COMPARATIVE ASSESSMENT OF CLIMATE CHANGE AND VARIABILITY INDUCED VULNERABILITY AND ADAPTATION STRATEGIES BETWEEN FOREST-BASED AND NON-FOREST BASED HOUSEHOLDS IN DECHA DISTRICT, KAFFA ZONE

M.SC. THESIS

BY

ABRAHAM ALEMAYEHU WOLDE

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JIMMA, ETHIOPIA

Comparative Assessment of Climate Change and Variability Induced Vulnerability and Adaptation Strategies Between Forest-Based and Non-Forest Based Households in Decha District, Kaffa Zone

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Submitted to the School of Graduate Studies College of Agriculture and Veterinary Medicine, Department of Rural Development and Agricultural Extension in Partial Fulfilment of the Requirements for the degree of Master of Science in Rural Development

Major Advisor: Abayineh Amare (Ph.D. Associate Professor of Environment and Development Studies)

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DEDICATION

I dedicate this thesis to my father, Alemayehu Wolde for his unending support and love to live my dreams. He is excellent uneducated farmer but clearly understand the value of education.

STATEMENT OF THE AUTHOR

I, Abraham Alemayehu Wolde, hereby declare that the thesis work entitled "Comparative Assessment of Climate Change and Variability Induced Vulnerability and Adaptation Strategies between Forest-based and Non-Forest Based Households in Decha District, Kaffa Zone is submitted by me in partial fulfilment of the requirements for the award of the degree of M.Sc. in rural development and agricultural extension at Jimma University. It is the original work carried out by myself and the matter embodied in this thesis work has not been submitted to any other educational institutions for achieving any academic awards and Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made.

Name of the student: Abraham Alemayehu Wolde

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BIOGRAPHIC SKETCH

The author, Abraham Alemayehu Wolde was born in 1990 E.C. in Decha District, Kaffa Zone of South Western Ethiopian Peoples Regional State. He completed his elementary education at Barta Elementary School. He also attended his secondary and preparatory education at Grazmach Paulos and Bishaw W/Yohannes Secondary and Preparatory Schools. After successful completion of his preparatory school education, he joined Wolaita Sodo University in 2009 and graduated with a BSc degree in Rural Development and Agricultural Extension in July 2011 E.C. After his graduation, he was employed in Kaffa Zone, Goba District agriculture and natural resource development office as rural women's extension expert and served from January 2012 to January 2013 E.C. After one-year service in Goba district he joined Werabe University as Graduate Assistant in February 2013. Subsequently, he joined Jimma University in 2014 to pursue his MSc degree in Rural Development.

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LIST OF ACRONYMS

AR5	Fifth Assessment Report
CC	Contingency Coefficients
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization
FB	Forest Based
FGD	Focus Group Discussion
HHs	Household Heads
IPCC	International Panel on Climate Change
KII	Key Informant Interview
LVI	Livelihood Vulnerability Index
LVI- IPCC	Intergovernmental panel on climate change livelihood vulnerability index
MNL	Multinomial Logit Model
MVP	Multivariate Probit Model
NABU	Nature and Biodiversity Conservation Union
NFB	Non-Forest Based
NR	Natural Resource
NTFPs	Non-Timber Forest Products
PFM	Participatory Forest Management
REDD^{+}	Reduction of Emission from Forest Deforestation and Degradation
SPSS	Statistical Package for Social Science
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit
TRA	Theory of Reasoned Action
VIF	Variation Inflation Factor

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ABSTRACT

The biophysical and socio-economic factors make forest-based and non-forest-based livelihood systems vulnerable to climate change. However, the extent of vulnerability varied for spatial variation of determining factors. Despite their vulnerability, households employed relevant adaptation measures to reduce effects of climate change. Therefore, the main objective of this study was investigating the factors for the variation of vulnerability, and undertaken adaptation measures based on forest-based and non-forest-based households. A cross sectional research design was employed to collect qualitative and quantitative data from household heads. Primary data was collected through focus group discussion, key informant interviews, and household interview; while secondary data was collected through document analysis. About 312 respondents were randomly selected respectively 142 from non-forest-based and 170 from forest-based strata. The collected data were analysed through descriptive statistics, inferential tests, multivariate probit model and narration. Additionally, livelihood vulnerability index estimated to analyse the livelihood vulnerability of households. The result of livelihood vulnerability indicated non-forest-based households were vulnerable to climate change due to their frequent exposure to climate events accompanied by low adaptive capacity. To reduce the adverse effects of climate change, 82.9%, 61.3% and 52.1% of non-forest-based households adjusted planting date, diversified crop and used fertilizer respectively and 50.6%, 57.6%, and 62.4% forest-based households expanded enset, diversified crop, and managed forest as adaptation strategy. The multivariate probit model result showed adaptation strategies was significantly determined by sex, geographic area, age, household size, frequency of extension contact, credit access, livestock size, total income, perception of climate change, and size of farmland. Generally, analysing spatial and livelihood based variation of households to exposure, sensitivity and adaptive capacity components of vulnerability are imperative to identify contextually relevant adaptation strategies and its determinants. The results suggested, measures that reduce climate change related effects, encourage use of agriculture technologies, expand livelihood options and infrastructures should be implemented. Moreover, promotion of adaptation measures should consider spatial variation of livelihood and key determining factors.

Key words: Adaptation, Decha, Forest-based, Multivariate probit, Non-forest-based, Vulnerability

1. INTRODUCTION

1.1. Background of the Study

Climate change is a contemporary global issue and the primary stressor of our planet (Van Pelt, 2018). Its fact is evidenced by changes in temperature, rainfall, sea levels, and soil moisture due to the increasing concentration of greenhouse gases (IPCC, 2019). The IPCC has projected that at the end of the 21st century; there will be an increase in average global surface temperatures by 3-6°C and a decrease of rainfall by 12–14%. The incidence of the extreme weather events affected ecological systems, human and animal health, loss of agricultural productivity, and water resources (Gebrechorkos, 2019).

No region is immune to the impacts of climate change; but, the extent of vulnerability differs widely. According to the IPCC sixth report approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change (IPCC, 2022). An analysis that measured the vulnerability of countries found that nearly twice as many people are living in most vulnerable countries compared to the number living in less vulnerable countries (Birkmann *et al.*, 2021). Moreover, the assessment revealed that in most vulnerable regions a double burden of existing destabilized livelihood conditions and additional climatic hazards is already visible and largely influenced societal impacts of climate change (Abrams, 2018).

Africa has been recognized as one of the most vulnerable continents to the impacts of climate change and experienced widespread loss and damage including biodiversity loss, water shortages, reduced food production, loss of lives and reduced economic growth (Serdeczny *et al.*, 2017). Sub-Saharan Africa, where smallholder farmers dominate agriculture is one of global hotspots for climate change-induced impacts (Adeniyi, 2016). As Sub-Saharan African country, Ethiopia is also identified as a country that is highly vulnerable to climate variability and change (Gebrechorkos, 2019). The climate change impacts like irregular and heavy rain falls, extreme droughts and heavy frosts as well as proliferation of pests are challenging farmers and ecosystems (Filho *et al.,* 2019).

The smallholder farmers are most vulnerable groups to climate change and variability due to the incidence of different climatic events and their high dependency on natural resource driven activities, rain fed agriculture, limited use of irrigation, and weak adaptive capacity (Dendir and Simane, 2019; Tessema and Simane, 2019). The frequent occurrence of drought and flood events, crop pests and disease, and soil erosion incorporated with rain fed agricultural practices and low adoption of agricultural technologies make farming communities vulnerable to climate change (Alemayehu and Bewket, 2016; Amare and Simane, 2017). Also, high dependence of households on forest ecosystem services and goods integrated with climatic events increased vulnerability to climate change (Mohammed *et al.*, 2018). Vulnerability of ecosystems and people to climate change is interdependent (IPCC, 2022). Smallholder farmers whose livelihood is dependent on natural resources are susceptible to climate variability (Birhanu, 2022).

Asrat and Simane (2017) reported that households in dry lowland agro-ecology were vulnerable to climate change due to their dependency on forest products as food and cash source compared with households in the wet lowland. In the contrary, the finding of Pavageau *et al.* (2018) confirmed that the larger forest resources reduced vulnerability because the importance of forests for protection, basic needs and income generation for the population in forest areas is high and communities' dependent on forest products were resilient because forests provided safety nets and were less affected by climate variability than agricultural production. The variations in asset, livelihood strategies, technology, infrastructure, socio-demography, social network and natural disasters contributed for the vulnerability variation between different geographical areas (Amare and Simane, 2017; Dendir and Simane, 2019).

A range of options is undertaken to reduce climate change risks. The farming households employed planting drought and heat tolerant varieties, changing planting schedules and using early maturing varieties (Kom *et al.*, 2020). Moreover, adopting climate smart and ecological agriculture are the major strategies undertaken by farming households to reduce the impacts of climate change (Makate *et al.*, 2019). In forest based livelihoods, forest ecosystem management is implemented to overcome the risks of climate change (Tadesse *et al.*, 2017). Forests assist adaptation to climate change through provision of ecosystem services that support sustainability of other sectors. Farmers' choices of adaptation measures are determined by several demographic, socio-economic, and institutional factors (Marie *et al.*, 2020; Weldegebrial, 2020). Thus, in depth understanding of determinants of farmers' choice of adaptation strategies helps to design appropriate interventions (Ashraf *et al.*, 2014).

The study undertaken by Mengist *et al.* (2021) indicated forest loss in Kaffa biosphere due to expansion of semi-forest coffee farm investment, population growth, and poor follow up on participatory forest management. Even though, smallholder farmers in the study area who live in proximity to the available forested areas are involved in subsistence agricultural practices including livestock sectors either within or outside the forest, and regularly use and market forest products. On the other hand, the farmers who do not access forest and its resources were mostly engaged in mixed farming practices (crop production and livestock sectors) with traditional and or newly introduced production techniques.

To the extent of the researcher's knowledge, there are no studies that investigated the vulnerability and adaptive capacity of smallholder farmers based on dominant livelihood strategies that are based on forest and non-forest resources. Accordingly, this study categorized these areas based on their livelihoods by characterizing forest-based and non-forest-based households to investigate how vulnerable and capable to adapt to climate change. Climate change manifestations in the form of rising temperatures and rainfall pattern variability coupled with human-driven rapid land-use changes are expected to affect these communities (Hein *et al.*, 2019). Thus, it is imperative to clearly understand the extent and factors of vulnerability, context-specific adaptation strategies, and their determinants at the contextual level to design appropriate intervention.

1.2. Statement of the Problem

Although having the favourable and diverse agro ecology zones, smallholder farmers in Ethiopia are highly vulnerable to climate change and variability due to frequent occurrence of climate change risks, and fragile and nature dependent livelihoods. Evidences indicated that Ethiopia is facing erratic and heavy rainfall, warming temperatures, drought, crop and livestock pests and disease, and flood (Amare and Simane, 2017a). On the other hand, smallholder subsistence farming is based on low-input, rain-fed and traditional farming system, and public services in rural areas are at initial stage. The climate change risks accompanied with these poor socio-economic conditions make households vulnerable to climate change (Filho, *et al.*, 2019; Wolde and Tolossa, 2019).

Asfaw *et al.* (2021) reported smallholder farmers in *Belg* dominated areas were more vulnerable relative to *Meher* dominated areas. Asrat and Simane (2017) reported farming households in dry lowland agro-ecology were more vulnerable than wet lowland. Moreover, Kolla agro ecology were more vulnerable (Teshome, 2016); Tesso *et al.*, (2012) reported farmers in Dega agro ecology were vulnerable; while Weyina dega was found to be more vulnerable (Abeje *et al.*, 2019). The aforementioned studies indicated variation of vulnerability depending on location, adaptation capacity and socio-economic and development factors.

The failure to effectively adapt the changing climate could result the serious short-term and long-term problems (Hugo., *et al.,* 2019). Thus, households in different areas undertake various measures to reduce climate change related challenges. However, the undertaken measures varied in type, and intensities among different areas. Farming in midland and highland increased use of small-scale irrigation, while farming in lowland increased use of soil and water conservation measures (Amare and Simane, 2017b). The intensity and type of adopted adaptation strategies varied between different areas (Alemayehu and Bewket, 2017).

The implemented adaptation strategy is also determined by different demographic, socio-economic, institutional and biophysical factors. The potential influences of determinants make the adaptation strategies to vary among different areas. Accordingly, Birhanu, (2022) reported age, education, and extension contacts has a significant relationship with implementation of adaptation practices in warm & moist sub-Weyina dega traditional agro-ecology, but no significant relationship with implementation of adaptation practices in other agro-ecology.

The target group of this study are vulnerable to climate variability and change for high occurrence of climate change events, nature based livelihood, and poor socio-economic conditions (Bender & Tekle, 2019). Appropriate actions must be taken to reduce the risks brought on by climate variability and change. The best way to do this is to gather empirical data on vulnerability factors, and synthesize existing knowledge of adaption strategies in various livelihood contexts while taking determining factors into account. Nonetheless, the body of knowledge in this area is deficient. Furthermore, previous research cannot be extrapolated to other particular regions for contextual and spatial variation of vulnerability factors, and used adaption strategies.

There is also lack of focus by previous studies particularly in forest dependents livelihoods like that of the study areas. Moreover, the methodological gap of using multinomial logit model, which considers the independent choice of adaptation strategies (Marie *et al.,* 2020) were bridged by using multivariate probit model. Multivariate probit model considered the interdependence of choices and adoption of multiple adaptation strategies (Belderbos *et al.*, 2004). This study categorized the livelihood systems of study area into forest-based and non-forest-based to explore variation of vulnerability, and adaptation strategies to climate change. Accordingly, this study was entitled with comparative assessment of vulnerability to and adaptation strategy for climate change and its' determinants based on forest-based and non-forest based livelihoods.

The generated information of this study gives the baseline knowledge on determining factors of vulnerability, and guide the future aspects of adaptation measures at the lowest levels of society (forest-based and non-forest based households). Furthermore, the finding also reported what and how the demographic, socio-economic, institutional and biophysical factors determine households' adaptation strategies. Thus, a better understanding of variation to climate change induced vulnerability based on dominant livelihood system, and adaptation strategies with determinants of specific area are milestone to design relevant policy.

1.3. Objectives

1.3.1. General objective

Comparatively assessing vulnerability to climate change and variability, and its adaptation strategies between forest-based and non-forest-based households in Decha district Kaffa Zone.

1.3.2. Specific objectives

1. To assess climate change and variability induced vulnerability of forest-based and non-forest-based households in the study area
2. To identify adaptation strategies of forest-based and non-forest-based households in response to climate change and variability in the study area
3. To identify determinants of adaptation strategies of forest-based and non-forest-based households to climate change and variability in the study area

1.4. Research Questions

1. What are the determining factors of vulnerability of forest-based and non-forest-based households to climate change and variability?
2. What are the adaptation strategies undertaken by forest-based and non-forest-based households to climate change and variability?
3. What are the determinants of adaptation strategies of forest-based and non-forest-based households to climate change and variability?

1.5. Significance of the Study

The vulnerability assessment result revealed the major causes of vulnerability variation in specific areas of forest-based and non-forest based households to climate change and variability. The comparatively revealed result of vulnerability can assist to identify the most vulnerable groups. This could support for decision making about targeting interventions and priority setting in reducing vulnerability to climate change effects. Additionally, the study also provides information about most commonly and specifically used adaptation strategies among the set of options and also verifies determinants that significantly influence adaptation options of forest and non-forest based households.

The finding would also assist local policy makers and development experts in designing and formulating policies that seeks to invest on the farmers' dominant adaptation strategies to reduce climate change effect in the study area. Finally, the study can be used as a base for further studies in the area of climate change. It will serve as source of information and reference material for studies that will be conducted on vulnerability, adaptation strategies and determinants of adaptation strategies against climate change impacts.

1.6. Scope and Limitations of the Study

The study was limited to Decha district of Kaffa zone. This study focused on livelihood based assessments of climate change and variability induced vulnerability, identified adaptation strategies and determinants of adaptation strategies of forest-based and non-forest-based households focusing only in few Kebeles. Moreover, only single time data is used to conclude the finding, however climate change vulnerability and undertaken adaptation measures varied from time to time. Also, the data was collected from few respondents for time and budget limitations.

The major limitation of this study is lack of metrology station in the study area. There is only one meteorological station at the zonal level to take temperature and precipitation data which is better if it is available in both forest-based and non-forest-based livelihood zones to compare the variability of two communities for climate events (temperature and precipitation). Moreover, the subjectivity of selecting vulnerability indicators, the interaction of respondents with enumerators and the limited skill of data collectors were the major challenges faced while undertaking this study. Despite the limitations faced, efforts were made to capture the data from different sources, triangulations with local situations, and data were collected after giving training, and frequent supervision of enumerators. Furthermore, only five major adaptation strategies commonly employed in both livelihood zones were identified for the choice of MVP model.

1.7. Organization of the Thesis

The thesis included five chapters. The first chapter presents the background of study, statement of the problem, objectives of the study, significance of the study, and scope and limitations of the study. The second chapter reviewed different literature concerning concepts, and theory on climate change induced vulnerability, adaptation strategies and determinants of adaptation strategies. It also included empirical studies on climate change and variability induced vulnerability, adaptation strategies and determinants of adaptation strategies. The third chapter presents description of the study area, research design, sources and types of data, methods of data collection, sampling procedures and sample size, and methods of data analysis. The fourth chapter included the findings on household characteristics of sample respondents for continuous and dummy variables, vulnerability of forest-based and non-forest-based households to climate change and variability, employed adaptation strategies, and determinants of climate change adaptation strategies. Finally, summary, conclusion, and recommendation were presented in the fifth chapter.

2. LITERATURE REVIEW

2.1. Concepts and Definitions of Terms

Climate change: “refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period of time. Climate change is due to natural processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere” (IPCC, 2001).

Climate variability means variation in the mean state of the climate and inconsistency, on temporal and spatial scales, including short-term variations that occur throughout the year. Climatic variability is the sort of variations (temperature, rainfall, occurrence of extremes) (Ziervogel *et al.*, 2006).

Vulnerability to climate change: The scientific use of “vulnerability” has its roots in geography and natural hazards research but scholars from different fields of specialization have conceptualized it in different ways. According to IPCC (2014) vulnerability is “the propensity or predisposition to be adversely affected”. It is also considered as a characteristic of all people, ecosystems, and regions confronting environmental or socioeconomic stresses. The IPCC (2001) report defined it as a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and adaptive capacity. The definitions indicated that vulnerability is a combination of institutional, economic, environmental, social and cultural factors as well as it combines the risk, impact and ability of the communities to adapt.

Vulnerability assessment evaluates the system’s potential exposure to the climatic risk, the sensitivity of the system to that climatic risk, and the system’s capacity to adapt to the climate risk (Fussel and Klein, 2006). The components of vulnerability in the same report are defined as: Exposure is the manifestation of climate change (the nature and degree to which a system is exposed to significant climatic variations). Sensitivity is the extent to which system is positively or negatively affected for its’ exposure to climate stressors. Adaptive capacity is “the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."

Climate change adaptation strategies: The general idea of adaptation is that organisms can be modified to face sustained changes in their environment and it corresponds to the modification of an existing function (Prablanc *et al.*, 2020). Climate change adaptation refers to the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2001). 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.

Forest-based households: Forest is a natural resource consisting of biodiversity, water resources and forestland with various tree species. It is a source of multiple ecosystem services (Chazdon *et al.*, 2016). People who live in proximity to forests are usually involved in agricultural practices either within or outside the forest, and regularly use and market forest products (timber, fuel wood, NTFPs) for subsistence purposes and income generation (Rao, 2016). Rural communities living adjacent to forested areas are dependent on forest resources for their livelihoods with low contribution of other sectors. Thus, forest-based households live in proximity to forested areas and make major livelihoods from forest and its resources.

Non-forest-based households: After the 1950s, the rapid population growth and human civilization have resulted in a fast transformation of the natural habitats into a human dominated landscape (Hailu *et al.*, 2020). Anthropogenic effects such as deforestation, agricultural land expansion, booming population, and expansion of settlement area degraded and depleted forests in developing countries (Mengist *et al.*, 2021; Tsai *et al.*, 2019). As a result, it is common to see extensive forest fragmentation which is attributed to the forest resources to be limited in fragmented forest patches (Farah *et al.*, 2017). In anthropogenic or natural cases, most areas have limited access to dense forest. Accordingly, non-forest-based households are the farmers who are engaged on mixed farming practices with traditional and or newly introduced production techniques with minor contribution of other sectors.

2.2. Theoretical Review

2.2.1. Theoretical approaches to assess climate change induced vulnerability

Vulnerability assessments were held by different theories of what causes and constitutes vulnerability i.e. factors that determine the potential for a system to be harmed. These factors are usually described as ‘external’ or ‘internal’ to the system being assessed i.e. biophysical (climate) and socioeconomic in character (Fussel, 2007). Different disciplines have combined these vulnerability factors to propose different theoretical approaches for explaining how vulnerability is shaped and therefore how it can be reduced.

The biophysical approach is related with exposure and sensitivity of natural environment to climate change. It assesses the level of damage that a given environmental stress causes on both social and biological systems (Olesen *et al.,* 2000). The biophysical factors (topography, exposure, environmental conditions, and current climate) determine the vulnerability of households to climate change (Fussel, 2007). The physical manifestations of climatic variability and change such as drought, floods, storms, heavy rainfall, and long-term changes in the mean values of climatic variables resulted lives lost, people affected, and economic losses. The vulnerability of a human system is determined by the “nature of the physical hazard(s) to which it is exposed, the likelihood of occurrence of the hazard(s), the extent of human exposure to hazard, and the system’s sensitivity to the impacts of the hazard(s).”

Biophysical vulnerability is concerned with the ultimate impacts of a “climatic event, and is often viewed in terms of the amount of damage experienced by a system as a result of an encounter with a hazard”(Brooks, 2003). Rao *et al.,* (2016) assessed the district level vulnerability of agriculture to climate change and use annual rainfall, maximum and minimum temperature, frequency of heat wave, and other climatic events. The focus of this approach is solely on physical damages, such as impact on yield makes it criticized. A study on the impact of climate change on yield can show the reduction in yield, but do not show what that particular reduction means for different people.

Vulnerability does not only depend on the likelihood that a system will encounter a particular hazard; rather, it results from the interaction of various socio-economic processes.

Socioeconomic vulnerability factors are those that relate to economic resources, the distribution of power, social institutions, cultural practices, and other characteristics of vulnerable system (Fussel, 2007). The degree of vulnerability is depended on the intrinsic socio-economic characteristics of a system regardless of whether it is exposed to external stresses and shaped by non-climatic factors and multidimensional inequalities (Yimam and Holvoet, 2023). An array of conditions and resources influences adaptive capacity, including structures and institutions (Alare *et al.*, 2022) economic resources, social capital, awareness and training (Deressa, 2010).

