega is the having more extension services, and accessibility to basic infrastructure like road and market for their cash crops productions particularly chat and climatic condition relative to kolla. The result is consistent with the findings of Ogalleh *et al.* (2012) and Alem Kidanu *et al*. (2016) that showed the less adoption of agronomic practices in kolla relative to Woinadega. According to Wondimagegn Tesfaye and Lemma Seifu (2016) the highest percentage crop diversification is common in midland (Woinadega) areas of eastern Ethiopia in relatively hotter (kolla) areas. Reason for that is in the hot areas there was not have alternatives to switch crops.

Table 14: CSA Technologies Adopted in Midhega Tola District across Agro ecologies

CSA practices	**Woinadega**		**kolla**	
	Frequence	Percent	Frequence	Percent
No adaptation	12	18.75	23	20
agronomic practices	16	25	13	11.3
SWC	14	21.87	22	19.13
Integrating crop-livestock	18	28	41	36
Rainwater harvesting	4	6.25	16	14

According to information from FGD in study area sawing (planting) crops before one to two weeks before rainy seasons was emerged as CSA strategy to reduce crop failure due to early termination of rainfall. Generally, similar adaptation strategies haven reported in different area (Nhemachena and Hassan Rashid 2007; Fosu-Mensah *et al*., 2012).

The result in Table 14 indicated the SWC measures were adopted nearly similar in both agroecologies because of the study area is one the water stressed area the farmers were experienced to implement it in order to overcome the moisture deficit for crop production. In Midhega Tola Woreda, culturally SWC measures like soil bund, stone bund, and minimum tillage (locally named as Miigo) are practicing to combat soil erosion and fertility loss from arable land as well as to preserve moisture in the soil for dry time crop production supplementary. The result is in line with the finding of Temesgen Tadesse *et al*. (2009) who reported significantly increases the probability of practicing soil and water conservation practices in Kolla and Woinadega compared to dega (highland). It has been linked with addressing climate change because they conserve the soil and improve water availability for crops by conserving water and the soil structure and, thus, reducing erosion (Dumanski *et al.* 2006; Hailemariam Teklewold *et al*., 2019).

Integrated crop -livestock production is also the main sources of livelihood for great number of people in study area as adaptation strategies to climate variability (Table 14). The result reveals 28 and 35% of sampled households were adopt the integrated crop with livestock in Woinadega and kolla respectively. The reason for this is more grazing land and water availability for livestock, climatic unsuitability for cash crops production (chat) to generate additional income instead farmers in Kolla herds small ruminants (Sheep and Goats) as immediate income sources, relative to Woinadega agro-ecological zone. This is agree with the finding of Melaku Jirata *et al*. (2016) who reported that traditionally mixed crop-livestock practice as animal fattening through a cut-and-carry system is one of the CSA technologies practiced in Hararghe**.** Similarly, the finding of Österle *et al*, (2012) in central rift valley of Ethiopia that showed the crop-livestock farming system is used in adaptation to climate change as rangeland has been converted to cropland. Furthermore, the survey results in Figure 5 indicated the 14 and 6% of respondent were adopt the rainwater in kolla and Woinadega respectively. The reason for this is frequently drought occurrence experience, soil condition suitability for rain water harvesting (high clay content) in kolla relative to Woinadega in where soil condition is not appropriate for water harvest due to high sand soil condition Table 14. Yet, there is high water shortage in the study area, the rain water harvesting technologies' adoption was too low compare to the other CSA practices, because it needs high capital investments in designing and constructing of ponds. The results is consistent with the report of Alem Kidanu *et al*. (2016) that indicated the farming in kola increases the probability of using water harvesting practices as adaptation options, compared to Woinadega agro-ecological zone in Dire Dawa Administration eastern Ethiopia. The finding of Temesgen Tadesse *et al. (*2008), Mahmud Yesuf *et al. (*2008), Dejene K. Mengistu (2009), Mertz *et al. (*2009), Gandure *et al. (*2012), and Seid *et al*. (2016) also report that farmers in southern and parts of East Africa, in where countries are water stressed, have been developed water conservation methods such as water harvesting, waste water re-use in agriculture and crop irrigation.

Generally, the majority of the households adopted the SWC measures and integrating crop with livestock at both agroecologies to diversify the farm out puts and thus increases the farmers' adaptive capacity, due to the campaign made by agricultural extension services from the local government agents and NGOs. This results is further consist with the finding of Hailay Tsigab *et al*. (2019) that shows SWC, irrigation, stress tolerant crop variety, changing cop calendar, tree planting are dominantly adopted CSA strategies in semiarid region of Tigray, northern Ethiopia. According to Tesfaye Samuel (2017) in Southern Ethiopia, that shows soil and water management measures, crop management and used livestock management practices were adopted as adaptation strategies to climate change. Similarly the Nyasimi *et al*. (2017) also found that changes in agricultural practices as response to climate variability are targeting both crop and livestock production; include use of new crop varieties and animal breeds, soil and land management practices, water conservation technologies, and improved fodder production.