The socioeconomic vulnerability assessment approach principally emphasizes identifying the socioeconomic and political status of households (Adger, 1999). The socioeconomic factors such as response capacity (average household income, social networks, and access to information) determine the vulnerability of households to climate change (Fussel, 2007). Moreover, individuals in a community often vary in terms of education, gender, wealth, health status, access to credit, access to information and technology, social capital, political power, and so on. These variations are responsible for the variations in vulnerability levels due to the internal state of a system that exists within a system (Kelly and Adger, 2000). Thus, vulnerability is considered to be constructed by society.

This approach revealed the socioeconomic factors which contributed for the vulnerability of society. However, there are some drawbacks. It suppressed the environment-based intensities, and climate change and variations. It also didn't account the availability of natural resource bases potentially counteract the negative impacts of the environmental shocks. The analysis of vulnerability which takes into account the inherent socioeconomic characteristics helps to understand "who is vulnerable and why" remains scanty. Although, the two approaches are completely different theoretically, social approach cannot be completed without analyzing biophysical vulnerability since vulnerability is hazard specific. Hence, it is rational to integrate both the approach to give a complete picture of vulnerability. In climate change vulnerability research, studies often strive to have an 'integrated' perspective, to address both the biophysical and social dimensions of vulnerability in theory (Fussel and Klein, 2006). The integrated approach corrects the weaknesses of other approaches.

2.2.2. Theories of climate change adaptation strategies

Households implement adaptation measures to reduce the effects of climate change. It can be seen as a component of technology that has been implemented to improve household livelihood, agricultural output, and production in addition to lessening the consequences of climate change. Although there aren't well-developed theories that examine adaptation practices to climate change, adoption theories can be customized to examine adaptation practices. Therefore, the next section discussed tailored adoption theories to look at the adoption of adaption strategies.

2.2.2.1. ***The theory of reasoned action (TRA)***

This theory was created by (Fishbein and Ajzen (1977). and discussed the factors that influence an individual's behavioural intention. This theory proposes that a person's attitude toward a behaviour and subjective norm have an impact on his intention to accept an innovation (Sadeghi and Farokhian, 2011). The intention behind a person's actions determines that person's conduct. An individual's favourable or negative beliefs about engaging in certain behaviour are reflected in their attitude towards it. According to Hillmer (2009), this theory also holds that the desire to act is determined by the result of the attitude measures and subjective norms. A person will approach engaging in an activity with a positive attitude if they believe the conduct will have a favourable result, and vice versa.

Beliefs about what other people would think of an action, or the perceived effects of social pressure on an individual to engage in or refrain from engaging in a behaviour, are known as subjective norms. The individual's incentive to follow the specific references stems from his belief that certain people or groups think he should or shouldn't engage in the action (Sadeghi and Farokhian, 2011). Positive behaviour is therefore expected if societies view it as positive, as this will push individuals to live up to social expectations, which in turn will lead to the expectation of a positive subjective norm.

Adopting climate change adaptation measures also revealed households employed measures if they have clear understanding positive attitude toward that specific technology. Moreover, some measures were also subject to the view of groups or community towards those measures. Accordingly, households implemented different indigenous and technology oriented measures to reduce climate change impacts. Tun *et al.* (2017)stated that reducing vulnerability to climate change can be achieved through the smallholder farmers themselves taking adaptive actions or by governments implementing policies aimed at promoting sustainable adaptation measures.

2.2.2.2. ***Theory of perceived attribute***

According to the theory, if potential adopters believe that an innovation can be tried on a limited basis before adoption, that it offers observable results, that it has an advantage over other innovations, that it is not complex, that it is compatible with current practices and values, or any combination of these, it will be adopted at a higher rate (Hillmer, 2009) . Regarding the aforementioned, it is crucial to understand that perception is subjective and varies throughout adopters; hence, it would be unjust to categorize certain people as low adopters because what one person considers significant may not be significant to another. Put another way, in the social structure, farmer B may consider something that farmer A considers significant to be less significant.

Therefore, it is very important to understand the farmers' perceptions towards a specific technology, for development and technology dissemination. Households' recognition about the effects of climate change on their livelihoods obliged them to take different measures. Belay *et al.* (2017) indicated crops like barley, peas and beans were performing poorly in the highland areas of Ethiopia, and some farmers had already reduced the portion of land allocated for such crops and majority of the farmers opted to grow other crops. Additionally, cultivation of drought tolerant crops, and intensification of agricultural production by using more inputs especially fertilizer per unit area is becoming popular (Sedebo *et al.*, 2021).

2.2.3. Frameworks on determinants of climate change adaptation strategies

Sustainable livelihood framework: ″A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living″. The sustainable livelihoods framework presents the main factors that affect people's livelihoods, and typical relationships between these. Sustainable livelihood approach is serving as an instrument for investigating poor people's livelihood, whilst inspecting the main factors of influence. It is used to understand how people's adaptation options are shaped by different factors including institutions, organizations, policies, and legislation. These institutional arrangements, political organizations and power relations may generate on their own different levels of access to the livelihood resources, which in turn will determine different combinations of livelihood activities to be pursued and their possible outcomes (Scoones, 1998)

The framework provides insights on how people use a range of livelihood assets (natural, social, financial, and human capitals) to devise adaptation options within the goal of achieving positive livelihood outcome (DFID, 1999). Under livelihood outcome, reduced vulnerability is one component which is the result of livelihood strategies. This is similar with the climate change vulnerability concept, in which better adaptation strategies reduced vulnerability. The framework also indicated livelihood strategy is determined by structures and processes and different physical, financial, human, social, and natural assets. Accordingly, sustainable livelihood literature traces the constraints in the use of adaptation options to institutions, power, inequality and other social factors (Adger, 2006).

DFID (1999) indicated assets such as financial capital, social capital, physical capital and natural capital are influenced by the institutions and organizations through types of policies and legislation that shape adaptation options of people. The framework further explains the ability to pursue different adaptation options is dependent on how human capital (skills, knowledge and good health), ownership of natural resources (land and forest), availability of physical assets (basic infrastructures) and financial capital (credit facilities, household income) enable people to pursue different adaptation options to moderate vulnerability which is caused by climate change.

2.3. Empirical Review

2.3.1. Climate change induced vulnerability of smallholder farmers

Smallholder farmers in Ethiopia are vulnerable to climatic change mainly due to their high exposure to climatic events, sensitivity and low adaptive capacity. Additionally, high dependence on rain-fed livelihood activities makes smallholder farmers vulnerable to the climatic events (Mohammed *et al.*, 2018). Accordingly, the finding of Tessema & Simane (2019) confirmed that 96.8% and 56% households perceived as there was an increasing trend of temperature and decreasing trend of precipitation respectively in the past 20 years. Abebe (2017) finding, also revealed the mean annual temperature was increased between 0.028 ◦C and 1.65 ◦C from 1955 to 2016 and Samy *et al.* (2019) also reported a significant decreasing trend in rainfall in the southwestern part of the upper Blue Nile basin. Rurinda *et al.* (2014) noted that increased rainfall variability together with rising temperatures reduces soil moisture availability and increases the risk of crop failure. Amare & Simane (2017) confirmed farmers are most vulnerable for the highest percent of death, number of severe drought and flood and variations in maximum monthly temperature and precipitation.

Tessema & Simane (2019) indicated that the smallholder farmers with the highest average number of drought events and flooding are most vulnerable compared with their counterparts. In addition, Asrat & Simane (2017) confirmed "farm households in the dry lowland faced more frequent challenge (7 times), crop disease/pest outbreaks (4 times) and livestock disease (4 times) in the past 10 years compared to those in the wet lowland with frequent challenges (3 times), crop disease/pest outbreaks (3 times) and livestock disease (4 times)" which made the dry lowland agro-ecology and residents more exposed and vulnerable. ″Land degradation due to flash floods, landslides, erosions and lack of efficient agricultural practice" make majority of the households vulnerable to climate change (Amare and Simane, 2017a).

Households those practiced irrigation on the small size of land, less hectare of land under soil and water conservation measures and low crop diversification indicated for high sensitivity of households to climate change risks which resulted vulnerability of households to climate change (Amare & Simane, 2017; Asrat & Simane, 2017). Moreover, smallholder farmers those did not saved seeds and stored crops to grow and consume for the next season and those who struggled more months per year to find adequate food for their families were more sensitive to the impacts of climate change. The finding of Abeje *et al.* (2019) also revealed that the farmers in Aba Gerima had a lower level of food source diversification, no consistent access to water sources and took long time to fetch water compared with farmers in the other watersheds which makes the area relatively more sensitive and more vulnerable to the effects of climate-related shocks.

The contribution of different assets to reduce vulnerability is high and its endowment variation would determine the vulnerability levels differently. The better livestock asset of *Meher* dominated areas (4.79) than *Belg* (3.52) dominated areas make households in *Meher* dominated areas less vulnerable to climate change (Asfaw *et al.,* 2021). Asrat & Simane (2017) also reported the livestock holding is higher in dry lowland agro-ecology (5.57 TLU) than (3.37 TLU) wet lowland agro-ecology with less adaptive capacity of wet lowland. Households those owned small average landholding and cultivated land sizes, and access to credit, have less adaptive capacity which in turn increased households' vulnerability to climate change (Amare & Simane, 2017; Zeleke *et al.,* 2021)

The socio-demographic profile of household also determined the vulnerability of households to climate change and variability. Accordingly, female-headed, households who did not attended agricultural training and school, and old age headed household were more vulnerable to climate change (Abeje *et al.*, 2019). Similarly, Dendir & Simane (2019) confirmed Ezha *Woreda* showed greater vulnerability (0.61) based on the percentage of household heads with no basic education than Cheha (0.52) and Sodo (0.37). Moreover, households who did not used improved seeds, fertilizer and farm chemicals and those who had more time to reach the main road, school, veterinary service, market, health center and water point have less adaptive capacity. Scanty access to infrastructural and socio demographic indicators would also result less adaptive capacity and higher vulnerability (Asrat & Simane, 2017; Asfaw *et al.*, 2021)

Changes in temperature and rainfall patterns would have several implications for the forest communities (Naidoo *et al.,* 2013). The changing climate coupled with human-driven rapid land-use changes lead to losses of biodiversity and alteration of ecosystems. Birhanu (2022) identified farmers are susceptible to climate variability because their livelihood depends on natural resources. The availability of such natural resources depends on climatic variables such as rainfall and temperature. The vulnerability of ecosystems and people to climate change is interdependent but differs substantially among and within regions (IPCC, 2022). Low livelihood diversification, forest degradation, access restrictions and conflicts with other users makes forest communities susceptible to climate change (Pavageau *et al.*, 2018).

The vulnerability of forest-based rural communities is not merely related to the direct and indirect effects of climate variability and change (Quinn *et al.*, 2011). Poor socioeconomic conditions reduce the ability of households to deal with climate risks, shocks and stresses (Shah *et al.*, 2013). They lack sufficient adaptation capacity to cope with climate variation and extremes, and have limited access to alternative sources of income (Huong *et al.,* 2019). Naidoo *et al.* (2013) also indicated underdeveloped infrastructure, institutional services, employment opportunities and dependency on forest resources for income and subsistence make forest households vulnerable. Large dependence on natural resource diverted farmers' attention away from the regular farm activities and enhance their exposure to climate change induced risks (Asrat and Simane, 2017).

2.3.2. Adaptation strategies of smallholder farmers

Global warming beyond 2℃ will place nearly all of sub-Saharan Africa cropland substantially outside of its historical safe climate zone (Kummu *et al.*, 2021) and the future sustainability of the sector depends on the types of adaptation strategies used by farmers (Alemayehu and Bewket, 2016). There are options considered as effective in reducing climate change risk. The mostly implemented strategies in farming households include crop diversification, intercrops, crop rotation, and change in crop variety, and planting early maturing crops (Snowdon *et al.*, 2021).

Smallholder farmers in Ethiopia used a range of strategies against long term impacts of climate change. Belay *et al.* (2017) reported farmers reduce the impacts of climate change through changing crop planting dates and crop varieties, maintenance of grain reserves, crop diversification, and using early maturing crop varieties. In the highland areas of Ethiopia, crops like barley, peas and beans were performing poorly and some farmers had already reduced the portion of land allocated for such crops and majority of the farmers opted to grow other crops like teff and maize. Cultivation of drought tolerant crops such as Enset (Ensete ventricosum) as a source of both food and livestock feed was becoming popular. In addition, intensification of agricultural production by using more inputs especially fertilizer per unit area, fruit and fodder tree planting, soil and water conservation practices, and using crop residues as livestock feed were also practiced.

The smallholder farmers in Muger Sub basin employed soil and water conservation measures, small-scale irrigation, agronomic practices (using drought-tolerant and/or improved crop varieties and crop diversification) and livelihood diversification. The use of soil and water conservation measures (28.7%) and small-scale irrigation (27.4%) were the two most widely used adaptation strategies. About 14% engaged in diversifying their livelihood strategies and (13.6%) of smallholder farmers were engaged in agronomic practices in adapting to the effects of climate variability and change (Amare and Simane, 2017b).

The finding of Sedebo *et al.* (2021) reported smallholder farmers adopted practices like soil and water conservation techniques (46.35%), increased chemical fertilizer use (45.42%), adjusting planting or harvesting dates (42.52%), crops diversification (40.92%), crop rotation (40.33%) and intercropping (2.45%). Similarly, the finding in Burie and Ale district showed smallholder farmers practiced soil and water conservation (73.5%), changing planting dates (64.4%), implemented agro forestry practices (62.9%), beekeeping (79.3%) and planting shade trees (62.2%) as adaptation strategies to climate change (Tadesse and Madduri, 2020).

Forests assist adaptation to climate change through provision of ecosystem services that support sustainability of other sectors. Adaptation options for forests ecosystems include provincial and community forest management, agro ecological farming, developing agroforestry systems, and utilizing traditional knowledge for conservation (Aju *et al.,* 2015). The conservation of forests regulate air, climate, water, erosion, disease, pest, and natural hazard, and support soil formation, nutrient and water cycling (Lukina *et al.,* 2021). Moreover, animal husbandry in Ethiopia relies on free grazing mainly forest grazing for fodder. Forests therefore support animal husbandry and income diversification (Wubalem *et al.,* 2017).

The adaptation strategies reported by households of forest dependent communities are collection of non-timber forest products (Basu, 2018). The major NTFPs are food, medicines, fodder, coffee, honey and bee wax, bamboo, fibers, spices, etc. The goods from forests help households to diversify their livelihood portfolio and assist households in the rural and agricultural sector to reduce their vulnerability to climate change. The Ethiopian government integrated with different NGOs and established community centered forest management to protect forest and insure the ownership and utilization of NTFPs by local farmers (Taye, 2020). Forest management is essential to increase forest ecosystem services and reduce vulnerability of communities to climate change.

2.3.3. Determinants of climate change adaptation strategies

The choices of adaptation measures are determined by several socio-economic, biophysical and demographic factors (Ashraf *et al.*, 2014). Atinkut & Mebrat, (2016) identified that sex and age of household heads, access to extension services, agro ecological location, farm and family size and perception on temperature significantly determined choice of adaptation strategies to climate change through using MNL model. Similarly, Belay *et al.* (2017) investigated determinants of smallholder farmers' adaptation decisions through using similar model and indicated that education, family size, sex, age, livestock ownership, farming experience, frequency of contact with extension agents, farm size, access to market, access to climate information and income were the key factors of determining farmers' choice of adaptation practices.

Adimassu & Kessler (2016) employed MVP model to determine coping and adaptation strategies to declining rainfall and crop productivity in the central rift valley of Ethiopia and reported access to resources, labor, knowledge, access to information and social capital were significant determinants of choice of coping and adaptation strategies. Sani *et al.* (2016) used similar model and indicated literacy status of household head, family size, distance from the market center, livestock ownership, farm income, frequency of extension visit, access to credit and land holding significantly affected climate change adaptation strategies. The Heckman Probit model of Basu (2018)showed that the age of household head, farm income, forestry income, temperature and family size positively and significantly influenced the adaptation options of forest communities to climate change.

Marie *et al.* (2020) revealed that farmers educational level, age, sex of the household head, farm income, access to extension service, access to credit and climate information, and agro-ecological settings were the most important determinant factors that significantly affected the choice of farmers' adaptation strategies to climate change through using MNL model. Weldegebrial *et al.* (2020) also reported that households' adaptation strategies to climate change was found positively and significantly affected by education, livestock holding, extension services, and households' perception to climate change, but age of the household head and distance to market were found negatively and statistically affecting smallholder farmers' adaptation strategies to climate change.

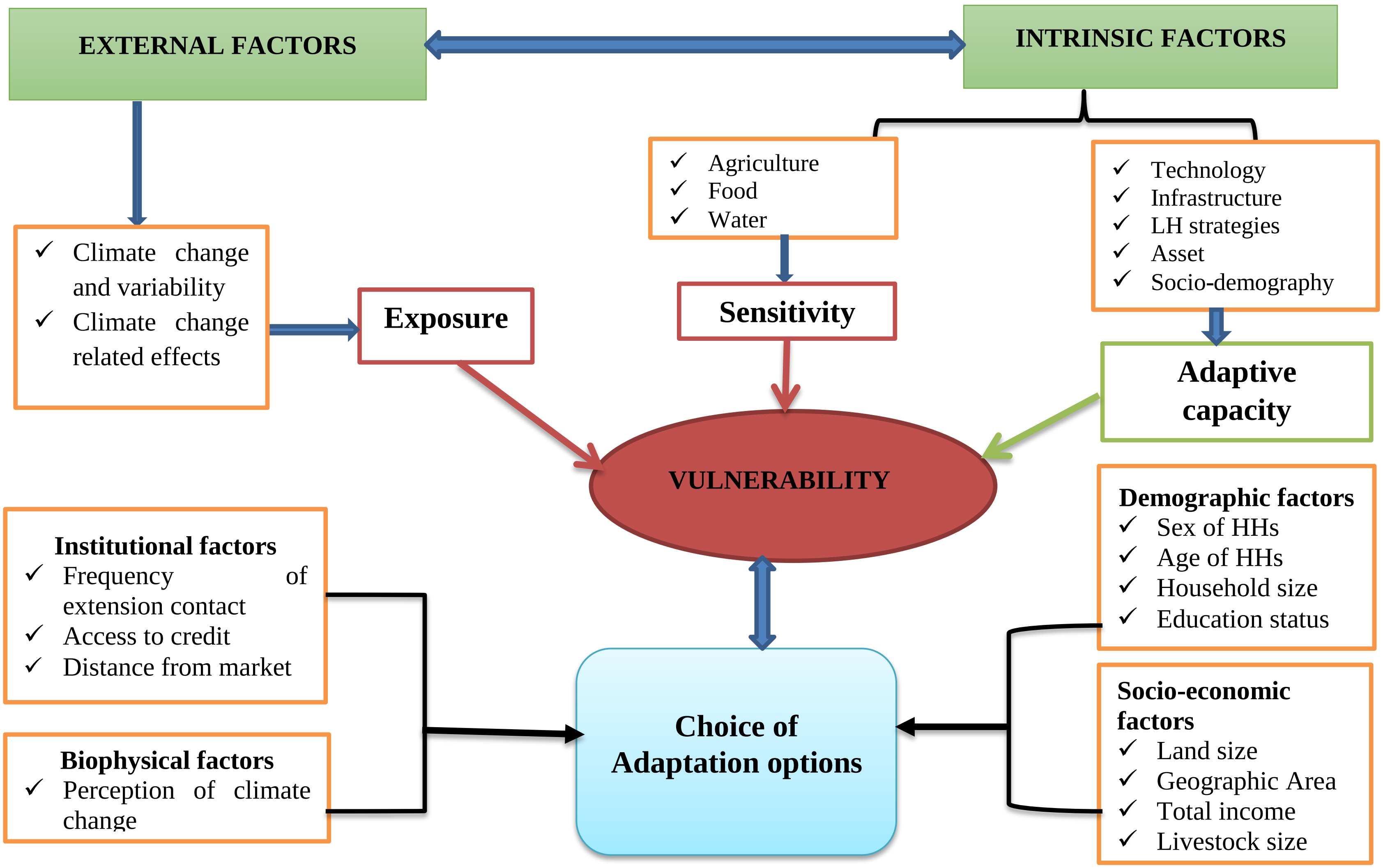
2.4. Conceptual Framework

The conceptualizations of vulnerability have evolved through various research traditions. In the climate change vulnerability context, interdisciplinary approaches are often claimed to be essential in order to incorporate information from climate and non-climate stressors that affect the location, population, or sector that is going to be assessed (Fussel and Klein, 2006). Non-climate and climate stressors can interact in a variety of ways, with the former exacerbating or reducing the impact of the latter, and vice versa. Considering both types of stressors and their interactions in an assessment ensures broader understanding of the drivers of vulnerability.

The IPCC (2014) report conceived vulnerability as the "propensity or predisposition of a system to be adversely affected including sensitivity or susceptibility to harm and lack of capacity to adapt the risks of climate change, which considered only the intrinsic and non-climatic factors; but the IPCC (2001) report included the exposure component which is seen as an external factor. Thus, climate vulnerability has been conceptualized in terms of integrated relationship between exposure (external), sensitivity and adaptive capacity (intrinsic) factors.

The households are presumed to have taking the adaptation strategies in response to their vulnerability to climatic and non-climatic factors. Farmers took certain measures to adapt the climate change from a number of adaptation options and the measures they employed have influences on their vulnerability. Finally, the choice of particular adaptation measures is subject to various factors (Weldegebrial *et al.*, 2020). The following conceptual framework depicted the most important variables of vulnerability, choice of adaptation strategies to climate change and variability and its' determining factors.