4.4.1. Major Barriers to CSA Technologies adoption

This research results show, although diverse climate change adaptation strategies exist in the area, a number of sampled household were not practicing them to their full potential due to different constraints. The major constraint was unavailability of water both for domestic and agricultural purpose. About 25 % of the respondents reported lack water as the major constraint to adaptation to climate change (Figure 5). This was followed by financial constraint, concurrent drought, and lack of access to information through mass media (limited knowledge), soil condition and labor respectively. The findings of the current study are in line with the findings of Ringler *et al*. (2009) and Yibekal Abebe *et al*., (2013) who reported that the main barriers to adaptation strategies mentioned by farmers were lack of access to credit in South Africa and lack of access to land, information, and credit in Ethiopia. These results are also in line with the finding of Abrham Belay *et al*. (2017), who reported that the farmers were not practicing all adaptation options to their full potential due to constraints including low level of education, shortage of labor, lack of access to information, shortage of farm implements, and financial constraints, in central Rift valley of Ethiopia. Lack of money hinders farmers from getting the necessary resources and technologies that facilitate adapting to climate change Temesgen Tadesse *et al*. (2008). Other studies indicated that insufficient access to inputs, lack of knowledge about other adaptation options, no access to water, lack of credit, lack of information about climate change, high cost of adaptation and insecure property rights were the main climate change adaptation constraints (Acquah-de Graft & Onumah, 2011).

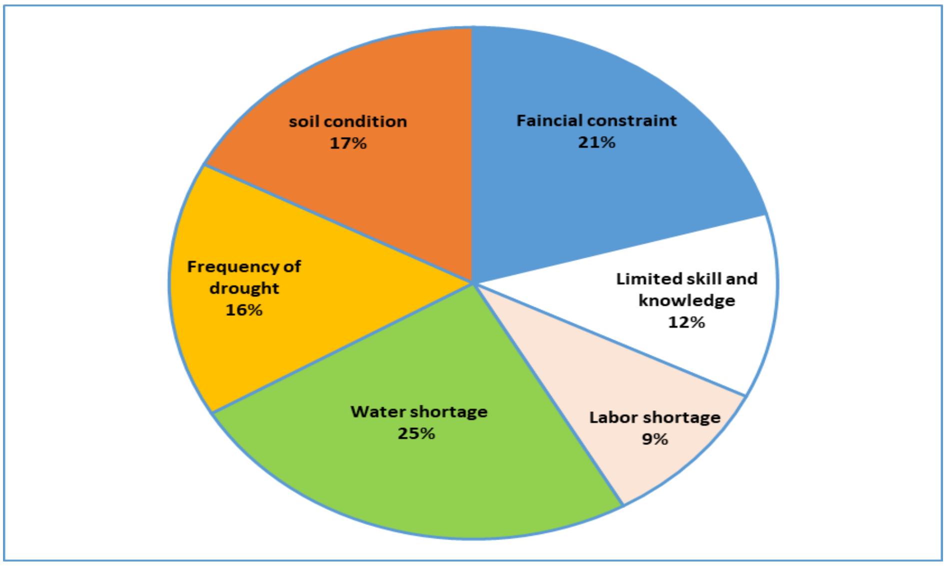

Figure 5: Farmers' primary constraints in adoption of CSAt to the in Midhega Tola.

Source; survey data 2019

4.6. Determinants Factors of Adoption of CSA Technologies

The result of multinomial logit (MNL) model showed how factors that influence farmers' choice of CSA technologies in the study area. Table 15 represented the parameter of MNL Regression model. The likelihood ratio statistics as indicated by ch2 statistics (LR chi2 (48) = 264.47 are highly significant P < 0.001), suggesting the model has a strong explanatory power. In all cases, the estimated coefficients should be compared with the base category of no adaptation. As mentioned earlier, this analysis uses the estimated coefficients of **no adaptation** as the base category and evaluates the other choices as alternatives to this option. Table 16 presents the marginal effects along with **p-**values. Multinomial logistic regression model results show that most of the explanatory variables determined adoption of adaptation options are as expected.

Table 15: Parameter estimates of the multinomial logit climate smart agriculture adoption model

Variables	Agronomic practices		SWC		Integrated crop-livestock		Rainwater harvest	
	Coefficients	P- level	Coefficients	P- level	Coefficients	P- level	Coefficients	P- level
Credit	0. 609	0.527	-0. 176	0.843	-0. 507	0.564	-1.195	0.319
Extension	2.295	0.022**	1.413	0.107	0. 654	0.460	0. 136	0.912
Age	0. 088	0.084*	0. 065	0.165	0. 088	0.059*	-0. 0017	0.979
Agro-eco	0. 603	0. 145	0.873	1.89	1.89	0.046**	3.21	0.026**
Education	0. 426	0.002***	0. 255	0.047**	0. 345	0.007***	0. 543	0.001***
Farm size	0. 362	0.472	0. 813	0.083*	0. 77	0.100	-0. 509	0.412
Gender	-3.192	0.003***	-1.842	0.068**	-2.858	0.005***	-2.856	0.025**
Income	0.0005	0.040**	0.000025	0.304	0.000019	0.419	0 .00008	0.010**
HHs size	0. 418	0.020**	0. 394	0.021**	0. 212	0.232	0. 285	0.172
TLU	0. 376	0.179	0. 292	0.268	0.665	0.012**	0. 943	0.003***
Weather	1.333	0.152	2.181	0.008***	1.222	0.142	1.458	0.236
Market	2.089	0.030**	0.589	0.457	-0.096	0.906	-1.35	0.278
_cons	-13.726	0.001***	-9.252	0.015**	-11.41	0.004***	-14.46	0.006***