Figure 1: Conceptual framework



Source: Own sketch by analysing literatures

3. RESEARCH METHODOLOGY

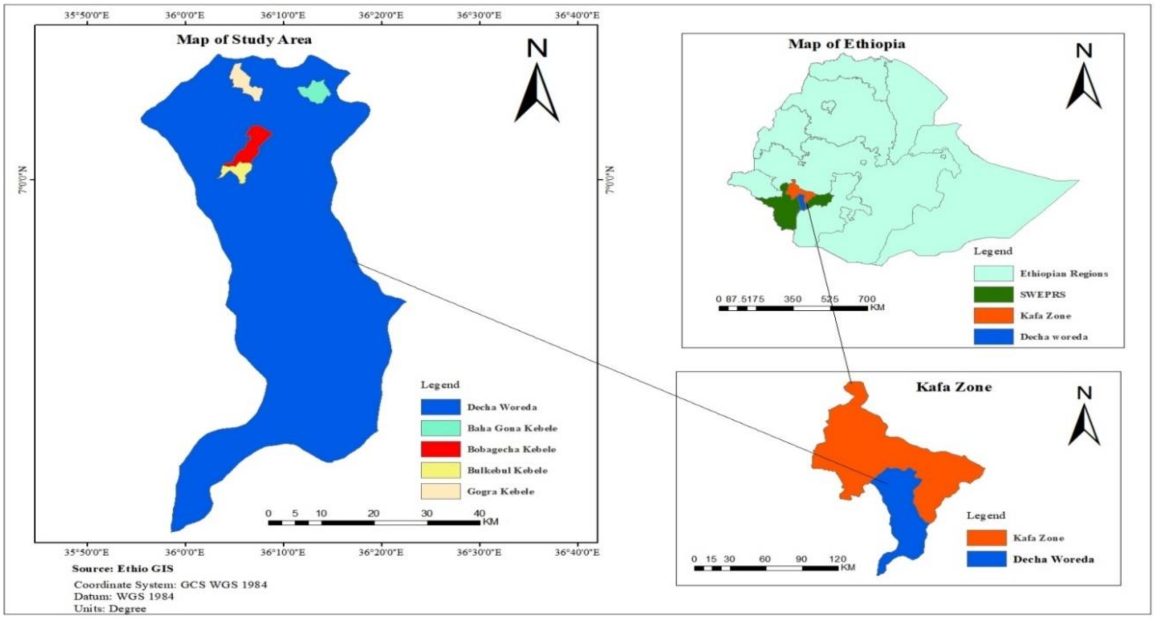
3.1. Description of the Study Area

The study was conducted in Decha district of Kaffa Zone which is astronomically located between $7^{0}0'0''$ North latitude and $35^{0}50'0''$ to $36^{0}40'0''$E East longitude in South Western Ethiopia (Figure 2). It shares borders with Gimbo *woreda* in the North, Goba *Woreda* in the South, and Cheta, Telo, Adiyo woredas in the Northeast. The woreda is situated 24 km from Bonga (zonal capital) and 473 km South West of Addis Ababa. The altitudinal variation ranges from 800-2500 masl. The annual average temperature ranges from 12.4^{o} c –26.8^{o} c (Wogayehu *et al.*, 2016). The warmest months are February, March and April while the coldest months are July and August.

In the rural area, life is still in primitive conditions. Public services such as schools, health facilities and other services are at the initial stage. More than 70% of rural children do not attend any form of schooling and unemployment is subsequently very high (Wolde and Tolossa, 2019). More than 90% of the inhabitants’ livelihoods depend on subsistence farming, the sale of coffee, forest honey and use of natural resources. Different types of cereal crops, including the local Ethiopian grain species teff (Eragrostis *teff*), legumes, Abyssinian banana (Ensete ventricosum), and spices and cash crops are cultivated in the area (Chernet, 2008).

Crop production system of the area is traditional and rain-fed with limited application of inputs. The most common livestock reared in the area is cattle followed by poultry, sheep and goats. Wild coffee harvesting has been practiced over centuries; complex tenure arrangements and traditions and rites have been developed. The cloud forest of the area forms a carbon sink of superregional importance, and makes an important contribution to the livelihoods of people in the area. It provides coffee, a variety of commercially valuable spices and honey from wild bees. Additionally, local communities directly use resources from forest like construction materials, tree ferns, climbers, bee forage and traditional hanging beehives, firewood, charcoal, bamboo, and medicinal plant collection (Filho *et al.,* 2019). However, the ecosystems are threatened by overexploitation and climate change (Fekadu *et al.,* 2020).

Figure 2: location map of study area



3.2. Research design

Research design provides specific direction that guides the researcher to link conceptual research problems to relevant and practicable empirical research. To explore the factors of climate change and variability induced vulnerability and adaptation strategies of forest-based and non-forest-based households a cross sectional research design was used. The qualitative and quantitative research approach was employed by taking a cross-section of data at only one time with regard to the study population. The quantitative approach is used to analyse the data that was collected from sampled farmers through an interview by using semi-structured questionnaire. The qualitative method is used to analyse the information obtained from focus group discussants, and key informants.

3.3. Sampling Techniques, and Sample Size Determination

The study employed multi stage sampling techniques. In the first stage, Decha district was selected purposively due its vulnerability to climate change and variability and consisted forest-based and non-forest based households. Secondly, total *Kebeles* found in the district were stratified into forest-based and non-forest based livelihood dominant *Kebeles*. Accordingly, 28 forest-based and 12 non-forest based *Kebeles* was identified. The *Kebeles* were stratified depending on the information from the district agriculture, cooperative, and environment protection office through identifying the degree of households' use of forest resources. Thirdly, random sampling technique was used to select study *Kebeles* from each stratum. Total of four *Kebeles*, two from each stratum was selected. Lastly, the sample respondents were selected through a simple random sampling technique. The list of household heads obtained from the *Kebeles* served as sampling frame.

The total sample size was determined by using the formula of Kothari (2004).

$$n = \frac{Z^2 * p * q * N}{e^2(N-1) + Z^2 * p * q}$$

n = total sample size

N = represent the total rural household heads

Z= Standard variation at a given confidence level (95%=1.96)

P= Estimated proportion of the target population (0.55)

q = 1-p which is equal to 0.45

e = Margin of error (5%)

The numbers of respondents were taken based on probability proportional to the population size of each Kebele (Kothari 2004).

$$n = \frac{Ni}{N} * ni$$

Where n = total number of samples taken from each *Kebele*;

Ni= the total number of HH in each *Kebele*,

N= total number of HHs in all selected *Kebeles*;

ni= the determined sample size

Total of 312 respondents, 170 from forest-based, and 142 from non-forest based households were selected. The list of household heads living in selected *Kebeles* was used as a sampling frame.

Table 1: Sampled study *Kebeles*, total number of HHs and determined sample size

Selected *Kebeles*	**Category**	**Total Number of HHS**	**Sample size**
Googira	Forest-based	542	97
Beha-Gona	Forest-based	406	73
Bulkabul	Non-forest based	327	59
Boba-Gecca	Non-forest based	462	83
Total		**1737**	**312**

3.4. Types and Sources of Data

Qualitative and quantitative types of data were gathered from primary and secondary sources. The primary data was collected from the household heads of forest-based and non-forest based livelihoods; and the qualitative data was collected from community representatives and knowledgeable persons through FGDs and KII. Secondary data was collected from published and unpublished sources, document analysis of the agriculture and natural resource development offices. The recorded meteorological data was taken from nearest meteorology station. Focus group discussants were men and women community members of sampled Kebeles; and key informants included experts of district agriculture, cooperative, and environment protection office.

3.5. Methods of Data Collection

The primary data was collected through using semi-structured questionnaire while qualitative data was collected through FGDs, and key informant interview using qualitative checklist. Secondary data was collected by analysis of published and unpublished documents. The collected data emphasized on the IPCC determining factors of vulnerability (lower adaptive capacity, higher sensitivity and exposure), the implemented adaptation strategies and its determinants. The questionnaire was developed by English language and then translated to Kafinono language.

Primary data collection methods

Interview schedule

The randomly selected household head was interviewed using a semi structured questionnaire containing both open ended and closed ended questions. The enumerators who can fluently speak and write local language and have in-depth knowledge about the culture of local peoples were selected and get training on the data collection procedure. Pre-test of questionnaires was undertaken with randomly selected farmers to ensure the quality of questioner. After that, the enumerators conducted the survey from side to side supervision of researchers.

Focus group discussion

In order to collect the necessary qualitative data for the study, focus group discussions were held with a purposely selected group of men and women farmers. A total of four FGDs, each with six to ten men and women members, were undertaken to collect essential information. The FGDs was selected in consultation with development agents of the *Kebele*[1], and all men and women participants were encouraged to contribute their own ideas by intensive management of researchers to reduce the dominance of one group. Open-ended questions about climatic change scenarios, contributing socio-economic and biophysical factors of vulnerability, and adaptation strategies of households were discussed through facilitation of the researcher.

Key informant interview

In addition to household survey and focus group discussion, experts from Decha district agriculture, cooperative, and environment protection office were selected to give in-depth, information about the climate change manifestations and its effect, factors of vulnerability, and implemented adaptation strategies. In addition, key informants were posed to point out the difference in occurrence of climate change related effects, and variation of climate change variables. Moreover, they informed the spatial variation of households' capacity to deal with climate change and the systems sensitivity to climate change. A total of 9 key informants from natural disaster prevention unit, crop production unit, natural resource management unit, and environmental protection unit were selected to conduct key informant interview until the information is saturated by using checklist.

Secondary data collection method

Relevant secondary data for this study was gathered by reviewing various documents and literature, including journals, books, articles, and *Woreda* reports. Moreover, meteorological data of precipitation, maximum and minimum temperature of 2003-2022 was collected from the proxy stations.

[1] Kebele is the smallest administrative unit of Ethiopia, contained within a district.

3.6. Method of Data Analysis

The collected quantitative data were analysed through using descriptive statistics, inferential tests and econometric model. Qualitative data was analysed by thematic and content analysis. Statistical Package for Social Sciences (SPSS) version 26, Stata 15 and Microsoft excel was used to analyse the collected data from the sampled respondents. The analysed data were presented in table and diagram form.

Descriptive and Inferential analysis

The descriptive statistics (frequency, percentage, minimum, maximum, mean, and standard deviation) was used to analyse households' characteristics. Moreover, the adaptation strategies were analysed by descriptive statistics (frequency, percentage). After running descriptive analysis inferential tests were used to identify the mean difference of variables between two groups. The continuous explanatory variables of vulnerability factors, and household characteristics were analysed by using t-test to identify statistically significant differences in means of variables between two groups. Additionally, chi-square test was used to analyse dummy variables of household characteristics, and adaptation strategies to identify statistically significant differences of variables between two groups.

Methods of Vulnerability Assessment

Vulnerability assessment is mandatory to understand the vulnerable systems, and households. There are different vulnerability assessment methods. The econometric and indicator method of vulnerability assessment were extensively used (Hahn *et al.*, 2009; Deressa, 2010). The econometric method "uses household level socio-economic data to analyse the level of vulnerability and welfare loss due to shocks" (Hoddinott and Quisumbing, 2003). While indicator method selects indicators from a diverse set of potential indicators and merge them to identify the levels of vulnerability at different scale of analysis.

A composite indices capture the multi-dimensionality of vulnerability in the integrated form through combining both biophysical and socioeconomic indicators (Amare & Simane, 2017; Mekonnen *et al.*, 2019). This study employed similar method based on the selected key indicators to indicate the level of vulnerability of households. The indicators which represent both households were selected based on extensive review of literatures that provide insight into the nature and causes of vulnerability and was verified with insights gained from development agents. It is the most common method adopted for quantifying vulnerability in the global change community (Gbetibouo *et al.*, 2010). It is mandatory to assign weights to the selected key indicators to assess the vulnerability of households. Thus, indicators were assumed as they have equal contribution to the vulnerability of households (Gbetibouo *et al.*, 2010; Asrat & Simane, 2018).

Two methods of vulnerability assessment were employed to identify the vulnerable areas through using selected key indicators. Firstly, LVI methods of vulnerability assessment which is robust and flexible tool to measure vulnerability of livelihood to climate change was used (Hahn *et al.*, 2009). It uses different indicators to assess vulnerability of households. Then, the IPCC's vulnerability index (LVI-IPCC) which measures vulnerability as a function of exposure, sensitivity, and adaptive capacity was also employed to identify the vulnerable households (Amare and Simane, 2017a). The major components used for this study are climate change related effects, climate change and variability, agriculture, food, water, technology, infrastructure, asset, livelihood strategies, and socio-demography; and 40 sub-components were used to assess vulnerability of forest-based and non-forest based households.

As the sub-components were measured on a different scale, it is mandatory to standardize as an index through adopting computation of the Human Development Index by using the following equation 1.

$$\text{Index } S_n = \frac{S_n - S_{min}}{Smax - Smin} \ldots\ldots\ldots\ldots\ldots\ldots \text{ equation 1}$$

Where, S_n= the actual value of the given indicator for n-based households; Smax and Smin are the highest and lowest values of the given indicator. But, if the inverse of indicator is considered to assess vulnerability, the above formula was changed to

$$\text{Index } S_n = \frac{S_{max} - S_n}{Smax - Smin} \text{ or 1- Index } S_n \text{ of equation 1} \ldots\ldots\ldots \text{ equation 2}$$

After standardizing each indicator, the value of each major component was calculated using equation 3.

$$M_n = \frac{\sum_{i=1}^{n} Sn}{n} \text{.............................equation 3}$$

Where M_n= one of the major components for the n-based households; Sn represents the sub-components, that make up each major component, and n denotes the number of sub-components in each of the major component. Once values for each of the major components for the n-based households were calculated, they were averaged to obtain the community-level LVI through using equation 4.

$$LVI_n = \frac{\sum_{i=1}^{n} W_{mi} M_{ni}}{\sum_{i=1}^{n} W_{mi}} \ldots\ldots\ldots\ldots\ldots\ldots \text{ equation 4}$$

Where LVI_n= the Livelihood Vulnerability Index for n-based households; W_{mi} = number of sub components that makes up each major component; M_{ni}= one of the major components for n-based households.

LVI-IPCC diverges from LVI but instead of using the weighted averages of all major components as LVI approach, the weighted averages of the major components in LVI–IPCC were calculated based on the three contributing factors explained from the IPCC vulnerability definition. So, the contributing factors (exposure, sensitivity and adaptive capacity) were calculated using equation 5.

$$CF_n = \frac{\sum_{i=1}^{n} W_{mi} M_{ni}}{\sum_{i=1}^{n} W_{mi}} \ldots\ldots\ldots\ldots\ldots\ldots \text{equation 5}$$

where CF_n is contributing factor based on the IPCC (2001) definition (exposure, sensitivity and adaptive capacity) for n-based households, M_{ni} are the major components among the contributing factors, W_{mi} is the number of sub-components that makes up major component, and n is the number of major components in each contributing factor. After calculating exposure, sensitivity and adaptive capacity the three contributing factors were combined as:

$$\text{LVI - IPCC} = (En - An) * Sn \ldots\ldots\ldots\ldots. \text{equation 6}$$

Where LVI-IPCC is the LVI for n-based households expressed using the IPCC vulnerability framework, E is the calculated exposure score for n-based households, A is the calculated value of adaptive capacity for n-based households and S is the calculated sensitivity score for n-based households. For LVI-IPCC, the value was assigned between -1 (lowest or least vulnerable) and 1 (highest or most vulnerable) (Sisay, 2016; Asfaw *et al.*, 2021).

Econometric model

Specifying econometric model depends on the nature of data, and objective of the study (Wooldridge, 2020). The economics model is precise in assessing the relationship between dependent and explanatory variables. Households implemented many strategies to reduce climate change effects. In this case, there are many dependent variables considered to econometric analysis. Scholars used multinomial logit, and multivariate probit model to deal with many dependent variables. Multinomial logit model considers, implemented adaptation strategies are independent of each other and farmers adopt only one strategy at the time (Marie et al., 2020). However, climate change adaptation strategies are sometimes interdependent and farmers can implement multiple adaptation strategies (Huguenin et al., 2009). Thus, after computing descriptive statistics and inferential tests, a multivariate probit model was used to identify determinants of households' adaptation strategies.

Before running the model, the explanatory variables were checked for multicollinearity using variation inflation factor (continuous explanatory variables) and the contingency coefficients (dummy variables). VIF values is below 10 among continuous variables, and contingency coefficient is below 0.75 among dummy explanatory variables (Gujarati, 1995).

Multivariate probit model

The determinants of farmers' adaptation strategies to climate change were identified depending on the assumptions of interdependence of different adaptation practices, suggesting that the decision to adopt adaptation practices is multivariate. The farmer might choose more than one adaptation strategy at a time to deal with a multitude of climate induced risks than adopting a single strategy. The multivariate probit (MVP) model is an appealing model of choice behaviour because it allows a flexible correlation structure for the unobservable variables (Huguenin *et al.,* 2009). The MVP can simultaneously estimate the influence of the set of explanatory variables on each of the different practices, while allowing for the potential correlation between unobserved disturbances as well as the relationship between adoptions of different practices (Belderbos *et al.,* 2004).

The use of climate change adaptation strategies is modelled under the general framework of utility maximization (Nhemachena and Hassan, 2007). The dependent variable in the empirical estimation for this study is the choice of a particular or different adaptation options from the set of adaptation measures. Consider a rational farmer who pursues to reduce the negative impacts of changing climate over a specific time and must choose among a set of '*j*' adaptation options. Hence, the farmer '*i*' decides to use '*j*' adaptation options if the assumed benefit from option '*j*' is greater than the utility from other options stated as:

$$Uij\ \beta j\ 'Xi + \varepsilon j > Uik\ \beta k\ '\ Xi + \varepsilon k,\ k \neq j \text{-------------------eqn 1}$$

Where Uij and Uik are the assumed values by farmer i of adaptation options j and k, respectively; Xi is a vector of explanatory variables that influence the choice of the adaptation option: βj and βk are parameters to be estimated and εj and εk are the error terms. The MVP econometric model was characterized by a set of n binary dependent variables Y_{ij}. The utilization of adaptation options (Y_{ij}) are determined by demographic, socio-economic, institutional and biophysical factors (Xij) and error terms (εij) such that:

$$Y_{ij} = Xij\ '\beta j + \varepsilon ij;\ \text{where } j=1, 2, 3\ldots\ldots n \text{ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ eqn 2}$$

Where Yij = adaptation options undertaken by farmers, Xij is a vector of explanatory variables, βi are conformable parameter vectors, and random error terms εi are distributed as multivariate normal distribution with zero means and unitary variance. Under the revealed assumptions, the farmer practices an adaptation option that generates net benefits and does not practice an adaptation option otherwise; the observable discrete choice of practices to the unobservable continuous net gain variable is related as

$$Yij = \begin{Bmatrix} 1\ if\ Uij > 0 \\ 0\ otherwise \end{Bmatrix} \text{--------------------------eqn 3}$$

In this formation, Y is a dichotomous dependent variable taking the value of 1 when the farmer chooses an adaptation option in question and 0 otherwise (Nhemachena and Hassan, 2007). It is assumed that a rational farmer has a latent variable, which captures the unobserved preferences or demand associated with the choice of adaptation strategy. This latent variable is assumed to be a linear combination of observed household and other characteristics that affect the adoption of adaptation strategy, as well as unobserved characteristics captured by the stochastic error term. Given the latent nature of the variable, the estimation is based on the observable variable Yij which indicates whether or not a household adopt a specific climate change adaptation strategy. Since adoption of several adaptation strategies is possible, the error terms in equation (2) are assumed to jointly follow a multivariate normal distribution, with zero mean value and variance normalized to unity.

The off-diagonal elements in the covariance matrix represent the unobserved correlation between the non-deterministic component of the $j^{th}$and n^{th} types of adaptation strategies. These assumptions mean that equation (*3*) gives a multivariate probit model that jointly represents decision to adopt a particular adaptation strategy.

3.7. Definition and Measurement of Variables and Working Hypothesis

The dependent variables considered for this study were vulnerability of households to climate change, and adaptation strategies undertaken by households to reduce the negative effects of climate change and variability. The first dependent variable was vulnerability of households to climate change, and exposure, sensitivity, and adaptive capacity were independent variables. Functionally, vulnerability is related directly with exposure and sensitivity but inversely with adaptive capacity.

Exposure

The more exposure of households to climate change related effects and climate change and variability components, the highest vulnerability of households to climate change and variability. The exposure components encompassed perception of households about increasing trend of temperature and decreasing trend of rainfall, occurrence of crop pests and diseases, landslides and erosion, erratic rainfall, shifts of crops growing season, drying up of rivers and streams. High occurrence of these climatic events indicated for high exposure of households to climate change and variability (Asrat & Simane, 2017; Tessema & Simane, 2019).

Sensitivity

The highest sensitivity of the given indicators implied for more vulnerability of the systems. The households with more diversified crop, more hectare of cultivated land, and saving seeds for the next growing seasons make households less sensitive to the impacts of climate change (Asrat and Simane, 2017). Households those depend only on family farm for food, more food insufficient months and less saved crops implied for highest sensitivity (Abeje *et al.*, 2019). Additionally, more water related conflict, using natural water for consumption, and inconsistent supply of water suggested for highest sensitivity.

Adaptive capacity

Adaptive capacity and climate change vulnerability is related inversely. The distance from households' home to health centre, school, all weather roads, and veterinary and input-output market services is low; the households' adaptive capacity is high. Access and ownership of assets and utilization of technology reduce vulnerability of households through its contribution for better adaptive capacity. Majorly depending on natural resources as source of household income reduce adaptive capacity while households who additionally work in non-farm and off farm activities have better adaptive capacity. Moreover, female headed households, low adult equivalent, low access to extension services, and illiterate headed households' have low adaptive capacity and high vulnerability to climate change and variability (Amare & Simane, 2017; Asfaw *et al.*, 2021) .

Table 2: Summary of explanatory variables of vulnerability, measurements and hypothesized relationship

Vulnerability Factors	Major components	Sub-components	Unit of Measurement	Hypothesized relationships
Exposure	**Climate change related effects**	HHs reported occurrence of malaria with in the family HHs reported occurrence of flood in the farm HHs reported crop pests/diseases HHs reported drying up of rivers and streams HHs raised the shift of crops growing season HHs reported occurrence of landslides and erosions in their farm	Dummy (1, if yes and 0, no)	High occurrence of malaria, flood, crop pests and disease, dry of rivers and streams, shift of crops growing season, landslides and erosion inferred for high exposure
	Climate Change and Variability	HHs perceived increased trend of Temperature in last 10 years HHs perceived decreased trend of Precipitation in last 10 years HHs reported occurrence of erratic rainfall patterns	Dummy (1, if yes and 0, no)	High perception of increased T°, decreased precipitation and erratic nature of rainfall implied for high exposure
Sensitivity	**Food**	HHs depending solely on family farm for food HHs that do not save crops for future consumption Average months in which HHs were in trouble of getting enough food	Dummy (1, if yes and 0, no) Continuous(Average)	Only depending on family farm, do not saving crops and more months in trouble of getting food implied for high sensitivity
	Water	HH reporting any water related conflict HHs that utilize natural water source for home consumption HHs that do not have consistent water access	Dummy (1, if yes and 0, no)	High report on water conflict, use of natural water and inconsistent water access implied for high sensitivity
	Agriculture	HHs do not save seeds Size of cultivated land (inverse) Crop diversity (inverse)	Dummy (1, if yes and 0, no) Continuous(Ha, Average)	Do not saving seed, small size of cultivated land, and less diversified crops indicated for high sensitivity

Summary of explanatory variables of vulnerability, measurements and hypothesized relationship (Continued)

Adaptive capacity	**Technology**	HHs not used fertilizer HHs not used improved seed HHs not used pesticides and herbicides	Dummy (1, if yes and 0, no)	High use of fertilizer, improved seed, and pesticide and herbicides increase adaptive capacity
	Socio-Demography	Female headed households	Dummy (1, if male and 0, female)	Female headed households, small size of family in AE, low access to extension services; illiterate headed households have low adaptive capacity.
		Family Size (inverse)	Continuous (AE)	
		HHs accessed extension services (inverse) HH heads who do not attended school	Dummy (1, if yes and 0, no)	
	Assets	Size of households farm land (inverse) Size of livestock (inverse) Total annual income of households (inverse)	Continuous (Ha, TLU, ETB)	Large size of farmland, livestock and better income increase adaptive capacity
		HHs owned cash crops (inverse) HHs who do not accessed credit HHs living in houses made of roof/grass HHs do not easily accessed fodder	Dummy (1, if yes and 0, no)	Limited access to cash crops, credit, living in roof/grass house and limited access to fodder reduce adaptive capacity of households
	Livelihood Strategies	HHs mostly depend on income from natural resources HHs who work in non-farm activities (inverse) HHs who work in off-farm activities (inverse)	Dummy (1, if yes and 0, no)	Mostly depending on natural resources, non-engagement in non/off-farm activities reduce the adaptive capacity of HHs
	Infrastructure	Distance from veterinary services Distance from input output market Distance from health centre Distance from school Distance from all-weather road	Continuous(km)	The longest distance reduced adaptive capacity of HHs

The second dependent variable for the econometric model of this study was adaptation strategies to climate change and variability. The choice of adaptation strategy is dummy variable which were valued as 1, for adopters and 0, otherwise. Independent variables used in this study were identified from different literatures regarding about determinants of adaptation strategies to climate change by smallholder farmers. The identified independent variables were categorized as demographic, biophysical, socioeconomic and institutional determinants.

Sex of household head: It is a state of being maleness or femaleness. It is a dummy variable taking a value of 1 if the household head is male and 0, otherwise. Marie *et al.* (2020) stated that being male-headed households used irrigation as an adaptation strategy to climate change than female headed households. Most of the climate change adaptation strategies undertaken in crop based, livestock based and natural resource management based strategies are labour and time intensive in which female headed households are busy with their daily routine and time consuming activities. Therefore, this variable is expected to have positive effect on choice of adaptation strategy.

Geographic Area: It is dummy variable being living in forest-based and non-forest-based areas (1 living in non-forest based area and 0, living in forest based area). The findings indicated that adoption of different adaptation strategies to climate change varied from place to place due to different factors. Accordingly, Amare and Simane, (2017b) identified farming in midland and highland increased use of small-scale irrigation than farming in lowland; whereas farming in lowland increased use of soil and water conservation measures. Alemayehu and Bewket (2017) also indicated smallholder farmers of Basona Werana areas used larger number of adaptation strategies than Menz Gera Meder and Efratana Gidim. Hence, geographic area was hypothesized to have a positive or negative effect on household's adoption decision of climate change adaptation strategies.

Age of household head: Age is a continuous variable that indicates the length of time that household head has existed, measured in years. According to the findings of Belay *et al.* (2017) as the age of household head increased by a year, the probability of households practicing different climate change adaptation strategies were increased. The older section of communities has better understanding about the situation of temperature and precipitation in past and present time. Thus, the older the farmer, there is the probability of adopting climate change adaptation strategies. Hence, the variable is hypothesized to have a positive effect on choice of adaptation strategy.

Education status of household head: It is household heads completed years of schooling for formal education which is a continuous variable. A unit increase in number of years of education increased the likelihood of adopting crop diversification, changing planting date and tree planting as adaptation measures (Belay *et al.*, 2017). Similarly, Birhanu (2022) identified, level of education has a significant and positive relationship with implementation of adaptation practices in warm & moist sub-Weyina dega traditional agro-ecology zone. Therefore, it is expected to have a positive influence on choice of adaptation strategies.

Access to credit: It is about the access of credit by households to employ different adaptation strategies. It is a dummy variable taking a value of 1 if accessed and 0, otherwise. Access to credit increased the financial capacity of households. It has a positive and significant impact on likelihood of using improved crop varieties and soil conservation practices (Seid *et al.*, 2016). This indicated access to credit services increase the probability of using climate change adaptation strategies. So, it is expected to have a positive effect on choice of adaptation strategies.

Distance from market: It is about the distance from the centre of market which is continuous variable measured in kilometre. As the farmers distanced from the market centre they faced shortage of information about the access and affordability of different agricultural inputs. Amare & Simane (2017b) confirmed distance from market significantly and negatively affected use of adjusting planting date and using agronomic practices. Hence, this variable is hypothesized to have negative influences on choice of different climate change adaptation strategies.

Household size: It indicated the number of active aged individuals within a household and it is continuous variable measured by adult equivalent. The adulthood within the family makes the household members to migrate in other area to search for their own jobs and engage their own life. According to Khanal & Wilson (2019) smaller size of household increased the likelihood of adoption. Thus, the variable is expected to negatively determine choice of adaptation strategy.

Land size: It is the size of owned land by a household. The variable is continuous and measured in hectares. As land size of household head increased, the probability of using improved crop varieties, use of mixed cropping and mixed farming increase (Marie *et al.*, 2020). The more the landholding, the more likely the farmers adopt climate change adaptation strategies. Thus, the variable is hypothesized for its positive determination of the choice of adaptation strategy.

Total income: It is continuous variable and measured the amount of income obtained from sale of crop, livestock or livestock products, NTFPs and off/non-farm activities measured in Ethiopian Birr. It indicated for the financial capital of households which is used to procure different agricultural inputs and fulfil all necessary household needs and want. Enough financial capital is mandatory to hire daily labour for farm management and operation, and buy oxen. A unit increase in total income of households increased the probabilities of using farm inputs and soil and water conservation practices (Belay *et al.*, 2017). Hence, it was hypothesized as the increment of total income is expected to positively influence choice of adaptation strategies.

Frequency of extension contact: It is a continuous variable measured in number of extension visit by the development agents per year. The frequently contacted farmers with development agents have better understanding about the production techniques of different crops, livestock management and environment protection. According to the findings of Birhanu (2022) the number of contacts with development agents has a significant and positive relationship with the implementation of adaptation practices to reduce negative impact of climate change. Therefore, frequency of extension contact is expected to have a positive effect on adaptation strategies.

Livestock size (TLU): Livestock size is the total amount of all livestock owned by households. It is a continuous variable measured in tropical livestock unit (TLU). According to Weldegebrial *et al.* (2020) livestock ownership in TLU has positive and significant impact on implementation of adaptation practices. In farming activities, animals such as oxen, cows, donkey, horse, and mule serve as a means of ploughing, harvesting and transporting inputs and outputs. Therefore, it is hypothesized to have a positive effect on choice of adaptation strategy.

Perception of climate change: It is about the behaviour of farmers to understand the increasing trend of temperature and decreased rainfall patterns. It is dummy variable and takes a value of 1, if yes and 0, otherwise. Weldegebrial *et al.* (2020) identified that households' adaptation to climate change was found positively and significantly affected by households' perception of climate change. Therefore, perception of climate change was hypothesized to influence climate change adaptation options positively.

Table 3: Explanatory variables of adaptation strategies, measurements and hypothesis

Explanatory variables	Measurement	Hypothesis
Sex of household head (SeHH)	Dummy (1=male, 0=female)	+
Geographic Area	Dummy (1=NFB, 0=FB)	±
Age of household head (AgHH)	Continuous (years)	+
Education level of household head	Continuous (years)	+
Distance from input and output market	Continuous (km)	-
Household size	Continuous /adult equivalent/	-
Access to credit	Dummy (1=yes, 0=no)	+
Total income	Continuous (ETB)	+
Land size	Continuous (hectare)	+
Frequency of extension contact	Continuous (number)	+
Perception of climate change	Dummy (1=yes, 0=no)	+
Livestock size	Continuous (TLU)	+

3.8. Ethical Consideration and Approval

This study was conducted after its approval by the concerned ethical committees of Jimma University College of agriculture and veterinary medicine. Before collecting the data, the signed Jimma University supporting letter was given to the district administration offices and written permission was obtained prior to collecting data. Collected data was used for only this research purpose and confidentiality of the respondents was maintained. The participants were asked for their willingness to participate in the study. Hence, all participants throughout the data collection time were informed about objectives of the study. In general, the study obeyed all necessary research regulations and ethical consideration.

4. RESULT AND DISCUSSION

This section presents the result of collected data from sampled households of study Kebeles'. It has four sections. The first section focused on description of sampled households. The second section comparatively analysed the vulnerability of forest-based and non-forest-based households to climate change and variability. The third section discussed the adaptation strategies undertaken by forest-based and non-forest-based households to climate change and variability. Lastly, the determinants of households' adaptation strategy to climate change and variability were elaborated.

4.1. Descriptive Statistics

This section presented the description of dummy and continuous variables. Dummy variables included under this section were sex of household head, access to credit services, and perception of climate change, while continuous variables were age, household size, education status, extension contact, livestock size, farm size, total income, and distance from market. These variables were presented by descriptive statistical tools (frequency, percentage, means and standard deviation) to identify the distribution of independent variables. Additionally, chi square ($\chi 2$) and t-test results were presented to identify either there is statistically significant variation of variables between two groups.

4.1.1. Household characteristics for dummy variables

The result indicated that 261 (83.7%) of the sampled household heads were male and 51 (16.3%) were females. About 144 and 117 male respondents were from forest-based and non-forest-based households respectively and 26 and 25 female respondents were from forest-based and non-forest-based households respectively (table 4). About 31.1% of total respondents accessed credit with better access to non-forest-based households (37.3%). The $\chi 2$ analysis also revealed the existence of statistical difference on access of credit between forest-based and non-forest-based households at 5% significant level.

Respondents from both forest-based and non-forest-based areas also articulated the increasing trend of temperature and decreasing and erratic nature of precipitation for more than decades. Accordingly, 65.3% of forest-based and 80.3% of non-forest-based household heads indicated the existence of climate change in their respective areas. 72.1% of total respondents from both areas raised they have faced more hot temperature, shortage and irregular patterns of rainfall from time to time. The χ2 result revealed statistically significant difference on perception of climate change at 1% significant level between groups (table 4).

Table 4: Summary of sampled household characteristics for dummy variables

Variables		**Forest-Based (170)**		**Non-Forest - based (142)**		**Total**		**p-value**	**χ2**
		N	**%**	**N**	**%**	**N**	**%**		
Sex	Male	144	84.7	117	82.4	261	83.7	0.582	0.302
	Female	26	15.3	25	17.6	51	16.3		
Access to credit	Yes	44	25.9	53	37.3	97	31.1	0.030	4.728**
	No	126	74.1	89	62.7	215	68.9		
Perception of climate change	Yes	111	65.3	114	80.3	225	72.1	0.003	8.643***
	No	59	34.7	28	19.7	87	27.9		

*Note: *** and ** indicated for the significance level at 1% and 5% respectively.*

Source: own computation survey data, 2023

4.1.2. Household characteristics for continuous variables

According to table 5 depicted below, eight variables named age of household head in years, household size in adult equivalent, educational status of household heads in years of schooling, frequency of extension contacts in number of extension agent visit per year, size of livestock in TLU, farm size in hectare, total income in ETB, and distance from market in km were analysed to understand the characteristics of households for continuous variables. Additionally, the distributions of these variables across groups were tested by conducting t-test.

Age (years): According to the finding, the average age of household heads of forest-based households was 48.84 with standard deviation of 6.798 and non-forest-based households were 50.61 having the standard deviation of 8.103. The average age of total respondents was 49.64 with standard deviation of 7.460, which indicated most of household heads are on their productive age. However, the t-value (2.099) indicated there is statistically significant variation of age distribution between forest-based and non-forest-based areas at 5% significant level; which inferred more aged household heads were found in non-forest-based areas (table 5).

Household Size (AE): As depicted in table 5, the overall mean value of household size was 5.525 having the standard deviation of 1.148. The average household size of forest-based households was 5.545 with 1.167 standard deviation and non-forest-based households was 5.501 with standard deviation of 1.129 with insignificant variation of family size between forest-based and non-forest-based areas (t-value of 0.330).

Education status (years of school): According to the survey result in table 5, the mean years of schooling of the sample households was 2.20 grades, and the forest-based and non-forest-based households were 2.06 and 2.37 grades respectively. The education level in years of schooling is insignificant and most of household heads living in both areas were illiterate (table 5).

Extension contact: Extension contact was measured by the frequency of development agents visit of households' farm per year. Accordingly, table 5 indicated forest-based households were visited on average of 2.33 times with standard deviation of 2.109 and non-forest-based households were visited on average of 3.56 times having standard deviation of 2.502. The t-test result (4.727) also indicated that there is statistically significant difference of extension agents' contact between two groups at 1% significant level which indicated non-forest-based households have more frequent contact with development agents.

Livestock size (TLU): It indicated the size of livestock ownership measured by tropical livestock unit. The overall mean of livestock in the study area was 5.66 with standard deviation of 1.487. The average livestock size was 5.676 and 5.643 for forest-based and non-forest-based households respectively. The t-value (0.195) is statistically insignificant; this indicated ownership of livestock between forest-based and non-forest-based was nearly similar (table 5).

Farm size: It is the size of total land owned by respondents measured by hectare. Accordingly, forest-based households owned average of 2.844 hectare of land while non-forest-based households owned 2.672 hectare of land (table 5). The total average was 2.766 with standard deviation of .757 which was more than the average of non-forest-based households. The t-test with value of -2.003 indicated there is statistically significant difference in land size ownership between groups at 5% significant level; which indicated forest-based households owned more size of land.

Total income: It is measured by Ethiopian birr earned from selling different agricultural crop products, forest and NTFPs, livestock and livestock products. The average total income of forest-based households was 31279.84 ETB and non-forest-based was 27901.13 ETB. The mean income indicated households of forest-based areas earned better income than non-forest-based ones. The t-value (-2.448**) also confirmed there is statistically significant variation on total income between forest-based and non-forest-based households at 5% significant level (table 5). It indicated forest-based households earn better total income than non-forest-based households.

Distance from market: It is the distance from households' residential site to access for different agricultural inputs and outputs markets measured by kilometre. Accordingly, the average distance to market from forest-based households is 5.994 km with standard deviation of 2.015 and non-forest-based households is 6.620 having standard deviation of 2.731. The t-test result (2.263) indicated that there is statistically significant difference of distance from market between forest-based and non-forest-based households at 5% significant level (table 5). This implied non-forest-based household walk more distance to access market.

Table 5: Summary of sampled household characteristics for continuous variables

Variables	Forest-Based		Non-Forest-Based		Total		t-value
	Mean	**Std.D**	**Mean**	**Std.D**	**Mean**	**Std.D**	
Age (years)	48.84	6.798	50.61	8.103	49.64	7.460	2.099 **
Household Size (AE)	5.545	1.167	5.501	1.129	5.525	1.148	-.330
Education status (years of schooling)	2.06	2.682	2.37	2.480	2.20	2.593	1.067
EXTENCONTACT (number of DAs contact)	2.33	2.109	3.56	2.502	2.89	2.374	4.727***
Livestock size (TLU)	5.676	1.593	5.643	1.356	5.66	1.487	-.195
Farm size (Ha)	2.844	.798	2.672	.696	2.766	.757	-2.003**
Total income (ETB)	31279.84	12052.17	27901.13	12243.998	29742.09	12236.864	-2.448**
Distance from market (km)	5.994	2.015	6.620	2.731	6.278	2.384	2.263**

Note: ***, ** and * indicated for the significance level at 1%, 5% and 10% respectively

Source: Own computation survey data, 2023

4.2. Climate change and variability induced vulnerability of Forest-Based and Non-Forest-Based households

The vulnerability analysis results are presented in two parts. Firstly, the computation of sub and major indicators were done to find the livelihood vulnerability index. Secondly, the LVI-IPCC score for forest-based and non-forest-based households were identified based on vulnerability factors (exposure, sensitivity, and adaptive capacity). Some sensitivity and exposure indicators that reduce vulnerability of households were inverted. Similarly, some indicators which increase the adaptive capacity of households were inverted in LVI computation only, but their positive values were taken for the computation of LVI-IPCC. The LVI indicated information about the components which majorly determine climate change induced vulnerability, and LVI-IPCC indicated which of the three factors (exposure, sensitivity and adaptive capacity) mostly influenced vulnerability of households (Simane *et al.,* 2016).

Results of Livelihood Vulnerability Index

In the livelihood vulnerability index computation, the highest values of indicators, major components, and LVI implied for more vulnerability of households. Table 6 and 7 indicated the contribution of sub-components and major components on the vulnerability of households. The spider diagram of figure 3 has shown the variation of vulnerability of two areas for different major components. Accordingly, it depicted the major components which were scaled from the centre (less vulnerable) to 0.8 (more vulnerable). Figure 3 and table 7 indicated forest-based households scored highest index value in technology, socio demography, livelihood strategies, food, and agriculture components. However, non-forest-based households scored highest index value in infrastructure, assets, water, climate change related effects and climate change and variability components. The LVI score indicated non-forest-based households (0.510) were more vulnerable than forest-based (0.477) (table 7).

The high vulnerability of non-forest based households is stemmed from its low infrastructure access, assets, water, climate change related effects and high climate change and variability components. Different findings indicated, the difference in climate change and variability related events, access to different assets, use of technology, infrastructure, agricultural activities, food, livelihood strategies, and socio-demographic profile made one area more vulnerable than others (Sisay, 2016; Amare & Simane, 2017). The details of indicators, major components, and contributing factors are elaborated in the next section.

Table 6: The indexed value of sub-components for vulnerability factors

Major components	Sub-components	Unit	Forest-Based		Non-Forest-Based		Max. and Min value	
			Actual value	Indexed value	Actual value	Indexed value	Max	Min
Climate change related effects	HHs reported occurrence of malaria with in the family	%	39.4	0.394	56.3	0.563	100	0
	HHs reported occurrence of flood in the farm	%	15.9	0.159	35.9	0.359	100	0
	HHs reported crop pests/diseases	%	55.9	0.559	72.5	0.725	100	0
	HHs reported drying up of rivers and streams	%	38.8	0.388	63.4	0.634	100	0
	HHs raised the shift of crops growing season	%	78.8	0.788	80.3	0.803	100	0
	HHs reported occurrence of landslides and erosions in their farm	%	31.8	0.318	48.6	0.486	100	0
Climate Change and Variability	HHs perceived increased trend of T° in last 10 years	%	68.8	0.688	84.5	0.845	100	0
	HHs perceived decreased trend of Precipitation in last 10 years	%	61.2	0.612	74.6	0.746	100	0
	HHs reported occurrence of erratic rainfall patterns	%	65.9	0.659	55.6	0.556	100	0
Food	HHs depending solely on family farm for food	%	52.9	0.529	35.2	0.352	100	0
	Months households were in trouble of getting enough food	Months	1.8	0.450	1.36	0.340	4	0
	HHs that do not save crops for future consumption	%	52.9	0.529	38	0.380	100	0
Water	HH reporting any water related conflict	%	23.5	0.235	50	0.5	100	0
	HHs that utilize a natural water source for home consumption	%	92.4	0.924	81	0.81	100	0
	HHs that do not have a consistent water access	%	44.7	0.447	74.6	0.746	100	0
Agriculture	Crop diversity (inverse)	Number	8.41	0.659	10.35	0.465	15	5
	Size of cultivated land (inverse)	Hectare	1.520	0.592	1.643	0.543	3	0.5
	HHs do not save seeds	%	49.4	0.494	33.8	0.338	100	0

The indexed value of sub-components for vulnerability factors (Continued)

Technology	HHs not used fertilizer	%	68.2	0.682	47.9	0.479	100	0
	HHs not used improved seed	%	71.8	0.718	66.9	0.669	100	0
	HHs not used pesticides and herbicides	%	29.4	0.294	35.9	0.359	100	0
Socio-Demography	Female headed households	%	15.3	0.153	17.6	0.176	100	0
	Household Size (inverse)	AE	5.545	0.568	5.501	0.574	9.75	2.35
	HHs accessed extension services (inverse)	%	58.2	0.418	71.1	0.289	100	0
	HH heads who do not attended school	%	59.4	0.594	45.1	0.451	100	0
Assets	HHs owned cash crops (inverse)	%	97.6	0.024	65.5	0.345	100	0
	Size of livestock (inverse)	TLU	5.676	0.611	5.643	0.614	11.432	2.012
	Total annual income of households (inverse)	ETB	31279.84	0.562	27901.13	0.630	59180	9550
	Size of households farm land (inverse)	Hectare	2.844	0.646	2.673	0.684	5.75	1.25
	HHs who do not accessed credit	%	74.1	0.741	62.7	0.627	100	0
	HHs living in houses made of roof/grass	%	31.8	0.318	45.1	0.451	100	0
	HHs do not easily accessed fodder	%	21.2	0.212	57.7	0.577	100	0
Livelihood Strategies	HHs majorly depend on income from natural resources	%	14.7	0.147	5.6	0.056	100	0
	HHs who work in non-farm activities (inverse)	%	29.4	0.706	38	0.620	100	0
	HHs who work in off-farm activities (inverse)	%	47.6	0.524	42.3	0.577	100	0
Infrastructure	Distance from veterinary services	km	4.303	0.229	6.94	0.444	13.75	1.5
	Distance from input output market	km	5.994	0.363	6.619	0.420	13	2
	Distance from health centre	km	6.287	0.337	7.032	0.403	13.75	2.5
	Distance from school	km	3.348	0.560	3.216	0.524	5	1.25
	Distance from all-weather road	km	5.187	0.242	5.303	0.249	17.5	1.25

Source: own computation survey data, 2023

4.2.1. Exposure of forest-based and non-forest-based households to climate change and variability

The exposure component comprised climate change related effects, and climate change and variability components. There are six indicators in climate change related effects component and three indicators in climate change and variability component.

Climate change related effects: The computed result of table 7 indicated non-forest-based households are more vulnerable (0.595) than forest-based households (0.434). This is due to the highest vulnerability score in all of sub-components of climate change related effects (table 6). More than half of respondents from non-forest-based areas reported high occurrence of malaria, crop pests and disease, drying up of rivers and streams, and shift of crops growing season. Additionally, 48.6% and 35.9% of respondents from non-forest-based areas reported occurrence of landslides and erosion, and flood in their farm (table 6). Thus, non-forest-based households were highly exposed to malaria, flood, landslides and erosion, crop pests and disease, and drying of rivers and streams, which exposed them to climate change related effects. Tessema & Simane (2019) indicated households who faced highest climate change related events, land degradation, and erosion problems were highly exposed to climate change.