Base category = no adaptation   Prob > chi2 = 0.0000

Number of obs = 179   Log likelihood = -150.17252

LR chi2 (48) = 264.47   Pseudo R2 = 0.4682

***, **,* Significant at 1, 5 and 10 probability level, respectively

Access to credit

These results indicated that having access to credit increases the probability of adoption of agronomic practices by 11.1% (Table 16). The reason for this is, with access to credit farmers can purchase agricultural inputs such as improved and stress tolerant seeds, and fertilizers. Several studies conducted on the determinants of adaptation show a positive relationship between adaptation and credit (Tizale Chilot, 2007; Temesgen Tadesse *et al*., 2009; Gbetibouo, 2009; Nabikolo *et al*, 2012; Aemro Tazeze *et al*, 2012).

Table 16: Marginal effects from the multinomial logit of climate smart agriculture adoption model

Variables	Agronomic practices		SWC		Integrated crop-livestock		Rainwater harvest	
	Coefficients	P- level	Coefficients	P- level	Coefficients	P- level	Coefficients	P- level
Credit	0. 111	0.027**	-0.0139	0.811	-0.0575	0.324	-0.0528	0.158
Extension	0.1496	0.010**	0.043	0.507	-0. 0798	0.175	-0. 056	0.151
Age	0. 0029	0.292	-0. 0002	0.944	0.0048	0.086*	-0.0037	0.041**
Agroecol.	-0.0698	0.092*	-0.1339	0.118	0. 1546	0.018**	0.0975	0.043**
Education	0.0108	0.075*	-0.0087	0.168	0.0047	0.460	0.0087	0.051*
Farm size	-0.0202	0.373	0.0524	0.035**	0.0542	0.028**	-0.0506	0.002***
Gender	-0.0939	0.057*	0.0794	0.148	-0.0986	0.073*	-0.00588	0.869
Income	0.0054	0.095*	-0.007	0.648	-0.0058	0.149	0.015	0.026**
Market	0.2189	0.000***	-0.0023	0.968	-0.0981	0.111	-0.0986	0.013**
HHs size	0.0131	0.091*	0.0185	0.042**	-0.0145	0.148	-0.0014	0.800
TLU	-0.0150	0.194	-0.0218	0.102	0.0389	0.001***	.0212	0.007***
Weather	-0.030	0.588	0.145	0.015**	-0.0340	0.567	0. 0023	0.956

*******, ******, ***** Significant at 1, 5, and 10% probability level, respectively

Extension services

Extension services are an important source of information on agricultural practices as well as on weather information. The result in Table 15 shows that access to extension is positively and significantly related to agronomic practice climate-smart agriculture technologies adoption at least a 5% probability level. The result in Table 16 shows that having extension services enhances the likelihood adoption of agronomic management by14.96%. This is due to expansion of farmer training center and crop-livestock extension services could support the effort to adapt to climate change impacts with providing important agricultural advices, climatic information and technologies. Results obtained in the present study are in agreement with arguments of Hailemariam Teklewold *et al.* (2019) which stated that having extension contact increased the likelihood of using the agronomic practices in semiarid of Tigray region northern Ethiopia.

Age

The results indicated here that age of the household head, which is considered as a proxy indicator for farming experience, affects agronomic practices and integrating crop livestock CSA practices positively and significantly at least a 1% probability level (Table 15). In Table 16 the result revealed that a unit increases in the age of the household head increases the crop-livestock mixing practices adoption by 0.48%. This is due to the fact that older farmers might have larger farmlands and they are keen to implement the integrated crop with livestock practices. The other reason might be once farmers get age they prefer to uses their farmland as grazing land because of labor constraints to crop cultivation and thus rearing livestock particularly small ruminant animals as immediate and main source of income. The result in line with finding of Abrham Belay *et al*. (2017), that indicates, a unit increase in the age of the household head resulted in an increase in the probability of practicing soil and water conservation. Furthermore, the result in Table 16 verifies the probability of adopting rainwater harvesting practices decrease by 0.37% as a unit increase in age. This might be related to the intensive labor and capital requirement of the rainwater harvesting practices as well as probably having less chance to contact with extension workers; that might prohibit farmers' from practicing rainwater harvest as they get older. This result is in line with the finds of Etwire *et al*. (2013) who showed that the probability of adoption of a recommended agricultural-practice reduced as farmer ages. Accordingly, most elderly farmers do not usually want to try new technologies until they have been proven to be effective.

Agroecology

The result in Table 15 showed that agroecology affects positively and significantly the adoption of both integrated crop with livestock and rainwater harvest practice at 5% level. The result obtained from the multinomial logit Model indicated that farming in kolla significantly increased the probability of using rainwater harvesting practices and crop livestock mixed farming CSA technologies as adaptation options to climate variability by 9.75 and 15.46% respectively (Table 15). The reason for this is clay soil abundance (availability in area) that has high water holding capacity or suitable for water harvest technology in kola than Woinadega where the soil is sandy and more land availability for both livestock grazing and crop cultivation relative to Woinadega. The result is agree with argument of Belaineh Legesse *et al*. (2013) who report that the probability of adopting rainwater harvesting and livestock-crop integration increase with changes from Woinadega to Kolla agro ecologies of Doba district of West Harerghe, eastern Ethiopia.