Climate change and variability: The result of table 6 indicated non-forest-based households have more exposure score to the indicators of increased temperature (0.845) and decreased precipitation (0.746); and the score for increased temperature and decreased precipitation of forest-based households were 0.688 and 0.612 respectively. The overall indexed score of climate change and variability component of non-forest-based, and forest-based households were 0.716 and 0. 653 respectively, which exposed non-forest-based households to climate change and variability (table 7). This is due to high report of non-forest-based households on perception of increased temperature (84.5) and decreased precipitation (74.6) (table 6). High perception of increased temperature and decreased precipitation implied for high exposure. As households perceived these climate events, the occurrence of climate change is high (Simane *et al.,* 2016).

Due to lack of metrology station in both forest-based and non-forest-based areas, the data of temperature and precipitation were not used for comparison purposes. However, to understand the scenarios of climate change, metrology data were taken from proxy station.

Accordingly, the temperature records of 20 years have shown linearly increasing trends in average monthly maximum temperature, and decreasing trend in minimum temperature (Appendix figure 1). Also, analysis of rainfall data over the last 20 years showed fluctuating nature of rainfall. However, the trend line indicated decreasing trend of rainfall (Appendix figure 2).

The key informant information also revealed the highest and more frequent occurrence of climate change effects in non-forest-based areas. The households who live in non-forest-based areas are more prone to landslides, erosion and flood. They also coined more hot temperature, irregular and inadequate or insufficient rainfall highly occurred in non-forest-based areas. Similarly, the increasing trend of temperature, and decreasing and erratic nature of rainfall was confirmed by FGD discussants in both forest-based and non-forest-based areas. Teshome (2016) also revealed increasing temperature, decreasing rainfall, and abnormal precipitation distribution are making households vulnerable to climate change.

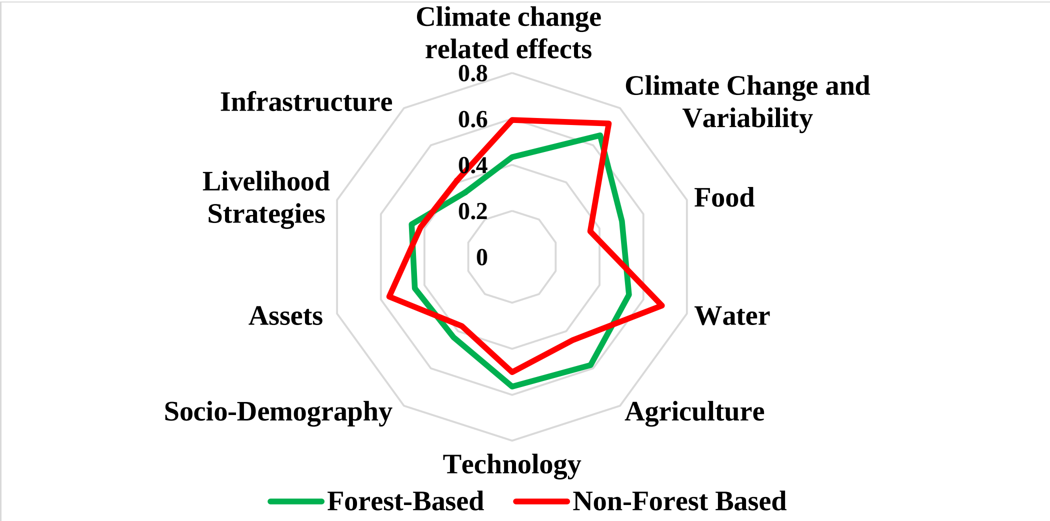
4.2.2. Sensitivity of forest-based and non-forest-based households to climate change and variability

The sensitivity factors included three major components (food, water and agriculture). There are sub-indicators under each of them, which are elaborated in the next section.

Food: The food components included depending only on family farm for food, number of months' households were in trouble of getting enough food, and do not saving crops for future consumption. Forest-based household were more sensitive (0.503) to food component than non-forest-based households (0.357) (table 7). This was for high portion of households depending only on family farm for food (52.9%), average of 1.8 months in trouble of getting enough food, and 52.9% of households didn't saved crops for future consumption (table 6). The farming practice in forest-based area was subsistence, which challenged households to save crops for future consumption. Moreover, there is certainly no other source of food items for home consumption. A study conducted by Amare & Simane (2017) confirmed not saving crops and being troubled by shortage of food for many months made *Kolla* agro-ecology sensitive to climate change.

Water: The overall score of water components is 0.685 and 0.535 for non-forest and forest-based households respectively, in which non-forest-based households were more sensitive to water components (table 7). This is due to high occurrence of water related conflict (50%) and lack of consistent water access (74.6%) in non-forest-based areas, while only 23.5% and 44.7% of respondents from forest-based areas reported the occurrence of water related conflict and lack of consistent water access respectively (table 6). The shortage of rain makes inconsistent water access; and communal use of available water source created conflict between individuals in non-forest-based areas. The KII indicated the lower sensitivity of forest-based households were associated with better ecosystem services, and the presence of sustainable forest management activities. The use of natural water for home consumption was reported by more than 80% of respondents from both areas (table 6). Similarly, Sisay (2016) identified high report of water related conflict, utilization of natural water source and households without consistent water supply were vulnerable to climate change.

Figure 3: The spider diagram of major components of LVI



Agriculture: Crop diversity, size of cultivated land and not saving seed were included under this component. Result of this finding indicated, the score of crop diversity, size of cultivated land, and not saving seed for non-forest-based households were 0.465, 0.543 and 0.338 respectively, while it was 0.659, 0.592 and 0.494 for forest-based households respectively. The overall score of agriculture components for non-forest and forest-based households were 0.448 and 0.582 respectively (table 7). All sub-components of agriculture make forest-based households' sensitive to climate change; which implied a forest-based area was more sensitive to the component of agriculture. The reasons were low crop diversity, small size of cultivated land, and high report of not saving seed. KII also coined non-forest based households are better in diversifying crop, saving seeds, and cultivating the available land.

The inferential analysis of size of cultivated land and crop diversity indicated the existence of significant variation between groups (table 8). This was for less focus of forest-based households on agricultural activities and engaging more time on forest and its' resource management related activities. Similarly, Yimam & Holvoet (2022) reported that farmers who do not diversify crop and do not have seed reserve are highly sensitive to climate change impacts.

Table 7: Values of major components across forest-based and non-forest based areas

Vulnerability factors	Major components	Forest-Based	Non-Forest-Based
Exposure	Climate change related effects	0.434	0.595
	Climate Change and Variability	0.653	0.716
Sensitivity	Food	0.503	0.357
	Water	0.535	0.685
	Agriculture	0.582	0.448
Adaptive capacity	Technology	0.565	0.502
	Socio-Demography	0.433	0.372
	Assets	0.445	0.561
	Livelihood Strategies	0.459	0.418
	Infrastructure	0.346	0.408
LVI		**0.477**	**0.510**

Source: own computation survey data, 2023

4.2.3. Adaptive capacity of Forest-Based and Non-Forest-based households

The factor of adaptive capacity included 5 major components (technology, socio-demography, assets, livelihood strategies and infrastructure) and 22 indicators. The major components and indicators were clearly discussed in below section.

Technology: The component of technology comprised use of fertilizer, seed, and application of pesticides and herbicides. The result in table 6 indicated, score of not using fertilizer for non-forest-based and forest-based households was 0.479 and 0.682 respectively; and not using improved seed was 0.669 for non-forest-based households and 0.718 for forest-based households. Additionally, the indexed score for not using pesticides and herbicides were 0.359 and 0.294 for non-forest and forest-based households respectively. The overall score of technology component was 0.502 and 0.565 for non-forest-based and forest-based households respectively (table 7). This indicated forest-based households have less adaptive capacity to this component. In forest-based area

71.8% and 68.2% of respondents didn't used improved seed and fertilizer respectively. The information of KII is similar with the result of finding, and informed non-forest-based households are in better line to intensify their production by using improved seed and fertilizer. Asrat & Simane (2017) indicated using technology (pesticides, fertilizer and improved seed) reduced households' vulnerability to climate change.

Socio-Demography: It was comprised of female headed households, household size, access to extension services and school attended household head. Being female headed household, small family size, low access to extension services and not school attended headed household reduced the adaptive capacity; the reverse is also true. In this regard, the result indicated in table 7 shown, forest-based households have less adaptive capacity to the socio-demography component with the overall score of 0.433; but it was 0.372 to non-forest-based households. This was for less access of extension services, and low educated household heads (table 6). Asfaw *et al.* (2021) indicated total family size in productive age group, educational status of household head, and frequency of extension contacts increased households' adaptive capacity

Assets: The component of asset included ownership of cash crops, size of livestock, total annual income, farmland size, and access to credit, living in houses made of roof/grass, and no easy access to fodder. Access of households to these assets increased their capacity to withstand different climate change and variability related stresses. According to the result in table 6, non-forest-based households have higher indexed values to all indicators of assets except access to credit. The overall averaged score of asset component was 0.561 and 0.445 for non-forest and forest-based households respectively. This indicated non-forest-based households have low adaptive capacity to the asset component. This is due to their low ownership of cash crops, small livestock size, low annual income, small size of farm land, low access of fodder, and living in houses made of roof/grass (table 6).

The inferential analysis for total income and size of farmland indicated the significant mean difference between two groups (table 8). The key informant information and FGDs also indicated better access of forest-based households for cash crops (coffee, cardamon, and spices) and other assets. Tessema & Simane (2019) confirmed access to different assets increased adaptive capacity of households.

Livelihood Strategies: Depending majorly on income from natural resources, engaging in non-farm and off-farm activities was included under this component. The indexed result indicated, forest-based households have low engagement on non-farm activities and relatively more respondents majorly depend on natural resources to generate income (sell of charcoal, timber, and firewood) (table 6). High dependence on these resources lead to exploitation of natural environment and it is considered as maladaptive practice. Forest-based households have better engagement in off-farm activities (farm wage work, working on others farm, and traditional medical practices).

The overall indexed average score of livelihood strategies was 0.459 and 0.418 to forest-based and non-forest-based households respectively (table 7); which indicated limited options of forest-based households for livelihood strategies. High dependence on natural resources for income generation, and low engagement of non-farm activities (petty trading, selling local drinks, making handicrafts, daily labour, and gifts from relatives) were high among forest-based households. Abeje *et al.* (2019) also confirmed the low adaptive capacity of Guder watershed, was attributable to households' restricted options for livelihood strategies.

Infrastructure: The indicators included in this major component were distance from veterinary services, market, health centre, school, and all weather roads. Accessing these institutions within short distance increased households' adaptive capacity. The overall indexed average score of infrastructure for forest-based household was 0.346 and non-forest-based household was 0.408; which make non-forest-based households vulnerable (table 7). Forest-based households have better access to veterinary services, input output market, health centre, and all-weather road (table 6). Table 8 indicated the existence of significant variation in distance from veterinary services, market, and health centre between two groups. The FGDs, from both forest-based and non-forest-based areas indicated the existence of challenges on availability of infrastructural services. However, KII revealed the better access of infrastructural services in forest-based areas. Mekonen (2021) noted limited access to infrastructures is trouble to improve adaptive capacity of households.

Table 8: t-test for continuous variables considered for vulnerability assessment

Variables	t-value	P-value
Total annual income	-2.448	.015
Size of farm land	-2.003	.046
Distance from veterinary services(km)	9.377	.000
Distance from market(km)	2.263	.024
Distance from health centre(km)	2.310	.022
Size of cultivated land	2.402	.017
Crop diversity	9.182	.000
Number of months HHs were in trouble of getting enough food	-2.746	.006

Source: own computation survey data, 2023

LVI-IPCC Results

The LVI-IPCC is computed depending on the three determining factors (exposure, sensitivity, and adaptive capacity). High values of exposure and sensitivity indicated for the systems highest vulnerability, while high value of adaptive capacity reduces vulnerability of households to climate change and variability, and increases households' ability to withstand the varying natures of climate. Accordingly, table 9 depicted the values of three factors (exposure, sensitivity and adaptive capacity). High values of exposure relative to adaptive capacity give positive vulnerability scores (high vulnerability), while low values of exposure relative to adaptive capacity give negative vulnerability scores (low vulnerability). The sensitivity factor acts as a multiplier. The LVI-IPCC score is on a scale from – 1 (least vulnerable) to + 1 (most vulnerable) (Asrat & Simane, 2017).

Table 9: The computed scores for LVI-IPCC factors

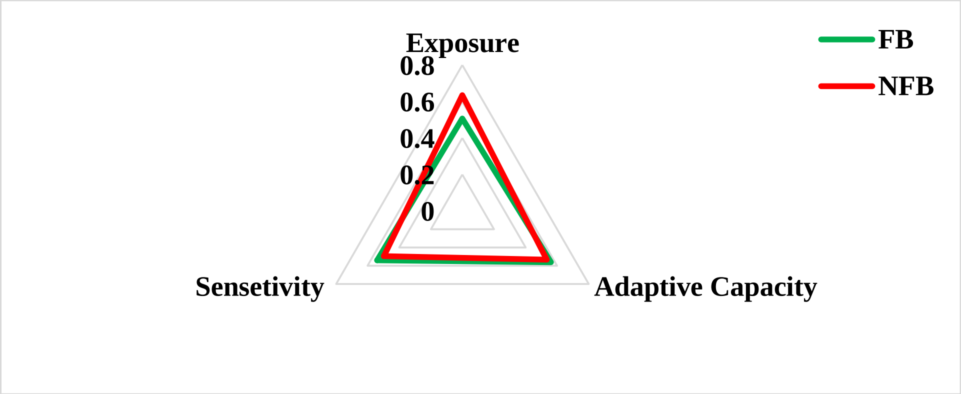
Contributing factors	Forest-based	Non-forest based
Exposure	0.507	0.635
Adaptive Capacity	0.561	0.535
Sensitivity	0.540	0.497
LVI-IPCC	**-0.029**	**0.049**

Source: own computation survey data, 2023

The LVI-IPCC result shown, non-forest-based households (0.049) were vulnerable to climate change and variability than forest-based (-0.029). This is due to their highest exposure to climate change related effects and climate change and variability components accompanied with low adaptive capacity. The sensitivity score in table 9 implied, forest-based households were more sensitive to climate change. However, non-forest-based households reported high occurrence of malaria, flood, crop pests and disease, landslides and erosion, and drying up of rivers and streams. The areas also faced highly increased temperature, and reduced rainfall and less access to cash crops, small livestock size, low income, low access to infrastructure and small farmland size (table 6).

The report of Decha district natural disaster and preparedness office indicated non-forest-based areas faced frequent flood, high occurrence of erosion, animal disease, crop pests and disease. According to the district report, the events of soil erosion and flood displaced around 36 households from non-forest-based areas in 2021 (Agriculture office report, 2021). The key informants' information also indicated, the nature of temperature in this area is too high, and the rainfall fluctuations brought unexpected effects, dying of animals, frequent occurrence of landslides and erosion. The FGDs of non-forest-based areas also confirmed the occurrence of aforementioned events in their *kebeles*.

Figure 4: Spider diagram of LVI-IPCC and its factors



The spider diagram of figure 4 indicated, factors of exposure between forest-based and non-forest-based households have high difference, but the score of adaptive capacity and sensitivity overlap each other with very small difference between two areas. High level of exposure accompanied with low adaptive capacity lead communities to vulnerability across different livelihood zones (Asfaw *et al.*, 2021; Mekonen and Berlie, 2021).

4.3. Adaptation Strategies of Forest-Based and Non-Forest-Based Households to Climate Change and Variability

Farmers in the study area employed different measures to reduce the adverse effects of climate change. In sense, there are many adaptation strategies undertaken by households in the study area. However, depending on the information of FGDs, KIIs, and literature more frequently adopted and relevant strategies were discussed in the following sections.

Table 10: Summary of adaptation strategies to climate change and variability

Adaptation strategies	% (Forest-Based)	% (Non-Forest-Based)	% (Total)	$\chi2$
Adjusting planting date of crops	62.9	82.4	71.8	14.459***
Expansion of enset	50.6	34.5	43.3	8.151***
Crop diversification	57.6	61.3	59.3	.420
Use of fertilizer	31.8	52.1	41	13.241***
Forest management	62.4	10.6	38.8	87.409***

*Note: *** indicated for the significance level at 1%.*
Source: Own computation survey data, 2023

Adjusting planting date of crops

According to the survey result indicated in table 10 above, 71.8% of households adjusted planting date of crops from both forest-based and non-forest-based areas. 82.4% and 62.9% of respondents adjusted the planting date of crops from non-forest and forest-based areas respectively. The $\chi2$ result indicated statistically significant variation of adaptation of this strategy between two groups. Adjusting planting date of crops was mostly implemented by non-forest-based households.

Forest-based households who produce teff, maize, and leguminous crops didn't change their planting date even they are obliged to change their cropping calendar. Households confirmed changing the cropping calendar reduced the productivity and even total loss of production of the aforementioned crops. Thus, forest-based households leave the year if the climate scenarios obliged them to change their cropping calendar and rely on available agricultural products, enset and forest products to make a living. However, those who do not worry about productivity adjusted planting date. Non-forest-based households mostly shifted their cropping calendar if they are obliged to do so because agricultural activities are basic source of their livelihood.

FGDs of both areas have the same arguments with result of the finding about shifting planting date of crops. KII also raised similar ideas with focus group discussants. Alemayehu & Bewket (2017) also revealed households in central highlands of Ethiopia adjusted planting date as adaptation strategies.

Expansion of *Enset*

The result of table 10 indicated 50.6% and 34.5% of households expanded *enset* from forest-based and non-forest-based areas respectively. The $\chi 2$ result implied the existence of significant variation on expanding *enset* between forest-based and non-forest-based households. Forest-based households highly expanded *enset* in their farm than non-forest-based households (Figure 5). This is for their highest perception and confidence on this product about its contribution on their livelihood in the face of climate change and variability. Moreover, there are many enset varieties (clones). *Nobo enset* is among enset varieties, which was highly adopted by households for its better capacity of resisting drought and bacteria wilt disease. This disease is severely affecting enset producers. However, households' perception and the finding of (Handoro & Said, 2016) confirmed the better ability of *nobo enset* on resisting the bacterial wilt disease. Belay *et al.* (2017) showed ″cultivation of drought tolerant crops (Ensete ventricosum) was becoming popular″.

The FGDs from forest-based areas coined increased temperature, and erratic nature of rainfall affected agricultural products. However, *enset* sustained the life of households from severe harm and hunger. The participants of FGDs of forest-based areas said ″ *Uuxo yooyoba magge amiyoono tuneba yongoono shataano; Qaawooba showee shuu'oonaa aachi aallittino biin woddii miixaane mixxe no gochaabeet maayi yaroone. Tambe gooroba kechi ashoon shaacoochee tuuggii yechiibeet no kashe budone uuxo*. This is translated as *enset* is not severely affected by heavy rain and winds of summer season, drought and loss of soil moisture of winter season. It is the only crop which is not severely affected by the fluctuation of these climate variables. He also coined, in hard times this crop protected households from unexpected hunger, and it can be considered as base of our life at the time of difficulty.

The KII also coined rural farmers highly expanded enset for home consumption, and experts of agriculture office also coined different mechanisms that target enset producers is being prepared by district agriculture office. Enset (*Ensete ventricosum*) farming system is one of the most sustainable indigenous and the best successful climate smart farming system. It is resistant to drought, flood and frost, and can be harvested and stored for food over long periods of time. It provides an important dietary starch source, as well as fibres, medicines, animal fodder, roofing and packaging. It stabilizes soils and microclimates and has significant cultural importance (Borrell *et al.,* 2019; Senbeta *et al.,* 2022).

Crop diversification

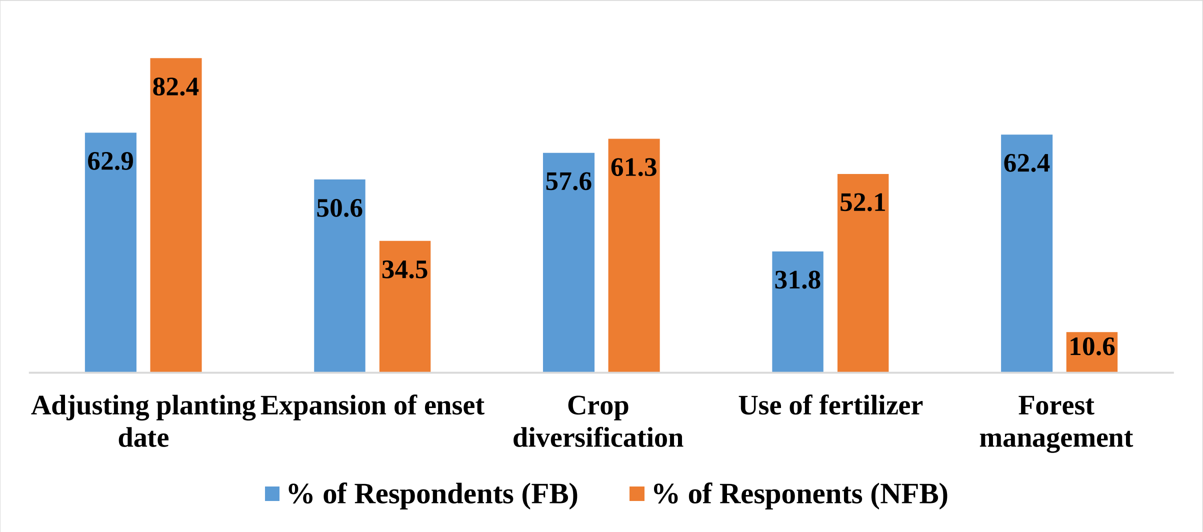
The result in table 10 indicated 57.6% and 61.3% of households from forest-based and non-forest-based households diversify crop respectively to reduce negative effects of climate change. The percentage of households adopted crop diversification were nearly the same and above half of total respondents diversified crop. A person who put all of his money in one pocket is severely affected than who put in two or more pockets if both of them faced thief. Forest-based households mostly produced teff, maize, sorghum, barley, pea, beans and haricot beans; and non-forest-based households produce teff, barley, haricot beans, onion, ginger, garlic, potato, pepper, maize, rice and sorghum. There was no significant variation of employing this strategy between two areas, which implied households of both areas diversified crops. Asravor (2022) identified crop diversification was implemented as adaptation strategies in three agro-ecology zones of Ghana.

Use of fertilizer

The productive land of the study area which gave agricultural outputs without requirement of chemical inputs became infertile to give even at subsistence level. This obliged the farmers those have means to use fertilizer to produce different agricultural crops. Accordingly, 31.8% of forest-based and 52.1% of non-forest-based households used fertilizer in their farm (table 10). Figure 5 indicated the difference in utilization level of fertilizer between forest-based and non-forest-based households, and $\chi 2$ result also implied the existence of statistical difference between two areas. This was for the curiosity of non-forest-based households to increase productivity and their eagerness to market oriented production.

The KII of Decha district agriculture office crop stream expert confirmed the interest of households to use fertilizer is increasing from time to time. The fertility of soil is degraded and the agricultural practices without using inputs is becoming nil. FGDs of non-forest-based areas indicated the farmers' interest to use fertilizer is high, but it is not supplied at the right time by the concerned bodies. Atube *et al.* (2021) indicated smallholder farmers in northern Uganda used chemical fertilizer as adaptation strategies to climate change.

Figure 5: Intensity variation of adaptation strategies between FB and NFB households



Forest management

According to the finding in table 10, 62.4% of forest-based households and 10.6% of non-forest-based households were engaged in forest management. The $\chi 2$ value indicated the existence of significant variation between groups, and figure 5 also implied high difference of implementing this strategy between two groups. Households in forest-based areas relied on forest as a source of cash crops (coffee, cardammon and spices), feed and shadow their livestock, and easily get construction materials. The area is well known in its dense forest coverage (Bender & Tekle (2019) and the aforementioned benefits are unhidden and households also articulated its benefit in the face of climate change.

The FGDs from forest-based areas coined forest shadowed their livelihood from climate change related damages. The information of KII indicated different supporting sectors such as NABU, and REDD^{+} organized groups of men and women farmers including marginalized peoples to manage, control and sustainably use NTFPs without exploitation of forest. They named it participatory forest management (PFM). Spittlehouse & Stewart (2003) indicated households engaged in sustainable forest management to adapt the threat of climate change.

4.4. Determinants of Climate Change Adaptation Strategies

This section comprised the result of econometric model. Before running the model, the explanatory variables were checked for multicollinearity using variation inflation factor (continuous explanatory variables) and the contingency coefficients (dummy variables). VIF values were below 10 for continuous explanatory variables and contingency coefficients of dummy explanatory variables were below 0.75 (Appendix table 3 and 4). The section critically analysed the factors that positively or negatively determined different climate change adaptation strategies in the study area. Twelve explanatory variables were selected to look for their effects on identified dependent variables. Thus, the influences of these explanatory variables on adaptation strategies were examined in the subsequent sections using multivariate probit model. Accordingly, the result of multivariate probit model is depicted in the following section.

Multivariate probit model

The climate change adaptation strategies were assumed to be interdependent in this study. The likelihood ratio test result of Wald was used to confirm this assumption. Accordingly, the Wald test result is highly significant ($\chi 2$ = 330.73***). Additionally, the value of all rho are jointly equal to zero which indicated the fitness of model or the decisions to adopt climate change adaptation strategies is interdependent (table 11).

The sign of correlations indicated implementing crop diversification and adjusting planting date, and forest management and expansion of *enset* were positively correlated. However, expansion of *enset* and adjusting planting date, use of fertilizer and adjusting planting date, forest management and adjusting planting date, crop diversification and expansion of *enset*, and forest management and use of fertilizer were negatively correlated. Positive correlation implied for adoption of one strategy increased the probability of others to be adopted, and the reverse is true for negative correlation. The joint probability of using all strategies was 2.9% and the joint probability of failure to adopt all strategies was 2.4%.

The results of MVP model indicated that the hypothesized explanatory variables significantly determined the choice of different climate change adaptation strategies. Thus, explanatory variables those are significant at less than or equal to 10% significance level were discussed in the following section.

Sex: As hypothesized, sex of household head positively determined expansion of *enset* and crop diversification at 5% significant level. Being male headed household increased expansion of *enset* and crop diversification (table 11). Expansion of enset required labour to prepare land, frequent management, and protection from different pests and attacker animals /porcupine/ in which female headed households were not enough competent with male headed households. Crop diversification is also mostly practiced among male headed households because it required more time and energy in which females were mostly engaged in routine activities. Thus, time, energy, and resource requirement nature of expanding *enset* and crop diversification hindered female headed households from engaging on these strategies. This finding is in line with (Marie *et al.,* 2020).

Geographical area: It is the physical location of respondents being found in forest-based or non-forest-based areas. As hypothesized, geographic area of households determined adaptation strategies positively and negatively. Accordingly, it positively determined use of fertilizer at 1% significant level, and adjusting planting date of crops at 5% significant level. The frequent changing scenarios of temperature and precipitation obliged non-forest-based farmers to adjust planting date of crops. Their small farm size and exhausted soil fertility make them to use chemical fertilizer. However, it negatively determined expansion of *enset* and forest management at 1% significant level. The high perception of forest-based households about the importance of *enset*, and better services of forest in the face of climate change encouraged households to manage forest and expand *enset*.

Generally, the finding indicated adjusting planting date and use of fertilizer were highly practiced by non-forest-based households, while forest management and expansion of *enset* were practiced by forest-based households. Eshetu *et al.* (2021); Adego & Woldie (2022) similarly indicated, farming in different agro-ecology make farmers to adopt different strategies to reduce the negative effects of climate change and variability.

Age: The aged households have better understanding about the climate change scenarios. Thus, it was hypothesized as for its positive effect on climate change adaptation strategies. Accordingly, table 11 below indicated the age of household head positively determined adjusting planting date of crops and expansion of *enset* at 5%, and forest management at 1% significant level. More aged household heads clearly articulated the benefit of expanding *enset* than focusing solely on other agricultural products for its better capacity of disease and drought resistance. Additionally, management of forest was undertaken by aged household heads for its first and last solutions to protect and shade their livelihoods from its perpetual services in the face of climate change.

Moreover, the aged households have more know how about the scenarios of climate change and they voiced, the cropping calendar was shifted from time to time. Thus, to reduce the negative effects of climate change they adjusted the planting date of crops. This finding is controversial with the finding of Hirpha *et al.* (2020) in which they stated that ″a unit increase in the age of a household head would decrease the likelihood of practicing climate change adaptation strategies in the study area; due to the fact that younger farmers are characterized by their flexibility in decision-making process, in seeking support and information from government and non-governmental institutions and they have higher interest in dealing with the risk as compared to older farmers’’. However, it is consistent with the research done in Dabus water shade (Asrat and Simane, 2018)

Household size: It is the total size of individuals with in the households measured in adult equivalent. As hypothesized, household size negatively determined forest management at 1% significant level. As the number of household size increased, the available plot per individual is decreased, and some of the members were obliged to disturb the private and or communal forest for different purposes. Thus, the increment of family size degraded forests. This result is consistent with the finding of Khanal & Wilson (2019) in Nepal and stated ″smaller size of household increased the likelihood of adoption″.

In contrary to the hypothesis, it positively determined crop diversification at 1% significant level. As household size increased in adult equivalent, the possibility of diversifying crop as adaptation strategy increased. This is due to the requirement of many labours for land preparation and overall management activities of crops. Additionally, the larger size of households accessed information about the benefits of diversifying crops from different sources, which encouraged them to diversify crops. This finding is in line with the finding of (Sani *et al.,* 2016).

Frequency of extension contact: The same with hypothesis, the result of table 11 below indicated that frequency of extension contact positively determined adjusting planting date of crops and use of fertilizer at 5% significant level. Likewise, it also positively determined diversification of crops at 10% significant level. As the number of households contact with development agents increased they accessed information about different agronomic practices, the importance of using agricultural inputs and climate change related events. Their frequent contact also equipped them with better attitude and skill about the use of fertilizer and crop diversification.

Additionally, households who have better contact with experts deal about climate information and the scenarios of seasonal change. Accordingly, households who have more frequent contact with agriculture experts have more probability to adjust planting date of crops diversify crop and use fertilizer. Similarly, Alemayehu *et al*. (2022); Asravor (2022) confirmed frequency of extension contact positively determined crop diversification, use of fertilizer and changing planting date of crops.

Credit access: As hypothesized, the result indicated access to credit positively determined crop diversification and use of fertilizer at 1% significant level (table 11). Access of credit for households gives financial power to fulfil different agricultural inputs including crop varieties and fertilizer. The farm operation and application of fertilizer also required many labours in which credit accessed households could pay for daily labour. Moreover, households those accessed enough size of land but dared by lack of oxen, and different farming equipment used the accessed credit to procure their gap. Therefore, households who accessed credit were better in crop diversification and use of fertilizer. This finding is consistent with the finding done in Nepal (Khanal & Wilson, 2019).

Size of livestock (TLU): It is the total livestock size owned by households measured in tropical livestock unit. In contradictory with hypothesis, size of livestock negatively determined crop diversification at 1% significant level. The households with large livestock size didn't focus on growing many crops. As crop diversification, large size of livestock required large size of land, time and labour for its' overall management. Thus, production of livestock competes with crop production for labour and land. Hence, as livestock size increased adoption of crop diversification reduced (table 11). The finding of Sani *et al.* (2016) is consistent with this result.

Total income: As hypothesized, the result indicated total income of households positively determined use of fertilizer and forest management at 1% significant level, and adjusting planting date of crops at 5% significant level (table 11). The households who have better income were more engaged on forest management activities, and live within forests for its follow up and overall management. This finding is supported by Belay *et al.* (2017) and indicated as the income of households increased they are encouraged to plant trees. Furthermore, this finding also confirmed, households with better income used the available cash when they faced hard times, and shifted their planting calendar. Indeed, households with better income managed forests, adjusted planting date and used fertilizer.

However, in contradiction with hypothesis the increment of total income reduced expansion of *enset* at 5% significant level. It was for less focus of households with higher income on expansion of enset and focusing on other agricultural practices that create better income. Atube *et al.* (2021) also confirmed as households income increased they used fertilizer and adjusted planting date.

Perception of climate change: The result in table 11 is consistent with hypothesis, and indicated perception of climate change positively determined forest management and expansion of *enset* at 5% significant level, and adjusting planting date of crops at 1% significant level. The households clear forecasting and understanding of reduced precipitation and increased temperature obliged them to shift cropping calendar. Also, *enset* is considered as tolerant of fluctuating climate elements. Accordingly, perception of climate change increased the expansion of *enset*.

Forest is perceived by households as the regulator of changing climate and its services gave relief for the accessed households at hardest time. Thus, households who perceived climate change intensively managed forests for its' services were better in the face of climate change than other sectors. Debalke *et al.* (2013) also indicated households' perception of changing temperature and rain obliged them to change planting date. Additionally, Khanal & Wilson (2019) in Nepal confirmed, farmers who believed local climatic conditions have changed were more likely to adapt different measures.

Size of farm land: As hypothesized, size of farmland positively determined crop diversification at 1% significant level. Crop diversification required large size of land to grow different crops. Hence, households with large size of land grow different crop types than small land size owned households. The finding of Alemayehu *et al.* (2022) also confirmed large farmland size increased adoption of crop diversification. However, in contradiction with hypothesis, size of farm land negatively determined use of fertilizer at 5% significant level. Households who owned large size of land in the study area increased the size of land they grow for enough harvests; but households who owned small size of farm land used fertilizer to increase their harvests from the available farm land (table 11). This result is consistent with the finding conducted in Bangladesh (Uddin *et al.*, 2014).

Table 11: Multivariate probit model simulation results

Explanatory Variables	Adjusting planting date Coef.	Std.err	Enset Expansion Coef.	Std.err	Crop Diversification Coef.	Std.er	Fertilizer Coef.	Std.er.	Forest management Coef.	Std.err
SEX	-.283	.239	.435**	.219	.607**	.241	.034	.223	-.339	.245
GEOAREA	.389**	.184	-.535***	.167	.045	.200	.475***	.178	-1.849***	.211
AGE	.024**	.0122	.027**	010	-.017	.012	.003	.011	.032***	.012
HOUSEHOLDSIZE	.004	.075	-.047	.068	.248***	.085	.080	.072	-.158**	.077
EDUSTATUS	-.034	.033	.007	.030	-.001	.036	.024	.032	.038	.035
EXTENCONTACT	.107**	.042	-.004	.039	.082*	.043	.089**	.039	.072	.043
CREDITACESS	-.015	.196	-.001	.176	1.357***	.244	.596***	.181	-.287	.201
SZLVSTOCK(TLU)	-.041	.055	.023	.050	-.212***	.062	.081	.053	-.075	.058
TOTINCOME	.000**	7.49	-.000**	7.09	7.26e	8.25	.000***	7.35e	.000***	8.23e
PERCLIMCHANGE	.825***	.177	.371**	.172	.302	.203	-.227	.179	.414**	.196
SIZEFARMLAND	-.052	.111	.121	.103	.507***	.128	-.208**	.104	.106	.114
DISTMRKT	-.000	.037	-.017	.033	-.046	.037	-.009	.034	.063	.038
Constant	-1.430	.904	-1.508*	.799	-1.648*	.923	-1.861**	.845	-1.597*	.888
Predicted probability	0.719		0.438		0.593		0.414		0.388	

Joint probability of success = .029 | Number of observations = 312 | Log likelihood = -774.527

Joint probability of failure = .024 | Number of draws = 100 | Wald $\chi2$ (60) = 330.73***

rho21= -.306616*** | rho31 = .461*** | rho41 = -.228** | rho51 = -.224**

rho32 = -.234** | rho52 = .406*** | rho54 = -.205*

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 53.6331***

Note: ***, ** and * indicated for the significance level at 1%, 5% and 10% respectively.

Source: Own computation survey data, 2023

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

This study aimed to comparatively analyse climate change and variability induced vulnerability, adaptation strategies to climate change and variability of forest-based and non-forest-based households in Decha district of Kaffa Zone. The study used total of 312 sampled respondents by randomly selecting 170 from forest-based and 142 from non-forest-based households. Both quantitative and qualitative data were collected from primary and secondary sources. Interview schedule, FGDs, and KIIs were used to collect primary data. Descriptive statistics (frequency, percentage, mean and standard deviation) were used to analyse household characteristics and adaptation options of households to climate change. The inferential analyses (t-test and chi square test) were used to identify the significant variation of continuous, and dummy explanatory variables between groups. Multivariate probit econometric model was used to identify determinants of adaptation strategies to climate change. Lastly, the vulnerability of households to climate change was assessed by using LVI and LVI-IPCC.

The chi-square result of household characteristics indicated statistically significant variation of forest-based and non-forest-based households on the variables of access to credit and perception of climate change. Additionally, the t-test result of age, extension contact, farm size, total income, and the distance from market indicated the existence of significant variation between forest-based and non-forest-based households. The LVI result of non-forest-based and forest-based households was 0.510 and 0.477 respectively. And the LVI-IPCC results were 0.049 and -0.029 for non-forest-based and forest-based households respectively. This result indicated non-forest-based households were more vulnerable to climate change and variability than forest-based households for both LVI and LVI-IPCC.

The vulnerability of non-forest-based households were for high exposure to increased temperature and reduced precipitation, high occurrence of malaria, flood, crop pests and disease, landslides and erosion, drying up of rivers and streams and shift of crops growing season. Additionally, less ownership of cash crops, total income, livestock, farmland, living in traditionally made roof houses, poor access to fodder of livestock, and low infrastructure services reduced the adaptive capacity of non-forest-based households. However, forest-based households were more sensitive to climate change.

The households of forest-based and non-forest-based areas implemented different measures to reduce adverse effects of climate change. Except crop diversification, $\chi 2$ result indicated the significant variation of implementing different strategies between forest-based and non-forest-based households. Forest-based households mostly focused on *enset* expansion and forest management; however non-forest-based households focused on adjusting planting date of crops and use of fertilizer.

The result of MVP model on determinants of adaptation strategies indicated adjusting planting date of crops was positively determined by geographic area, age, extension contact, total income and perception of climate change. Expansion of enset was positively determined by sex, age and perception of climate change, whereas negatively determined by geographic area, and total income. Crop diversification was positively determined by sex, household size, credit access, and size of farmland, but negatively determined by size of livestock. Use of fertilizer was positively determined by geographical area, extension contact, access to credit and total income, however negatively determined by size of farmland. Finally, forest management was positively determined by age, total income and perception of climate change while negatively determined by geographic area, and household size.

5.2. Conclusions

Understanding the vulnerability of households to climate change is crucial in developing effective interventions to reduce its negative impacts. By assessing the exposure, sensitivity, and adaptive capacity of households based on their spatial and livelihood variation, we can identify context-specific adaptation strategies and their determinants. The findings of a recent study showed that non-forest-based households were more vulnerable to climate change due to their high exposure to climate change-related effects and low adaptive capacity. On the other hand, forest-based households were found to be more sensitive to climate change due to their limited food and agriculture components, but had better adaptive capacity and less exposure to climate change-related effects.

The increased temperature, and decreased rainfall accompanied with its effect such as landslides and erosion, crop pests and disease, malaria, and flood exposed households to climate change. Its' risks could be reduced by diversifying crop, cultivating more arable land, and using agriculture technologies. Moreover, a better option to different livelihood strategies is important to deal with climate change. On the other hand, being illiterate, less contact with development agents, and limited working labour reduced access of relevant information to take appropriate measures. Limited ownership of different assets, and poor infrastructures also reduced adaptive capacity of households.

To reduce effects of climate change, both forest-based and non-forest-based households employed various adaptation strategies such as enset expansion, forest management, adjusting planting dates, crop diversification, and use of fertilizers. However, households extensively employed relevant adaptation options depending on their livelihood systems. The study also revealed that the choice of adaptation strategy was influenced by factors such as household head's age, sex, income, perception of climate change, household size, credit, livestock size, size of farmland, and frequency of extension contact.

Men and aged headed households, frequent extension contact, credit access and climate perception increased implementation of adaptation strategies. The decision making power and control of resources, understanding past climate scenarios, and the ability to forecast the future climate events capacitate households to employ relevant measures to reduce climate change effect. On the other hand, farmers implement relevant strategies depending on their livelihood, household and farm size, and available income. The results of this study provide valuable information for policymakers and stakeholders to develop effective interventions and support contextually-appropriate adaptation strategies. It also highlights the key determinants to consider when implementing these strategies.

5.3. Recommendations

The following recommendations were given in consideration of the results and conclusions of the study.

The district agriculture office in coordination with concerned NGOs should work together to develop and disseminate relevant measures to reduce the occurrence of flood, landslides, erosion, and crop pests and disease.

The district health office should take measures on pre-control systems of malaria, and provide enough medications.

South Western Ethiopian people's regional research centre and the district agriculture office should equip and follow up development agents to frequently contact farming households, train farmers to use agricultural technologies (fertilizer, improved seed and pesticides and herbicides).

Households should be encouraged to diversify crop, cultivate the available farming land, and save seeds for the next growing season.

The district government should build water pipe to increase consistent water access, and reduce reliance of households on natural water for home consumption. Moreover, rural infrastructures (school, veterinary services, all weather-road, input output market centre and health centre) should be built and accessed by district government.

The education services and informal teaching in rural areas should be expanded. Moreover, households should be encouraged to engage on livelihood diversification related activities.

Credit should be availed by district Omo micro finance institutions to farming households to implement different measures. Furthermore, the district livestock sector, and agriculture sectors in coordination with NGOs should encourage farmers to intensify livestock sectors, and cash crop productions.

In general, mechanisms should be developed to increase ownership and control of necessary assets to increase adaptive capacity of households.

Feasible policies should be framed by district government and concerned NGOs to promote forest management, enset expansion, use of fertilizer, crop diversification, and adjusting planting date of crops to reduce climate change effects. The promotion of a given adaptation strategies should give closer attention on the spatial variation of livelihood systems.

The district climate information should be availed by national metrology agency, and agriculture office should create awareness to the farming households about climate change. The aged households should be supported by the district government to implement relevant measures. Furthermore, farmers should implement relevant measures depending on their total income, size of land, and household size.

6. REFERENCES

Abebe, G. 2017. Data in Brief Long-term climate data description in Ethiopia', *Data in Brief*, 14, pp. 371–392. Available at: https://doi.org/10.1016/j.dib.2017.07.052.

Abeje, M.T., Tsunekawa, A., Haregeweyn, N., Nigussie, Z., Adgo, E., Ayalew, Z., Tsubo, M., Elias, A., Berihun, D., Quandt, A. and Berihun, M.L., 2019. Communities' livelihood vulnerability to climate variability in Ethiopia. *Sustainability*, 11(22), p.6302.

Abrams, L., 2018. Stockholm International Water Institute, Unlocking the potential of enhanced rainfed agriculture. Technical report.

Adego, T. and Woldie, G.A. 2022. The complementarity and determinants of adoption of climate change adaptation strategies: evidence from smallholder farmers in Northwest Ethiopia. *Climate and Development*, 14(5), pp. 487–498. Available at: https://doi.org/10.1080/17565529.2021.1943296.

Adeniyi, P.A., 2016. Climate change induced hunger and poverty in Africa. J *Global Biosci*, 5(3), pp.3711-3724.

Adger, K. 1999. social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change*, 4, pp. 253–266.

Adger, W.N. 2006. Vulnerability. *Global Environmental Change*, 16(3), pp. 268–281. Available at: https://doi.org/10.1016/j.gloenvcha.2006.02.006.

Adimassu, Z. and Kessler, A. 2016. Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the central Rift valley of Ethiopia', *Environmental Systems Research*, 5(1). Available at: https://doi.org/10.1186/s40068-016-0065-2.

Aju, P.C., Iwuchukwu, J.J.I. and Ibe, C.C. 2015. Our Forests, Our Environment, Our Sustainable Livelihoods. *European Journal of Academic Essays*, 2(4), pp. 6–19. Available at: www.euroessays.org.

Alare, R.S., Lawson, E.T., Mensah, A., Yevide, A. and Adiku, P., 2022. Assessing nuanced social networks and its implication for climate change adaptation in north western Ghana. *World Development Perspectives,* 25, p.100390.

Alemayehu, A. and Bewket, W. 2016. Vulnerability of Smallholder Farmers' to Climate Change and Variability in the Central Highlands of Ethiopia. *Ethiopian Journal of the Social Sciences and Humanities*, 12(2), pp. 1–24.

Alemayehu, A. and Bewket, W., 2017. Smallholder farmers' coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia. *Local environment*, 22(7), pp.825-839.

Alemayehu, Z.Y., Minale, A.S. and Legesse, S.A., 2022. Determinants of smallholder farmers' adaptation strategies to climate variability in Suha watershed, Upper Blue Nile basin, Northwest Ethiopia. A*rabian Journal of Geosciences*, 15(23), p.1725. Available at: https://doi.org/10.1007/s12517-022-11004-6.

Amare, A. and Simane, B., 2017a. Climate change induced vulnerability of smallholder farmers: agroecology-based analysis in the Muger sub-basin of the upper Blue-Nile basin of Ethiopia. *American Journal of Climate Change*, 6(4), pp.668-693. Available at: https://doi.org/10.4236/ajcc.2017.64034.

Amare, A. and Simane, B. 2017b. Determinants of smallholder farmers' decision to adopt adaptation options to climate change and variability in the Muger Sub basin of the Upper Blue Nile basin of Ethiopia', *Agriculture & Food Security*, pp. 1–20. Available at: https://doi.org/10.1186/s40066-017-0144-2.