However, the MNL model result in Table 16 revealed that the agronomic practices in Woinadega had 6.9% more likelihood of being adopted than Kolla. The reason behind this is might having more extension services, road and market access for their cash crops than kolla. This result is in line with that of Woldegebrial Zeweld (2018), who reported that the likelihood to adopt more drought-resistant crops or varieties, is much higher if the farmer is located in Woinadega at Tigray region of Ethiopia. The result also in line with the finding of Temesgen Tadesse *et al*. (2009) that report farming in kolla has been reported to significantly reduce the probability of diversifying crop varieties compared with farming in Woinadega.

Education status

The result in Table 15 shows that education has a positive effect on farmers' adoption CSA practices as adaptation options in changing climate and hence, it significantly increases adoption with at least a 1% probability level. The marginal effect in Table 16 shows that a unit increase in the number of years of schooling could increase by 0.8% rainwater harvest and 1% agronomic practices of CSA based adaptation measures in study area. The reason behind this is the better educated farmers may interpret and implement the new technologies. This result is in line with that of Temesgen Tadesse *et al*. (2009), Gutu Tesso *et al*. (2012) and Abrham Belay et *al*. (2017), who reported a positive and significant effect of education on adopting climate change adaptation measures in Ethiopia. This is because educated farmers are expected to adopt new technologies based on their awareness of the potential benefits from the proposed technology climate change adaptation measures (Regassa Namara *et al*. 2003; Hassan Rashid and Nhemachena, 2008). Furthermore, education is likely to enhance farmers' ability to receive, interpret and comprehend information needed to make innovative decisions in their farms (Maddison, 2007; Ndambiri et al., 2013). In contrast, Negash Mulatu (2011), reported a negative relationship between education and the choice of adaptation options.

Farm Land size

Farm size has a positive association with most of the CSA strategies and significant with SWC measures Table 15. The result in Table 16 revealed that increasing farm size increased the probability of using both SWC measures and integrated crop-livestock by 5.2 and 5.4% respectively. Because both SWC and crop with livestock need extra land for grazing and executing erosion controls measures. The finding is supported by the result of Temesgen Taddesse (2011) and Yibekal Abebe *et al*. (2013) who showed that farmers with large farm size have adopted one or a combination of climate change adaptation options as compared to the farmers with small landholdings. Furthermore, large farm sizes provide an opportunity for diversification of their crop and livestock enterprises, and it can help to distribute risks associated with unpredictable weather (Abrham Belay *et al*., 2017). According to research conducted by Asrat *et al*. (2004), Million Tadesse and Kassa Belay (2004), Aklilu Amsalu and Graaff (2007) and Kassa *et al* (2013) farmers with high farm land size have less risk of reduction to farm size that came out from constructing SWC measures on their farmland and allowing for grazing purpose.

However, this finding further revealed the probability of adopting the rainwater harvest was reduced by 5% with a unity increase of farmland (Table 16). The reason behind this could be the household with larger farmland intended to adopt other technologies like mixed crop with livestock rather than a rainwater harvest. The find consistent with Abrham Belay *et al*. (2017) who reported that large farm sizes provide more opportunity for crop diversification and livestock enterprises rather than rainwater harvest to reduce risks associated with unpredictable weather in central rift valley of Ethiopia.

Gender

The results in Table 15 show all CSA technologies were negatively and significantly affected by the gender of the household head at least at a 1% probability level. With the labor-intensiveness of agricultural technologies, this results indicate that being female-headed households more likely to decrease the probability of adopting to both agronomic practices and integrated crop and livestock technologies by 9.4 and 9.8% respectively (Table 16). This result goes with the argument that female-headed households in Ethiopia in general and in Midhega Tola, in particular, are less likely to adapt to climate-related shocks due to their limited access to land, information, inputs and institutions as a result of traditional social barriers (Wilson and Getnet, 2011; Alem Kidanu *et al*. 2016). Furthermore, it is in line with the previous argument by showing that male-headed households had better opportunity to take an adaptation measure than female household mainly due to cultural and social barriers in the area that limits women's access to land and information using agronomic practices (Temesgen Tadesse *et al.*, 20014). However, this result contradicts with the finding of Apata *et al*. (2009) who argued that sex has no a statistically significant relation with adaptation strategies

Household's Income

Household's income has a positive association with all of the CSA strategies and significant with agronomic and rainwater harvest measures at 5% probability level (Table 15). The marginal effect result in Table 16 shows that a unit increase in household income can increase the likelihood of use of agronomic practices, and rainwater harvest by 0.5 and 1.5% respectively. This because of capital requirement to farm input like improved seeds, and ponds construction. This finding is consistent with a study by Temesgen Tadesse *et al*. (2008) and Negash Mulatu (2011), which found that income has a positive relation with soil conservation measures, changes in planting date and use of crop diversification. The positive impact of household income on climate-smart based adaptation options could be associated to the fact that farmers with better financial capacity are more risk-averse to agriculture production (Temesgen Tadesse *et al*., 2008). Negash Mulatu (2011) also showed that the increase in income of the household increases the likelihood of adapting to climate change using soil conservation, irrigation, and livestock production.

Household size

Household size has a positive and significant association with agronomic and SWC measures at 5% probability level (Table 15).The marginal effect result in Table 16 shows that a unit increase in family members increases the likelihood of adopting both agronomic practices and the SWC practices by 1.3% and 1.8% individually. The reason behind this might because of labor intensiveness of these technologies. The result was agree with the findings of Jafer Mume and Aman Kemal (2014) in their study of impacts of rainwater harvest (RWH) technology in eastern Ethiopia that showed a positive and significant relationship with the household size. The probable reason is that larger family size increases agricultural production because it is associated with labor-intensive agricultural practices Kurukulasuriya and Mendelsohn (2008) and Gbetibouo (2009).

Market access

As hypothesized, access to market information has a significant (at $p < 0.05$) positive impact on the likelihood of choosing agronomic practices in Table 15. A unit increases in access to the market increase the likelihood of using agronomic practices by 21.89% (Table 16). The reason with this is an accessibility of market for their cash crops product. The results are consistent with the find of Mano *et al*. (2003) that indicated access to market output provides farmers with positive motivations to produce cash crops that can help improve their resource base and hence their ability to respond to changes in climate variability. According to Abrham Belay *et al*. (2017), access to market input and output has a positive and significant effect on farmer input intensity and crop diversification. This finding further consisted with the finding of Below *et al*. (2010), Temesgen Tadesse, *et al*. (2011) and Piya *et al*. (2013) who showed improving the market access for small-scale subsistence farmers would increase their capacity to adapt to climate change.

Nevertheless, result in Table 16 revealed access to the market decreased the likelihood adoption of rainwater harvest by 9.86%. The reason for this could farmer near the market probable might intended to invest the agronomic practices (cash crop) to generate off farm income since they might have a chance to participate on off-farm activities like petty trade and labor work. The results in line with Piya *et al*. (2013) that showed in Nepal distance to markets negatively and significantly affected the use of rainwater harvest technologies.

Livestock ownership in TLU

Livestock and crop production are the main economic activities in the Midhega Tola district. The result in Table 15 indicated that livestock production has a positive association with the adoption of climate-smart practices such as agronomic practices, at 5% as well as integrating crops with livestock rearing, and rainwater harvest at a 1% level of significance. The result of Table 16 indicated that the livestock owned by a household significantly increased the probability of using integrated crops with livestock and rainwater harvest as adaptation options by 3.89 and 2.12 %, respectively. This because of the farmer with better wealth in terms of livestock could implement the rainwater harvest technologies as this technologies needs capital and labor to construct ponds. A number of studies have shown that livestock ownership has a positive association with the climate change adaptation measures (Mahmud Yesuf, *et al*., 2008; Negash Mulatu, 2011; Abrham Belay *et al*. 2017). This result further in line with results of Mesfin Astatkie (2005), Temesgen Tadesse *et al*. (2009), Solomon Asfaw *et al*. (2011) who reported that livestock ownership facilitate the adoption of improved technologies.

Weather information

Smallholder farmers need different types of weather information during each stage of the agricultural production process in order to adapt to climate variability and change. As hypothesized, better access to weather information has a significant and positive impact on the probability of using SWC measures on their farmland at 1% significance level (Table 15). As such being informed about rainfall and temperature variability increased the likelihood of soil and water conservation by 1.45% (Table 16). The reason for this is that as farmers get weather information like early warning, they could try to construct different SWC measures such as stone bund, soil bund that used to preserve soil moisture content for crop production at a dry season or to reduce soil erosion in the study area. This is in line with the finding of Nhemachena and Hassan Rashid (2007) who reported that better access to weather information has a positive impact on the decision to invest in soil and water conservation measures, use of irrigation, applying of drought-tolerant crop varieties, and diversify livelihood options in response to climate change problem. These findings are further similar to the findings from various studies including (Nhemachena and Hassan Rashid, 2008; Negash Mulatu, 2011; Yoseph Melka *et al*., 2015). Major weather information includes early warning signals, weather forecasts, pest attacks, cultivation practices, pest and disease management (IPCC, 2007; Aker,2011).

5. Conclusion and Recommendation

5.1 Conclusion

From the study, it was concluded that the majority of the farmers in the study area have perceived changes in important climatic factors (precipitation and temperature) and thus experienced the effects of a changing climate over two decades. That is, prolonged dry periods and decreasing precipitation are more frequent across the agro-ecologies in the district which supported by historical observed metrological temperature and rainfall data.

Majority of sampled household perceived the CSA practices as adaptation strategies to reduce the negative impacts of climate variability. Accordingly, integrated crop-livestock and soil and water conservation were two of the most predominantly practiced CSA technologies in the Midhega Tola district. However, although diverse CSA practices exist in the study area, a number of sampled household were not able to practice them to their full potential due to constraints such as shortage of water, finance, recurrent drought and lack of access to information, among others.