Asfaw, A., Bantider, A., Simane, B. and Hassen, A., 2021. Smallholder farmers' livelihood vulnerability to climate change-induced hazards: agroecology-based comparative analysis in Northcentral Ethiopia (Woleka Sub-basin). *Heliyon*, 7(4). Available at: https://doi.org/10.1016/j.heliyon.2021.e06761.

Ashraf, M., Routray, J.K. and Saeed, M. 2014. Determinants of farmers' choice of coping and adaptation measures to the drought hazard in northwest Balochistan, Pakistan. *NaturalHazards*,73(3),pp.14511473.Availableat:https://doi.org/10.1007/s11069014 -1149-9.

Asrat, P. and Simane, B., 2017. Characterizing vulnerability of crop-based rural systems to climate change and variability: agro-ecology specific empirical evidence from the Dabus watershed, north-West Ethiopia. A*merican Journal of Climate Change*, 6(4), pp.643-667. Available at: https://doi.org/10.4236/ajcc.2017.64033.

Asrat, P. and Simane, B., 2018. Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological processes*, 7(1), pp.1-13.

Asravor, R.K. 2022. On-farm adaptation strategies to climate change: the case of smallholder farmers in the Northern Development Authority Zone of Ghana. *Environment, Development and Sustainability*, 24(4), pp. 5080–5093. Available at: https://doi.org/10.1007/s10668-021-01650-3.

Atinkut, B. and Mebrat, A. 2016. Determinants of farmers' choice of adaptation to climate variability in Dera woreda, south Gondar zone, Ethiopia. *Environmental Systems Research*, 5(1). Available at: https://doi.org/10.1186/s40068-015-0046-x.

Atube, F., Malinga, G.M., Nyeko, M., Okello, D.M., Alarakol, S.P. and Okello-Uma, I., 2021. Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agriculture & Food Security*, 10(1), pp.1-14.

Basu, J.P. 2018. Adaptation to climate change & Non-Timber Forest Products A Study of Forest Dependent Communities in Drought prone areas of West Bengal, India', in *IAAE*. Available at: https://doi.org/10.22004/ag.econ.277218.

Belay, A., Recha, J.W., Woldeamanuel, T. and Morton, J.F., 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security*, 6, pp.1-13. Available at: https://doi.org/10.1186/s40066-017-0100-1.

Belderbos, R., Carree, M., Diederen, B., Lokshin, B. and Veugelers, R., 2004. Heterogeneity in R&D cooperation strategies. *International journal of industrial organization*, 22(8-9), pp.1237-1263.

Bender, S. and Tekle, M. 2019. Community Action for Biodiversity and Forest Conservation and Adaptation to Climate Change in the Wild Coffee Forests (CAFA).*ClimateChangeManagement*.*Springer*InternationalPublishing.Availableat: https://doi.org/10.1007/978-3-319-98681-4_5.

Birhanu, K.Y., 2022. Vulnerability of Smallholder Farmers to Climate Variability and Adaptation Practices in Southern Part of Ethiopia: The Case of South Ari District.

S*audiJ.HumanitiesSocSci*,7(2),pp.6272.Availableat:https://doi.org/10.36348/sjhss.2022.v07i02.003.

Birkmann, J., Feldmeyer, D., McMillan, J.M., Solecki, W., Totin, E., Roberts, D., Trisos, C., Jamshed, A., Boyd, E. and Wrathall, D., 2021. Regional clusters of vulnerability show the need for transboundary cooperation. *Environmental Research Letters*, 16(9), p.094052. Available at: https://doi.org/10.1088/1748-9326/ac1f43.

Borrell, J.S., Biswas, M.K., Goodwin, M., Blomme, G., Schwarzacher, T., Heslop-Harrison, J.S., Wendawek, A.M., Berhanu, A., Kallow, S., Janssens, S. and Molla, E.L., 2019. Enset in Ethiopia: a poorly characterized but resilient starch staple. *Annals of botany*, *123*(5), pp.747-766.

Brooks, N., 2003. Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for climate change research working paper, 38(38), pp.1-16.

Chazdon, R.L., Brancalion, P.H., Laestadius, L., Bennett-Curry, A., Buckingham, K., Kumar, C., Moll-Rocek, J., Vieira, I.C.G. and Wilson, S.J., 2016. When is a forest a forest? Forest concepts and definitions in the era of forest and landscape restoration.*Ambio*,45(5),pp.538550.Availableat:https://doi.org/10.1007/s13280016-0772-y.

Chernet, T., 2008. Land Resources and socio-economic report of Bonga, Boginda, Mankira and the surrounding areas in Kaffa zone, SNNPRS, Ethiopia. Report for PPP Project on the Establishment of a Coffee Biosphere Reserve in Bonga Region. Addis Ababa, Ethiopia.

Debalke, N.M., 2013. Determinants of farmers' preference for adaptation strategies to climate change: Evidence from north shoa zone of Amhara region Ethiopia. M*unich Pers RePEc Arch*, 2, pp.1-12.

Dendir, Z. and Simane, B. 2019. Livelihood vulnerability to climate variability and change in different agroecological zones of Gurage Administrative Zone, Ethiopia. *Progress inDisasterScience*,3, p.100035.

Deressa 2010. Assessment of the vulnerability of Ethiopian agriculture to climate change and farmers' adaptation strategies. *Theoretical and Applied Genetics*. Available at:

http://dx.doi.org/10.1016/j.tplants.2011.03.004%0Ahttp://dx.doi.org/10.1016/j.pbi.2010.01.004%0Ahttp://www.biomedcentral.com/14712156/12/42%0Ahttp://dx.doi.org/10.1016/j.biotechadv.2009.11.005%0Ahttp://www.sciencemag.org/content/323/5911/240.short%0Apape.

DFID 1999. Sustainable Livelihoods Guidance Sheets, section. *Departement for InternationalDevelopment*,p.2.2.Availableat:http://www.livelihoodscentre.org/documents/20720/10145/Sustainable+livelihoods+guidance+sheets/8f35b59f820743fc8b99df75d3000e86.

Eshetu, G., Johansson, T., Garedew, W. and Yisahak, T., 2021. Determinants of smallholder farmers' adaptation options to climate change in a coffee-based farming system of Southwest Ethiopia. C*limate and Development*, 13(4), pp.318-325.

Fekadu, A., Soromessa, T. and Dullo, B.W. 2020. GIS-based assessment of climate change impacts on forest habitable Aframomum corrorima (Braun) in Southwest Ethiopia coffee forest. *Journal of Mountain Science*, 17(10), pp. 2432–2446. Available at: https://doi.org/10.1007/s11629-019-5722-2.

Filho, Walter Leal, Barbir, Jelena, Preziosi, R. 2019. Handbook of climate change and biodiversity. *Climate Change Management*.

Füssel, H.M., 2007. Vulnerability: A generally applicable conceptual framework for climate change research. Global environmental change, 17(2), pp.155-167. Available at: https://doi.org/10.1016/j.gloenvcha.2006.05.002.

Gbetibouo, G.A., Ringler, C. and Hassan, R. 2010. Vulnerability of the South African farming sector to climate change and variability: An indicator approach. *Natural ResourcesForum*,34(3),pp.175187.Availableat:https://doi.org/10.1111/j.14778947.2010.01302.

Gebrechorkos, S.H., Hülsmann, S. and Bernhofer, C., 2019. Changes in temperature and precipitation extremes in Ethiopia, Kenya, and Tanzania. International Journal of Climatology, 39(1), pp.18-30. Available at: https://doi.org/10.1002/joc.5777.

Gujarati, DN., 1995. Basic Econometrics. Third Edition. McGraw- Hill, Inc, New York.534p.

Hahn, M.B., Riederer, A.M. and Foster, S.O. 2009. The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique', *Global Environmental Change*, 19(1), pp. 74–88. Available at: https://doi.org/10.1016/j.gloenvcha.2008.11.002.

Hailu, A., Mammo, S. and Kidane, M., 2020. Dynamics of land use, land cover change trend and its drivers in Jimma Geneti District, South Western Ethiopia. *Land use policy*, 99, p.105011.Availableat:https://doi.org/10.1016/j.landusepol.2020.105011.

Handoro, F. and Said, A., 2016. Enset clones' responses to bacterial wilt disease (Xanthomonas campestris pv. Musacearum). *International Journal of Applied and Pure Science and Agriculture* (IJAPSA), 2(09), pp.45-53.

Farah, F.T., de Lara Muylaert, R., Ribeiro, M.C., Ribeiro, J.W., Mangueira, J.R.D.S.A., Souza, V.C. and Rodrigues, R.R., 2017. Integrating plant richness in forest patches can rescue overall biodiversity in human-modified landscapes. Forest ecology and management, 397, pp.78-88.

Fishbein, M. and Ajzen, I., 1977. Belief, attitude, intention, and behaviour: An introduction to theory and research.

Füssel, H.M. and Klein, R.J., 2006. Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic change, 75(3), pp.301-329. Available at: https://doi.org/10.1007/s10584-006-0329-3.

Hein, Y., Vijitsrikamol, K., Attavanich, W. and Janekarnkij, P., 2019. Do farmers perceive the trends of local climate variability accurately? An analysis of farmers' perceptionsandmeteorologicaldatainMyanmar.*Climate*,7(5),p.64.Availableat:https://doi.org/10.3390/cli7050064.

Hillmer, U., 2009.Technology acceptance on mechatronics, business and economics. *Available online at: books. Google. Com/books*.

Hirpha, H.H., Mpandeli, S. and Bantider, A. 2020. Determinants of adaptation strategies to climate change among the smallholder farmers in Adama District, Ethiopia. *International Journal of Climate Change Strategies and Management*, 12(4), pp. 463–476. Available at: https://doi.org/10.1108/IJCCSM-01-2019-0002.

Hoddinott, J. and Quisumbing, M.A.R., 2003. Data sources for micro econometric risk and vulnerability assessments. World Bank, Social Protection.

Hugo J. du Plessis, 2019. “A quantitative analysis of interstitial spaces to improve climate change resilience in Southern African cities,” Climate and Development, vol. 12, no. 7, pp. 591–599.

Huguenin, J., Pelgrin, F. and Holly, A., 2009. Estimation of multivariate probit models by exact maximum likelihood. Institute of Health Economics and Management (IEMS) Working Paper, (09-02).

Huong, N.T.L., Yao, S. and Fahad, S., 2019. Assessing household livelihood vulnerability to climate change: The case of Northwest Vietnam. Human and Ecological Risk Assessment: An International Journal, 25(5), pp.1157-1175.

IPCC 2001. Climate Change 2001. Synthesis Report. IPCC Third Assessment Report (TAR): A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change’, *Ipcc*, p. 409. Available at: http://www.ipcc.ch/ipccreports/tar/.

IPCC 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. *IPCC, Geneva, Switzerland, 151 pp, Climate Change 2014 Synthesis Report*. Geneva. Available at: https://doi.org/10.1177/0002716295541001010.

IPCC 2019. Climate Change and Land. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems Edited.

IPCC 2022. *C*limate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA. Available at: https://doi.org/10.1017/9781009325844.

Kelly, P.M. and Adger, W.N., 2000. Theory and practice in assessing vulnerability to climate change and Facilitating adaptation. *Climatic change*, 47(4), pp.325-352.

Khanal, U. and Wilson, C. 2019. Derivation of a climate change adaptation index and assessing determinants and barriers to adaptation among farming households in Nepal', *Environmental Science and Policy*, 101(August), pp. 156–165. Available at: https://doi.org/10.1016/j.envsci.2019.08.006.

Kom, Z., Nethengwe, N.S., Mpandeli, N.S. and Chikoore, H., 2022. Determinants of small-scale farmers' choice and adaptive strategies in response to climatic shocks inVhembeDistrict,SouthAfrica.*GeoJournal*,87(2),pp.677700.Availableat:https://doi.org/10.1007/s10708-020-10272-7.

Kummu, M., Heino, M., Taka, M., Varis, O. and Viviroli, D., 2021. Climate change risks pushing one-third of global food production outside the safe climatic space. *One Earth,* 4(5), pp.720-729. Available at:https://doi.org/10.1016/j.oneear.2021.04.017.

Lukina, N.V., Geraskina, A.P., Gornov, A.V., Shevchenko, N.E., Kuprin, A.V., Chernov, T.I., Chumachenko, S.I., Shanin, V.N., Kuznetsova, A.I., Tebenkova, D.N. and Gornova, M.V., 2021. Biodiversity and climate-regulating functions of forests: current issues and research prospects. Вопросы лесной науки, 4(1), p.1-60. Available at: https://doi.org/10.31509/2658-607x-202141k-60.

Makate, C., Makate, M., Mango, N. and Siziba, S., 2019. Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations. Lessons from Southern Africa. *Journal of environmentalmanagement,*231,pp.858868.Availableat:https://doi.org/10.1016/j.jenvman.2018.10.069.

Marie, M., Yirga, F., Haile, M. and Tquabo, F., 2020. Farmers' choices and factors affecting adoption of climate change adaptation strategies: evidence from northwesternEthiopia.*Heliyon*,6(4).Availableat:https://doi.org/10.1016/j.heliyon.2020.e03867.

Mekonen, A.A. and Berlie, A.B., 2021. Rural households' livelihood vulnerability to climate variability and extremes: A livelihood zone-based approach in the Northeastern Highlands of Ethiopia. *Ecological Processes,* 10, pp.1-23.

Mekonnen, Z., Woldeamanuel, T. and Kassa, H., 2019. Socio-ecological vulnerability to climate change/variability in central rift valley, Ethiopia. *Advances in Climate ChangeResearch,*10(1),pp.920.Availableat:https://doi.org/10.1016/j.accre.2019.03.002.

Mengist, W., Soromessa, T. and Feyisa, G.L. 2021. Monitoring Afromontane forest cover loss and the associated socio-ecological drivers in Kaffa biosphere reserve, Ethiopia.*Trees,ForestsandPeople*,6,p.100161.Availableat:https://doi.org/10.1016/j. tfp.2021.100161.

Mihiretu, A., Okoyo, E.N. and Tefera, T.L. 2017. Goat Farmers' Adaptation Choices To Climate Change in Abergelie District of Wag-Khimra Zone, Eastern Amhara, Ethiopia.Haramayauniversity.Availableat:https://www.researchgate.net/profile/AdemeMihiretu/publication/336216859_Goat_farmers'_adaptation_choices_to_climate_change_in_Abergelle_district_of_Wagkhimra_Zone_Eastern_Amhara_Ethiopia/links/6152eb370db8b034c9ef7a1/Goat-farmers-adaptation-choices-to.

Mohammed, Y., Yimer, F., Tadesse, M. and Tesfaye, K., 2018. Meteorological drought assessment in north east highlands of Ethiopia. *International Journal of Climate Change Strategies and Managemen*t, 10(1), pp.142-160.

Morecroft, M.D., Crick, H.Q., Duffield, S.J. and Macgregor, N.A., 2012. Resilience to climate change: translating principles into practice. *Journal of Applied Ecology*, 49(3), pp.547-551. Available at: https://doi.org/10.1111/j.

Naidoo, S., Davis, C. and Van Garderen, E.A., 2013. Forests, rangelands and climate change in southern Africa. Forests and climate change working paper, 12.

Nhemachena, C. and Hassan, R., 2007. Micro-level analysis of farmers' adaption to climate change in Southern Africa. *Intl Food Policy Res Inst*.

Olesen, J.E., Bøcher, P.K. and Jensen, T., 2000. Comparison of scales of climate and soil data for aggregating simulated yields of winter wheat in Denmark. *Agriculture, ecosystems & environment*, 82(1-3), pp.213-228.

Pavageau, C., Locatelli, B., Sonwa, D. and Tiani, A.M., 2018. What drives the vulnerability of rural communities to climate variability? Consensus and diverging views in the Congo Basin. *Climate and Developmen*t, 10(1), pp.49-60.

Van Pelt, J.C., 2018. Climate change in context: stress, shock, and the crucible of living kind: with Karl E. Peters, "Living with the Wicked Problem of Climate Change"; Paul H. Carr, "What Is Climate Change Doing to Us and for Us?"; James Clement van Pelt, "Climate Change in Context: Stress, Shock, and the Crucible of Living kind"; Robert S. Pickart,"Climate Change at High Latitudes: An Illuminating Example"; Emily E. Austin, "Soil Carbon Transformations"; David A. Larrabee, "Climate Change and Conflicting Future Visions"; Panu .... *Zygon*®, 53(2), pp.462-495.

Prablanc, C., Panico, F., Fleury, L., Pisella, L., Nijboer, T., Kitazawa, S. and Rossetti, Y., 2020. Adapting terminology: clarifying prism adaptation vocabulary, concepts, and methods.*Neuroscienceresearch,*153,pp.821.Availableat:https://doi.org/10.1016/j.neures.2019.03.003.

Quinn, C.H., Ziervogel, G., Taylor, A., Takama, T. and Thomalla, F., 2011. Coping with multiple stresses in rural South Africa. *Ecology and Society,* 16(3).

Rahman, L.M., 2016. Forest Resources. Bangladesh National Conservation Strategy, Government of the People's Republic of Bangladesh, pp.2-13.

Rao, C.R., Raju, B.M.K., Rao, A.S., Rao, K.V., Rao, V.U.M., Ramachandran, K., Venkateswarlu, B., Sikka, A.K., Rao, M.S., Maheswari, M. and Rao, C.S., 2016. A district level assessment of vulnerability of Indian agriculture to climate change. *Current Science*, pp.1939-1946.

Rurinda, J., Mapfumo, P., Van Wijk, M.T., Mtambanengwe, F.V., Rufino, M.C., Chikowo, R. and Giller, K.E., 2014. Sources of vulnerability to a variable and changing climate among smallholder households in Zimbabwe: A participatory analysis. *Climate Risk Management*, 3, pp.65-78.

Sadeghi, T. and Farokhian, S., 2011. The role of behavioral adoption theories in online banking services. *Middle-East Journal of Scientific Research*, *7*(3), pp.374-380.

Samy, A., G. Ibrahim, M., Mahmod, W.E., Fujii, M., Eltawil, A. and Daoud, W., 2019. Statistical assessment of rainfall characteristics in upper Blue Nile basin over the periodfrom1953to2014.*Water*,11(3),p.468.Availableat:https://doi.org/10.3390/w11030468.

Sani, S., Haji, J. and Goshu, D., 2016. Climate change adaptation strategies of smallholder farmers: The case of Assosa District, Western Ethiopia. *Journal of Environment and Earth Science*, 6(7), pp.9-15.

Senbeta, A.F., Sime, G. and Struik, P., 2022. Enset farming system–a resilient, climate-robust production system in South and South-Western Ethiopia. *Cogent Food & Agriculture*, *8*(1), p.2074626.

Scoones, I., 1998. Sustainable rural livelihoods: a framework for analysis (Vol. 72, pp. 1-22). *Brighton: Institute of Development Studies.Availableat:http://forum.ctv.gu.se/*learnloop/resources/files/3902/scoones_1998_wp721.pdf.

Sedebo, D.A., Li, G.C., Abebe, K.A., Etea, B.G., Ahiakpa, J.K., Ouattara, N.B., Olounlade, A. and Frimpong, S., 2021. Smallholder farmers' climate change adaptation practices contribute to crop production efficiency in southern Ethiopia. *Agronomy Journal,* 113(6), pp.4627-4638. Available at: https://doi.org/10.1002/agj2.20900.

Seid Sani, Jema Haji, D.G. 2016. Climate Change Adaptation Strategies of Smallholder Farmers: The Case of Assosa District, Western Ethiopia. *Journal of Environment and Earth Science*, 6(7), pp.9-15.

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., Schaeffer, M., Perrette, M. and Reinhardt, J., 2017. Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. *Regional Environmental Change*, 17, pp.1585-1600. Available at: https://doi.org/10.1007/s10113-015-0910-2.

Shah, K.U., Dulal, H.B., Johnson, C. and Baptiste, A., 2013. Understanding livelihood vulnerability to climate change: Applying the livelihood vulnerability index in Trinidad and Tobago. *Geoforum*, 47, pp.125-137.

Simane, B., Zaitchik, B.F. and Foltz, J.D. 2016. Agroecosystem specific climate vulnerability analysis: application of the livelihood vulnerability index to a tropical highland region. *Springer*, pp. 39–65. Available at: https://doi.org/10.1007/s11027-014-9568-1.

Sisay, T., 2016. Vulnerability of smallholder farmers to climate change at Dabat and West Belesa Districts, North Gondar, Ethiopia. *Journal of Earth Science and Climate Change,* 7, p.365. Available at: https://doi.org/10.4172/2157-7617.1000365.

Snowdon, R.J., Wittkop, B., Chen, T.W. and Stahl, A., 2021. Crop adaptation to climate change as a consequence of long-term breeding. *Theoretical and Applied Genetics*, 134(6), pp.1613-1623. Available at: https://doi.org/10.1007/s00122-020-03729-3.

Spittlehouse, D.L. and Stewart, R.B., 2003. Adaptation to climate change in forest management.

Tadesse, S. and Madduri, V. 2020. Smallholder farmers' Perception and Their Adaptation Strategies to Climate Variability and Change in Ale and Bure Districts of Ilubabor Zone, Southwest Ethiopia', *International Journal of Sciences: Basic and Applied Research (IJSBAR),53(2), pp.147158. Available at:http://gssrr.org*/index.php?journal=Journal of Basic and Applied.

Tadesse, W., Lemenih, M. and Alem, S., 2017. Forest management in the Sahel and Ethiopian highlands and impacts on climate change. Managing forest ecosystems: the challenge of climate change, pp.429-445.

Taye, B.M. 2020.Promises and Contests of Participatory Forest Management (PFM) Scheme within Kafa Biosphere Reserve, Southwest Ethiopia. *Journal of Resources Development and Management*, pp.18.Availableat:https://doi.org/10.7176/jrdm/65 01.

Teshome, M. 2016. Rural households' agricultural land vulnerability to climate change in Dembia woreda, Northwest Ethiopia. *Environmental Systems Research* [Preprint]. Available at: https://doi.org/10.1186/s40068-016-0064-3.

Tessema, I. and Simane, B. 2019. Vulnerability analysis of smallholder farmers to climate variability and change: an agro-ecological system-based approach in the Fincha'a sub-basin of the upper Blue Nile Basin of Ethiopia. *Ecological Processes*, 8(1). Available at: https://doi.org/10.1186/s13717-019-0159-7.

Tesso, G., Emana, B. and Ketema, M. 2012. Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia. *Agricultural Sciences*, 03(06), pp. 871–888. Available at: https://doi.org/10.4236/as.2012.36106.

Tsai, Y.H., Stow, D.A., López-Carr, D., Weeks, J.R., Clarke, K.C. and Mensah, F., 2019. Monitoring forest cover change within different reserve types in southern Ghana. *Environmental Monitoring and Assessment*, 191, pp.1-15.