The smallholder farmers' capability and interest to choose locally productive climate-smart technologies adaptation options are influenced by socio-economic and institutional factors. It was concluded from the Multinomial Logit model that education, family size, agroecology, gender, age, livestock ownership, extension, farm size, access to credit, access to market, access to climate information and income were the key factors determining farmers' choice of CSA practice. This research thus provide valuable information to the policy and discussion makers, extension workers, NGO and farmers to minimize the impact of climate variability and develop sustainable and appropriate CSA technologies for the country.

5.2. Recommendations

From the current study, the following recommendations are put forward.

- In order to improve agricultural production, productivity and quality as well as reduce climate change risks, the government's adaption strategies and policy choice should be based on the local farmers' perception of climate variability and potential of existing CSA practices, socio-economic and environmental factors.
- Strengthening rainwater harvest technologies from runoff and roof catchment as well as introducing ground water based small scale irrigation facilities is vital to reduce the climate impacts in study area.
- Encouraging climate smart agriculture in national education program and develops sustainable and agro-ecologically appropriate CSA strategies are vital.
- Within diversified extension service delivery there is a needs to build the capacity of all level extension workers and local farmers on climate related impacts and the climate smart agriculture practices benefits in adaptation.
- Government institutions need to put more efforts into providing farmers with accurate and timely weather forecasts in local language as some farmers have no confidence in the weather forecasts received. This will enable farmers to fully exploit seasonal rainfall distribution to improve and stabilize crop yields.
- Increasing market accessibility for rural farmers to sell their agricultural products and buy inputs for households as well as encouraging local farmers to sell livestock during dry period is also recommended.

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Appendix Ia : The Variance Inflation Factors for Multinomial Logit Model

```
. vif

    Variable |       VIF       1/VIF
-------------+----------------------
    eduction |      1.75    0.570534
         TLU |      1.63    0.613174
    hhincome |      1.61    0.620343
         age |      1.57    0.638717
      hhsize |      1.38    0.727096
    farmsize |      1.14    0.878568
-------------+----------------------
    Mean VIF |      1.51
```

Source: Own survey results, 2019Appendix Vb: Correlation Matrix

Appendix I b: contingency coefficient

Correlations

	sex of individual	agro ecological zone	access to weather information	Access to market information	access to extension service	access to credit
sex of individual	1	-.228	-.013	-.147	-.256	-.002
agro ecological zone	-.228	1	-.120	-.047	-.035	.043
access to weather information	-.013	-.120	1	.186	.211	.178
Access to market information	-.147	-.047	.186	1	.496	.176
access to extension service	-.256	-.035	.211	.496	1	.171
access to credit	-.002	.043	.178	.176	.171	1

Appendix II: Estimation Result of multinomial logit model

mlogit options accestocridet accesstoexten marketaccess weatherinfo hhincome TLU eduction farmsize hhsize age agroecology genderHH

```
Iteration 0:   log likelihood = -282.40569
Iteration 1:   log likelihood = -173.27015
Iteration 2:   log likelihood = -155.02553
Iteration 3:   log likelihood = -150.39772
Iteration 4:   log likelihood = -150.17373
Iteration 5:   log likelihood = -150.17252
Iteration 6:   log likelihood = -150.17252

Multinomial logistic regression                   Number of obs   =        179
                                                  LR chi2(48)     =     264.47
                                                  Prob > chi2     =     0.0000
Log likelihood = -150.17252                       Pseudo R2       =     0.4682

------------------------------------------------------------------------------
     options |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
```

no_adaptation	(base outcome)					
agronomic						
accestocridet	.6093475	.9629308	0.63	0.527	-1.277962	2.496657
accesstoexten	2.295413	1.005732	2.28	0.022	.3242151	4.266611
marketaccess	2.089751	.9638192	2.17	0.030	.2007004	3.978802
weatherinfo	1.333685	.9301044	1.43	0.152	-.4892861	3.156656
hhincome	.0000512	.0000249	2.05	0.040	2.27e-06	.0001001
TLU	.3763374	.2802472	1.34	0.179	-.1729371	.9256119
eduction	.4255864	.1370165	3.11	0.002	.157039	.6941338
farmsize	.3618034	.5031239	0.72	0.472	-.6243014	1.347908
hhsize	.4183233	.1803097	2.32	0.020	.0649227	.7717239
age	.0880179	.0509786	1.73	0.084	-.0118984	.1879341
agroecology	.6034091	1.00643	0.60	0.549	-1.369158	2.575976
genderHH	-3.19251	1.087685	-2.94	0.003	-5.324333	-1.060686
_cons	-13.72671	4.224328	-3.25	0.001	-22.00624	-5.447184
swc						
accestocridet	-.1758829	.8897347	-0.20	0.843	-1.919731	1.567965
accesstoexten	1.412887	.8753272	1.61	0.107	-.3027231	3.128496
marketaccess	.5892362	.7929177	0.74	0.457	-.964854	2.143326
weatherinfo	2.181301	.8272532	2.64	0.008	.5599141	3.802687
hhincome	.0000247	.0000241	1.03	0.304	-.0000225	.0000719
TLU	.2920981	.2636627	1.11	0.268	-.2246714	.8088676
eduction	.25546	.1284789	1.99	0.047	.003646	.507274
farmsize	.8130258	.4688847	1.73	0.083	-.1059713	1.732023
hhsize	.3941107	.1710576	2.30	0.021	.0588439	.7293775
age	.0649134	.0467645	1.39	0.165	-.0267434	.1565702
agroecology	.1449021	.9031632	0.16	0.873	-1.625265	1.91507
genderHH	-1.842235	1.011098	-1.82	0.068	-3.82395	.13948
_cons	-9.25258	3.808408	-2.43	0.015	-16.71692	-1.788238
integrated						
accestocridet	-.5069062	.8775786	-0.58	0.564	-2.226929	1.213116
accesstoexten	.6540352	.8859778	0.74	0.460	-1.082449	2.39052
marketaccess	-.0961808	.8175448	-0.12	0.906	-1.698539	1.506178
weatherinfo	1.222287	.8332114	1.47	0.142	-.4107771	2.855351
hhincome	.0000191	.0000236	0.81	0.419	-.0000273	.0000654
TLU	.6654929	.2641471	2.52	0.012	.1477742	1.183212
eduction	.3447539	.1279109	2.70	0.007	.0940531	.5954546
farmsize	.7704499	.4683154	1.65	0.100	-.1474313	1.688331
hhsize	.2121411	.1774857	1.20	0.232	-.1357245	.5600067
age	.0884066	.046751	1.89	0.059	-.0032237	.1800369
agroecology	1.895273	.9500668	1.99	0.046	.0331764	3.75737
genderHH	-2.858898	1.016359	-2.81	0.005	-4.850925	-.8668711
_cons	-11.40685	3.928568	-2.90	0.004	-19.1067	-3.706997
rh						
accestocridet	-1.19538	1.199454	-1.00	0.319	-3.546267	1.155507
accesstoexten	.1356896	1.234077	0.11	0.912	-2.283056	2.554435
marketaccess	-1.350758	1.244921	-1.09	0.278	-3.790757	1.089241
weatherinfo	1.458964	1.230586	1.19	0.236	-.9529401	3.870868
hhincome	.0000803	.0000312	2.57	0.010	.0000191	.0001416
TLU	.9434529	.3192563	2.96	0.003	.317722	1.569184
eduction	.5427388	.1625907	3.34	0.001	.224067	.8614107
farmsize	-.5095963	.6213598	-0.82	0.412	-1.727439	.7082466
hhsize	.2848143	.2085557	1.37	0.172	-.1239473	.693576
age	-.0016845	.0625649	-0.03	0.979	-.1243095	.1209405
agroecology	3.21468	1.44292	2.23	0.026	.3866097	6.042751
genderHH	-2.856923	1.275639	-2.24	0.025	-5.35713	-.356717
_cons	-14.46272	5.273667	-2.74	0.006	-24.79892	-4.126521

Appendix III: MNL model's marginal effects

. Margins, dydx (*)

Average marginal effects   Number of obs   =   179

Model VCE   : OIM

Dy/dx w.r.t.: accestocridet accesstoexten marketaccess weatherinfo hhincome TLU eduction farmsize hhsize age agroecology genderHH

1._predict   : Pr (options==no_adaptation), predict (pr outcome (0))

2._predict   : Pr (options==agronomic), predict (pr outcome (1))

3._predict   : Pr (options==swc), predict (pr outcome (2))

4._predict   : Pr (options==integrated), predict (pr outcome (3))

5._predict   : Pr (options==rh), predict (pr outcome (4))