Tun Oo, A., Van Huylenbroeck, G. and Speelman, S., 2017. Determining factors for the application of climate change adaptation strategies among farmers in Magwe District, dry zone region of Myanmar. *International Journal of Climate Change Strategies and Management*, *9*(1), pp.36-55.

Uddin, M.N., Bokelmann, W. and Entsminger, J.S. 2014. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh', *Climate,2(4),pp.223241.Availableat:https://doi.org/*10.3390/cli2040223

Weldegebrial, G., Ementa, H. and Phil-eze, P.O. 2020. Determinants of smallholder farmers' adoption of adaptation strategies to climate change in Eastern Tigray NationalRegionalStateofEthiopia.*Heliyon*,6(March),p.e04356.Availableat:https://doi.org/10.1016/j.heliyon. 2020.e04356.

Wogayehu, Y., Wossene, A., Getachew, S. and Kabtyimer, T., 2016. Epidemiological study of ticks and their distribution in Decha Woreda of Kafa zone, SNNPRS. *International Journal of Research in Agriculture and Forestry*, 3(6), pp. 7–19.

Wolde, B.G. and Tolossa, F. 2019. Local Development Effects of Largescale Agricultural Investments: A Case Study of Gimbo, Decha and Tella Woredas, Kaffa Zone, SNNPRS, Ethiopia. *Üniversitepark Bülten*, 8(1), pp. 30–43. Available at: https://doi.org/10.22521/unibulletin.2019.81.3.

Wooldridge, J.M. 2020. *Econometrics Introductory: a modern approach (7th ed.)*.

Yimam, D.A. and Holvoet, N., 2023. Assessing climate change vulnerability of smallholder farmers in northwest Ethiopia: application of a household intrinsic vulnerability index. International Journal of Climate Change Strategies and Management, 15(4), pp.537-560.

Zeleke, T., Beyene, F., Deressa, T., Yousuf, J. and Kebede, T., 2021. Vulnerability of smallholder farmers to climate change-induced shocks in East Hararghe Zone, Ethiopia. *Sustainability*, 13(4), p.2162.

Ziervogel, G., Bharwani, S. and Downing, T.E., 2006. Adapting to climate variability: pumpkins, people and policy. In Natural resources forum (Vol. 30, No. 4, pp. 294-305). *Oxford, UK: Blackwell Publishing Ltd*.

7. APPENDIX

A. Household Survey Questions

Dear Sir/Madam,

This is a survey questionnaire designed to collect data to identify climate change and variability induced vulnerability of forest-based and non-forest based households, their adaptation strategies to climate change and the determinants of adaptation strategies in case of Decha district, south-western peoples' region as part of MSc thesis work. This questionnaire is prepared only for academic purposes. Your responses to each item of the questionnaire are very much crucial for the success of this study. Thus, you are kindly requested to give a genuine answer for each of the questions outlined. Finally, the researcher assured the respondents responses were kept confidential and used only for this research purpose. I thank you in advance for your time and participation.

Household identification

1. Dear respondent, you are voluntary to react with the following questions prepared for this research purpose? _________
2. Code of the household head________________
3. Name of the *Kebele*________________________
4. Date of interview _________________________

Appendix Table 1: Household survey questionnaire

I. Demographic characteristics	
Questions	**Answer**
Sex of the household head	1. Male 0. female
Age of the household head	_____years
Marital status	1. Married 2. Single 3. Divorced 4. Widowed
Number of permanent household members (including household head) at the time of survey:	Male____female______total_____

Age category of household members				
Age group	**Male**	**Female**	**Total**	**Adult equivalent**
<10				
10-13				
14-16				
17-50				
>50				
Education status of household head	1. Illiterate 2. Literate….(years of formal schooling)			

Do you have access to agricultural extension services?	1. Yes 0. No
If "Yes", for the above question how many times the DA visit you last year?	_______times
Does the extension agent provide you information on climate change?	1. Yes 2. No
What types of advices did you receive from extension workers? (Multiple responses are possible) Improved crop production systems Improved livestock production soil and water conservation	

Irrigation use Natural resource management planting and harvesting time Crop diversification Using climate change tolerant variety If others, specify__________________		
Are/is there any social associations in your village?	Iddir Coffee union Ikub PFM	
Are you members of these/this association found in your village?	1. Yes 0. No	
Do you have access to credit from any sources?	1. Yes 0. No	
If "Yes", how many birr did you borrowed from any of the sources during the past year?	…………birr	

Appendix Table 2: Questionnaire related with vulnerability factors

II. Exposure components	
Questions	**Answers**
Have you noticed increase in temperature over the last 10 years?	1. Yes 0. No
Have you noticed decline of rainfall patterns over the last 10 years?	1. Yes 0. No
Have you noticed climate change over the last 10 years?	1. Yes 0. No
Have you perceived the occurrence of erratic rainfall patterns?	1. Yes 0. No
Have you observed crop pests/diseases in your farm?	1. Yes 0. No
Have you observed animal diseases in your farm?	1. Yes 0. No
Malaria is identified with in the family?	1. Yes 0. No
Have you observed the occurrence of flood in your farm?	1. Yes 0. No
Have you observed the occurrence of landslides and erosions in your farm?	1. Yes 0. No
Have you observed the drying up of rivers and streams in your locality?	1. Yes 0. No
Have you observed the shift of crops growing season?	1. Yes 0. No
III. Sensitivity components	
Agriculture	
Do you have farm land?	1. Yes 0. No
How many hectares of farm land do you have?	________Ha
How many hectares of cultivated land do you have?	________Ha
How many crops you produced last year? Multiple responses are possible. *Underline the choices*	Maize, Wheat, Teff, Barley, Pea, Bean, Haricot beans, Sorghum, sweet potatoes, Enset, Rice If others……………
Do you save/store seeds for the next growing season?	1. Yes 0. No
Food	
Are there times during the year that your family does not have enough food?	1. Yes 0. No
If your answer for the above question is yes, how many months a year does your family have trouble getting enough food?	-------months
Where does your family get most of consumed food?	1. Own production 2. Purchased 3. Aid 4. If others, specify-------
Do you saved crops for the future consumption?	1. Yes 0. No
Water	
Is there any water related conflict happened in your area?	1. Yes 0. No
Do you have consistent water access?	1. Yes 0. No
Do you use natural water for home consumption?	1. Yes 0. No
IV. Adaptive capacity component	
Technology	
Did you use improved seed?	1. Yes 0. No
Did you use fertilizer?	1. Yes 0. No
Did you use pesticides and herbicides?	1. Yes 0. No

Infrastructure	
How many km you spent to access all weather roads?	______ km
How many km you spent to access the nearest school?	______ km
How many km you spent to access veterinary services?	______ km
How many km you spent to the nearest input-output market?	______ km
How many km you spent to reach the nearest health center?	______ km
Asset	
Do you have cash crops (coffee, spices, chat, eucalyptus tree, honey etc.)?	1. Yes 0. No
Do you live in houses made of roof/grass, traditional hut?	1. Yes 0. No
Do you have easy access to fodder for livestock?	1. Yes 0. No

V. Adaptation strategies to climate change

1. Have you employed any of the following climate change adaptation strategies? (Multiple responses is possible)

Appendix Table 3: Adaptation Strategies of Climate Change

Adaptation strategies	**1, if adopt and 0, otherwise)**
Adjusting planting date of crops	
Expansion of enset	
Mixed cropping	
Intercropping	
Crop rotation	
Use of improved crop variety	
Use of fertilizer	
Application of pesticides and herbicides	
Agro-forestry/Planting trees	
Management of forest (protection, reforestation, afforestation)	
Increased use of soil and water conservation techniques	

VI. Main source of livelihood

Appendix Table 4: Agricultural Crops

Crop types	ha of cultivated land	Yield (kg)	Amount consumed (kg)	Amount sold (kg)	Price/ kg	Total income
Maize						
Wheat						
Teff						
Barley						
Pea						
Bean						
Haricot beans						
Sorghum						
Potato						
Sweet potatoes						
Enset						
Avocado						
Papaya						
Mango						
Banana						

Rice						
Pepper						
Onion						
Garlic						
Ginger						
Beetroot						
Cabbage						
Total						

Appendix Table 5: Off-farm Activities

Type of activities	Engagement (1, Yes 0. No)	Earned income
Farm wage work		
Working on others farm		
Land rent out		
Hunting and gathering		
Sales of farm tools		
Total		

Appendix Table 6: Non-farm Activities

Type of activities	Engagement (1, Yes 0. No)	Earned income
Gifts from relatives		
Petty trading		
Selling local drinks		
Pension		
Making handicrafts (welding, pottery, tanning)		
Daily labor		
If others, specify……………………		
Total		

Appendix Table 7: Forest and its' product

Types	Quantity harvested (kg)	Quantity consumed (kg)	Quantity sold (kg)	Price/kg	Total income earned
Timber					
Firewood					
Charcoal					
Coffee					
Honey					
Cardamom					
Spices					
Lianas					
Fodder					
Bamboo					
Homemade tools					
Building/ construction materials					
Total					

Appendix Table 8: Animal Husbandry

Types of livestock	No owned	TLU	No sold	Price	Total income
Cow and oxen					
Calf					
Weaned calf					
Heifer and bull					
Horses and mule					
Donkey (adult)					
Donkey (young)					
Sheep and goats (young)					
Sheep and goats (adult)					
Chicken					
Livestock products (milk, butter, cheese, egg)					
Total					

B. Guiding Questions for Focus Group Discussion

Dear focus group discussants, the purpose of these questions is to obtain in-depth information about the climate change scenarios in the area, and employed adaptation strategies. I would like to assure you that your response will be used only for this research purposes and will be kept confidentially. Thus, you are requested to kindly give your genuine responses. I thank you in advance for your willingness and cooperation to answer the questions.

1. How do you perceive the existing climate change and variability?
2. What do you think about the major causes for the climate change?
3. What are the manifestations of climate change happened/happening in the area?
4. Explain your opinion about the past and present scenarios of climate change?
5. Do you think the communities are facing challenges due to climate change? If yes, what are the challenges they are/were facing/faced?
6. Do you think there is difference of livelihood practices in the past and present? If yes, how do you express the difference in the past and present time?
7. What measures are undertaken by the communities to overcome uncertainties of climate change?
8. Do the residents of this kebele get enough extension advises on climate change related events?
9. How do you evaluate the infrastructural and institutional services of your respective residential areas?

C. Guiding Questions for Key informant interview

Dear key informants, the primary purpose of these questions is to conduct an in-depth analysis on the major types of households' livelihood, the climate change induced vulnerability of households, adaptations strategies and determining factors in Decha district of south western peoples' regional state. I would like to assure you that your response will be used only for this research purposes and will be kept confidentially. Therefore, you are requested to kindly give your genuine responses. I thank you in advance for your willingness and cooperation to answer various questions.

1. Do you think the climate change events are happening in Decha district?
2. If yes, what are the manifestations of climate change in the district you observed?
3. How do you describe the problems of climate change on the households' livelihood?
4. What are the recommended and implemented adaptation strategies by smallholder farmers in the district?
5. Which groups of people (from those more relied on forest resources/services and non-forest) are more vulnerable?
6. Does the government of the district prepared and implemented context based climate change adaptation strategies to combat the negative impacts of climate change? If yes, explain the types and its applicability?
7. How do you evaluate the agricultural extension services of your district?
8. How do you evaluate the infrastructural and institutional service of your district?

Appendix Table 9: Conversion factors of Adult equivalent

Age group (years)	Male	Female
Less than 10	0.0	0.0
10-13	0.2	0.2
14-16	0.5	0.4
17-50	1.0	0.8
More than 50	0.7	0.5

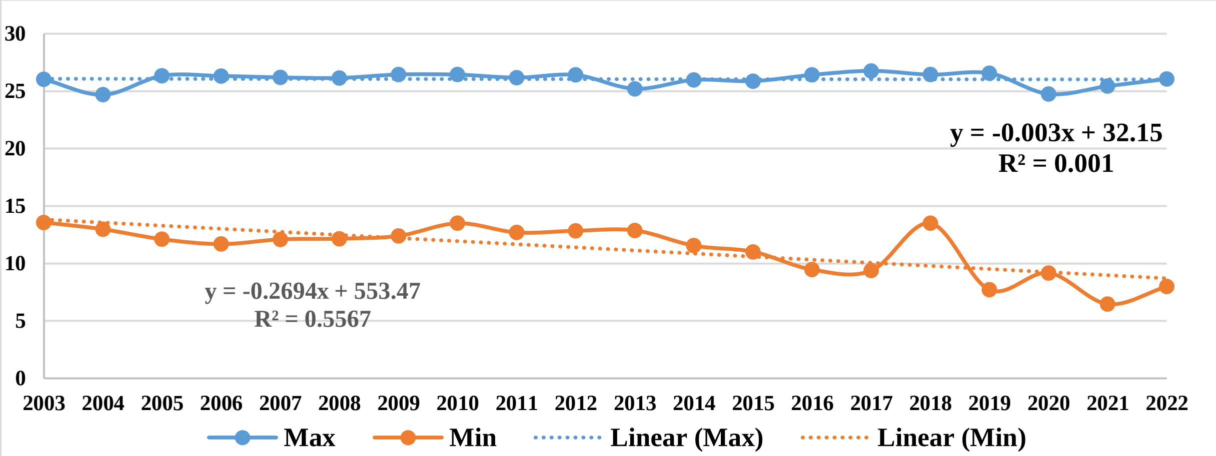
Source: Philip *et al.* (2013) cited by Mihiretu *et al.*, (2017)

Appendix Table 10: Conversion factors to estimate tropical livestock unit equivalents

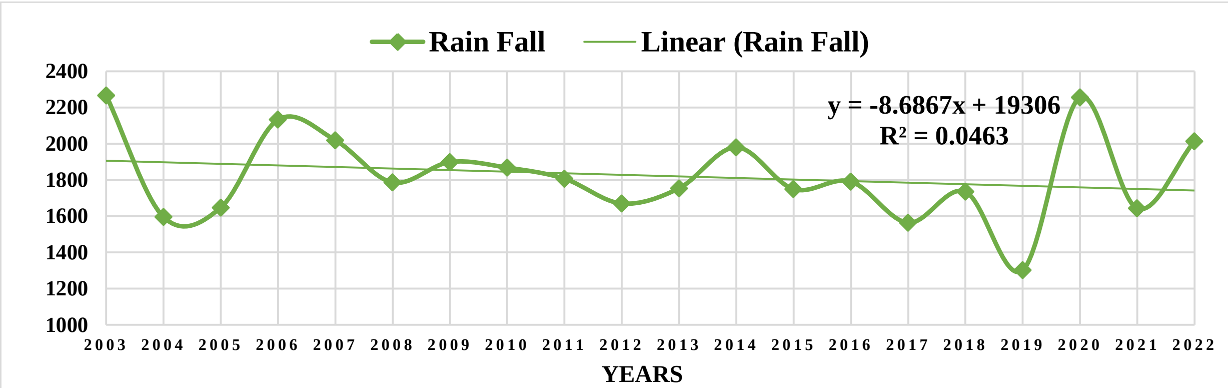
Livestock Category	Conversion factor	Livestock Category	Conversion factor
Calf	0. 25	Donkey (young)	0. 35
Weaned calf	0. 34	Sheep or goat (adult)	0. 13
Heifer	0. 75	Sheep or goat (young)	0. 06
Co w or ox	1. 00	Chicken	0. 013
Horse/ mule	1. 10	Bull	0. 75
Donkey (adult)	0. 70		

Source: Storck *et al*. (1991)

Appendix Figure 1: Trends of Max and Min Average T^0 from Wush-Wush station (2003-2022)



Appendix Figure 2: Trends of annual average precipitation of Wush-Wush station (2003-2022)



Appendix Figure 3: Multicollinearity test of continuous explanatory variables

Variable	VIF	1/VIF
Fextcontact	1.29	0.775698
TotAnnuaIn~e	1.20	0.830987
AgHH	1.13	0.888563
EdunstaHH	1.10	0.906607
FamSize	1.07	0.934620
DistNrstIn~t	1.05	0.952398
SzeLivstck~U	1.04	0.963271
SzeFarmLnd	1.03	0.972678
Mean VIF	1.11	

Source: Own survey computation (2023)

Appendix Figure 4: Contingency coefficients for dummy explanatory variables

	GeoAre~s	SeHH	Acredit	PerCli~e
GeoAreaHHs	1.0000			
SeHH	-0.0311	1.0000		
Acredit	0.1231	0.1846	1.0000	
PerClimate~e	0.1664	0.0344	-0.0147	1.0000

Source: Own survey computation (2023)

Appendix Figure 5: Sample of areas considered as forest based

Appendix Figure 6: Sample of areas considered as non-forest based

Appendix Figure 7: Climate change related effects happened in NFB area

Appendix Figure 8: Multivariate probit model result

Multivariate probit (SML, # draws = 100) Number of obs = 312
Wald chi2(60) = 330.73
Log likelihood = -774.52742 Prob > chi2 = 0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
AdjstPlantDtCops						
GeoAreaHHs	.3894325	.1839319	2.12	0.034	.0289326	.7499324
SeHH	-.2837025	.2391837	-1.19	0.236	-.752494	.185089
AgHH	.024209	.012286	1.97	0.049	.0001289	.0482891
HHSIZE	.0041122	.0750652	0.05	0.956	-.143013	.1512374
EdunstaHH	-.033609	.0332736	-1.01	0.312	-.0988241	.0316061
Fextcontact	.1067132	.0418085	2.55	0.011	.0247701	.1886563
Acredit	-.0146978	.1959758	-0.07	0.940	-.3988033	.3694077
SzeLivstckTLU	-.0409846	.0553607	-0.74	0.459	-.1494895	.0675203
TotAnnuaIncome	.0000165	7.49e-06	2.21	0.027	1.86e-06	.0000312
PerClimateChange	.8246311	.1769884	4.66	0.000	.4777402	1.171522
SzeFarmLnd	-.0521817	.1112145	-0.47	0.639	-.2701581	.1657947
DistMrkt	-.0003011	.0371246	-0.01	0.994	-.073064	.0724619
_cons	-1.430357	.9041306	-1.58	0.114	-3.20242	.3417065
EXPANDENSET						
GeoAreaHHs	-.5348892	.1672932	-3.20	0.001	-.8627777	-.2070006
SeHH	.4351938	.2191419	1.99	0.047	.0056836	.864704
AgHH	.0271862	.0107135	2.54	0.011	.006188	.0481843
HHSIZE	-.0467161	.0682622	-0.68	0.494	-.1805075	.0870753
EdunstaHH	.0068041	.0303042	0.22	0.822	-.052591	.0661992
Fextcontact	-.0040146	.0390654	-0.10	0.918	-.0805813	.0725521
Acredit	-.0013341	.1767677	-0.01	0.994	-.3477924	.3451242
SzeLivstckTLU	.0229339	.0502806	0.46	0.648	-.0756143	.1214821
TotAnnuaIncome	-.000017	7.09e-06	-2.40	0.016	-.0000309	-3.10e-06
PerClimateChange	.3710572	.1717032	2.16	0.031	.0345252	.7075892
SzeFarmLnd	.1211111	.1029618	1.18	0.239	-.0806902	.3229124
DistMrkt	-.0176373	.0327511	-0.54	0.590	-.0818283	.0465537
_cons	-1.508589	.7994848	-1.89	0.059	-3.075551	.058372
CropDiversfn						
GeoAreaHHs	.044922	.2003556	0.22	0.823	-.3477678	.4376118
SeHH	.606725	.2406947	2.52	0.012	.1349719	1.078478
AgHH	-.0169654	.0124713	-1.36	0.174	-.0414087	.007478
HHSIZE	.2476046	.0853465	2.90	0.004	.0803285	.4148807
EdunstaHH	-.0014203	.0359789	-0.04	0.969	-.0719377	.0690971
Fextcontact	.0817095	.0429712	1.90	0.057	-.0025124	.1659314
Acredit	1.357791	.2444968	5.55	0.000	.8785863	1.836996
SzeLivstckTLU	-.2120871	.0620855	-3.42	0.001	-.3337724	-.0904018
TotAnnuaIncome	7.26e-06	8.25e-06	0.88	0.379	-8.91e-06	.0000234
PerClimateChange	.3020776	.20337	1.49	0.137	-.0965202	.7006755
SzeFarmLnd	.5072956	.1276691	3.97	0.000	.2570688	.7575224
DistMrkt	-.0465937	.0376624	-1.24	0.216	-.1204107	.0272232
_cons	-1.648646	.9235213	-1.79	0.074	-3.458715	.1614223
UseFertlzr						
GeoAreaHHs	.4751423	.177637	2.67	0.007	.1269802	.8233044
SeHH	.0337113	.222897	0.15	0.880	-.4031588	.4705814
AgHH	.0031823	.0111996	0.28	0.776	-.0187685	.0251331
HHSIZE	.0800554	.0721839	1.11	0.267	-.0614226	.2215333
EdunstaHH	.0239232	.0321243	0.74	0.456	-.0390393	.0868858
Fextcontact	.0894564	.0398573	2.24	0.025	.0113375	.1675754
Acredit	.5958452	.1814569	3.28	0.001	.2401963	.9514941
SzeLivstckTLU	.0815423	.0533384	1.53	0.126	-.022999	.1860837
TotAnnuaIncome	.0000208	7.35e-06	2.83	0.005	6.42e-06	.0000352
PerClimateChange	-.2269384	.1790221	-1.27	0.205	-.5778153	.1239386
SzeFarmLnd	-.2077776	.1041157	-2.00	0.046	-.4118406	-.0037147
DistMrkt	-.0087233	.0339983	-0.26	0.798	-.0753588	.0579123
_cons	-1.861684	.8452746	-2.20	0.028	-3.518392	-.2049764
FRSTMGT						
GeoAreaHHs	-1.849035	.2113018	-8.75	0.000	-2.263178	-1.434891
SeHH	-.3390364	.2455997	-1.38	0.167	-.8204029	.1423302
AgHH	.0321453	.0123849	2.60	0.009	.0078712	.0564193
HHSIZE	-.1585811	.0770947	-2.06	0.040	-.309684	-.0074782
EdunstaHH	.0381073	.0349802	1.09	0.276	-.0304526	.1066673
Fextcontact	.0717439	.0438303	1.64	0.102	-.014162	.1576498
Acredit	-.2867357	.201424	-1.42	0.155	-.6815195	.1080481
SzeLivstckTLU	-.0753265	.0581106	-1.30	0.195	-.1892212	.0385683
TotAnnuaIncome	.0000282	8.23e-06	3.42	0.001	.000012	.0000443
PerClimateChange	.4141185	.1967641	2.10	0.035	.0284679	.7997691
SzeFarmLnd	.105916	.1140082	0.93	0.353	-.1175359	.3293679
DistMrkt	.0630301	.038634	1.63	0.103	-.0126911	.1387513
_cons	-1.597592	.8880445	-1.80	0.072	-3.338127	.1429434