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
accestocridet						
_predict						
1	.0130325	.0412811	0.32	0.752	-.067877	.0939419
2	.1113896	.0502352	2.22	0.027	.0129304	.2098488
3	-.0139558	.0583272	-0.24	0.811	-.128275	.1003635
4	-.0575804	.0584196	-0.99	0.324	-.1720807	.0569199
5	-.0528859	.0374343	-1.41	0.158	-.1262558	.020484
accesstoexten						
_predict						
1	-.0569452	.0390429	-1.46	0.145	-.1334679	.0195775
2	.1496664	.0579942	2.58	0.010	.0359999	.2633329
3	.0432419	.0651967	0.66	0.507	-.0845413	.171025
4	-.0798713	.0589358	-1.36	0.175	-.1953834	.0356407
5	-.0560917	.0391023	-1.43	0.151	-.1327309	.0205475
marketaccess						
_predict						
1	-.0197841	.0366153	-0.54	0.589	-.0915487	.0519806
2	.2189648	.0605083	3.62	0.000	.1003706	.3375589
3	-.0023464	.0577743	-0.04	0.968	-.1155819	.1108891
4	-.098192	.0616807	-1.59	0.111	-.219084	.0226999
5	-.0986423	.0398552	-2.48	0.013	-.1767571	-.0205274
weatherinfo						
_predict						
1	-.0836258	.0353746	-2.36	0.018	-.1529587	-.0142929
2	-.0300217	.0553978	-0.54	0.588	-.1385993	.0785559
3	.1453173	.0597906	2.43	0.015	.0281298	.2625048
4	-.0340268	.0594297	-0.57	0.567	-.1505069	.0824533
5	.0023569	.0422492	0.06	0.956	-.08045	.0851638
hhincome						
_predict						
1	-1.29e-06	1.06e-06	-1.21	0.225	-3.37e-06	7.95e-07
2	2.19e-06	1.31e-06	1.67	0.095	-3.77e-07	4.75e-06
3	-7.77e-07	1.70e-06	-0.46	0.648	-4.11e-06	2.56e-06
4	-2.34e-06	1.62e-06	-1.44	0.149	-5.52e-06	8.42e-07
5	2.22e-06	9.95e-07	2.23	0.026	2.67e-07	4.17e-06
TLU						
_predict						
1	-.0231791	.0118699	-1.95	0.051	-.0464437	.0000855
2	-.015078	.0116001	-1.30	0.194	-.0378137	.0076577
3	-.021826	.0133356	-1.64	0.102	-.0479633	.0043112
4	.0389266	.0122484	3.18	0.001	.0149202	.0629331
5	.0211565	.0078089	2.71	0.007	.0058514	.0364616
eduction						
_predict						
1	-.0155464	.0054354	-2.86	0.004	-.0261996	-.0048932
2	.0108182	.0060711	1.78	0.075	-.0010809	.0227172
3	-.0087393	.0063455	-1.38	0.168	-.0211763	.0036977
4	.0047295	.0063952	0.74	0.460	-.0078048	.0172638
5	.008738	.004474	1.95	0.051	-.0000309	.0175069
farmsize						
_predict						
1	-.0358318	.0210416	-1.70	0.089	-.0770726	.0054091
2	-.0202082	.0226901	-0.89	0.373	-.0646799	.0242635
3	.0524686	.0248268	2.11	0.035	.003809	.1011282
4	.0542558	.0246964	2.20	0.028	.0058518	.1026598
5	-.0506844	.0161259	-3.14	0.002	-.0822905	-.0190783
hhsize						
_predict						
1	-.0157584	.0076342	-2.06	0.039	-.0307212	-.0007956
2	.0131953	.0078152	1.69	0.091	-.0021222	.0285127
3	.0185187	.0090983	2.04	0.042	.0006863	.036351
4	-.0145792	.0100787	-1.45	0.148	-.0343331	.0051747
5	-.0013763	.0054406	-0.25	0.800	-.0120398	.0092871
age						
_predict						
1	-.0037216	.002086	-1.78	0.074	-.0078101	.0003669
2	.0029107	.0027648	1.05	0.292	-.0025082	.0083297
3	-.0002083	.0029533	-0.07	0.944	-.0059967	.0055801
4	.0048005	.0027966	1.72	0.086	-.0006808	.0102817
5	-.0037813	.0018501	-2.04	0.041	-.0074074	-.0001551

agroecology						
_predict						
1	-.0484158	.0422897	-1.14	0.252	-.131302	.0344704
2	-.0698166	.0534917	-1.31	0.092	-.1746584	.0350251
3	-.1339421	.0567014	-2.36	0.118	-.2450748	-.0228095
4	.1546584	.0654116	2.36	0.018	.0264541	.2828628
5	.0975161	.048224	2.02	0.043	.0029989	.1920334
genderHH						
_predict						
1	.1191252	.0427196	2.79	0.005	.0353963	.202854
2	-.0939912	.0493497	-1.90	0.057	-.1907149	.0027325
3	.0794048	.054829	1.45	0.148	-.0280581	.1868677
4	-.0986521	.0549399	-1.80	0.073	-.2063322	.0090281
5	-.0058866	.0355941	-0.17	0.869	-.0756498	.0638765

Appendix IV: Heteroscedasticity test

```
. hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of options

         chi2(1)      =     2.55
         Prob > chi2  =   0.1100
```

Appendix V: Suest test

```
suest m1 m2, noomitted

Simultaneous results for m1, m2

                                          Number of obs     =        179


. test [m1_agronomic  = m2_agronomic ], cons

 ( 1)  [m1_agronomic]accestocridet - [m2_agronomic]accestocridet = 0
 ( 2)  [m1_agronomic]accesstoexten - [m2_agronomic]accesstoexten = 0
 ( 3)  [m1_agronomic]age - [m2_agronomic]age = 0
 ( 4)  [m1_agronomic]agroecology - [m2_agronomic]agroecology = 0
 ( 5)  [m1_agronomic]eduction - [m2_agronomic]eduction = 0
 ( 6)  [m1_agronomic]farmsize - [m2_agronomic]farmsize = 0
 ( 7)  [m1_agronomic]genderHH - [m2_agronomic]genderHH = 0
 ( 8)  [m1_agronomic]hhincome - [m2_agronomic]hhincome = 0
 ( 9)  [m1_agronomic]hhsize - [m2_agronomic]hhsize = 0
 (10)  [m1_agronomic]marketaccess - [m2_agronomic]marketaccess = 0
 (11)  [m1_agronomic]TLU - [m2_agronomic]TLU = 0
 (12)  [m1_agronomic]weatherinfo - [m2_agronomic]weatherinfo = 0
 (13)  [m1_agronomic]_cons - [m2_agronomic]_cons = 0

           chi2(  2) =    0.00
         Prob > chi2 =    1.0000
```