FACULTY OF
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Adoption of sustainable agricultural practices to improve livelihoods in Tigray, Ethiopia

Woldegebrial Zeweld

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“The fear of the LORD is the beginning of knowledge: but fools despise wisdom and instruction.” Proverbs 1:7

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Adoption of Sustainable Agricultural Practices to Improve Livelihoods in Tigray, Ethiopia

Woldegebrial Zeweld

A dissertation submitted to Ghent University in partial fulfilment of the requirements for the degree of Doctor (PhD) in Applied Biological Sciences: Agricultural Economics and Rural Development

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This is dedicated to my beloved parents for their truly, selfless and unconditional love they gave me, and their endless support, encouragement and sacrifices

Zeweld Nugusse and Abeba Gidey

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Woldegebrial Zeweld
June 2018, Belgium

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List of abbreviations

3SLS	Three-Stage Least Square Regressions
CLAD	Censored Least Absolute Deviation
CSA	Central Statistics Agency of Ethiopia
DTBP	Decomposed theory of planned behaviour
ESCAP	The United Nations Economic and Social Commission for Asia and the Pacific
ESR	Endogenous switching regression
FAO	Food and Agriculture Organization of the United Nations
FGT	Foster-Greer-Thorbecke
GDP	Gross Domestic Product
HFIAS	Household Food Insecurity Access Scale
IB	Behavioural Intentions
IFAD	International Fund for Agricultural Development
IIA	Independence of Irrelevant Alternatives Assumption
IPCC	Intergovernmental Panel on Climate Change
MFI	Microfinance institutions
NGO	Non-Governmental Organizations
OLS	Ordinary Least Square Regression
SAI	Sustainable Agriculture Initiative Platform
SEM	Structural Equation Model
SSA	Sub-Saharan African Countries
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
WFP	World Food Programme of the United Nations
UNCTAD	The United Nations Conference on Trade and Development

Summary

In Sub-Saharan African countries, such as Ethiopia, food insecurity, malnutrition and poverty are problems that have been occurring more frequently. This is usually linked to the low productivity of agriculture and the low adaptive capacity of the local systems. Following this, improving the productivity of the sector has received increasing attention in the rural development paradigm and become a discussion point on the international agenda as well. Alternative mechanisms to improve agricultural productivity have also been suggested, for example, intensified use of the green revolution technologies, such as chemical fertilizers, high yielding varieties, pesticides, machinery and herbicides, expansion of cultivated farmland even to marginal and remote areas, and adoption of sustainable agricultural practices.

When evaluating the adoption or use of sustainable agriculture in these countries, it still remains below the expected levels. The same also holds true for the green revolution technologies. In the area under consideration, for example, a significant number of smallholder farmers have not adopted sustainable agriculture to increase productivity and to adapt to drought, climate change and other disasters. Such low adoption is largely associated with various factors, such as demographic characteristics, socio-psychological issues, biophysical factors, economic variables and institutional factors.

In this regard, this dissertation aims to understand and investigate how socio-psychological issues, such as attitudes, social capital (formal organizations and informal institutions), personal efficacy, information and capacity building influence smallholder farmers' stated (or intended) and revealed (or actual) behaviour towards sustainable agriculture. In addition, this paper evaluates the impacts of sustainable agricultural practices on agricultural production and rural livelihoods. For this purpose, cross-sectional data were collected using a pre-tested and standardized questionnaire, and focus group discussions. This primary data was further complemented by secondary data obtained from different sources.

The first empirical analysis examines the behavioural intentions of farmers toward conservation agriculture and how it is affected by socio-psychological issues. The results of the structural equation model and three-stage least squares regression indicate that attitudes towards the practice, attributes of the practice, capacity building training, social capital and favourable norms towards the practice are found to influence farmers' intentions and motivate them to adopt conservation agriculture. In contrast, extension services, and the availability of physical resources and rural facilities are insignificant in affecting farmers' behavioural intentions.

In the context of the second objective, it is found that nearly 45% of smallholder farmers are reported to be less risk averse while the remaining are either more risk averse or risk indifferent. Farmers' aversion is reduced if they are members of formal organizations; if they have strong relationships and networks with local community groups (informal institutions); if they are literate, if they have a large household; if they have received capacity building training; and if they have positive attitudes towards sustainable agriculture. Besides, the actual adoption of sustainable agriculture, especially the use of agroforestry systems, application of crop rotation and the use of compost are significantly affected by the educational level of the household head,

attitudes towards these practices, farmers' attitudes towards risks (risk attitudes), social capital and agricultural extension services.

In addition, this dissertation investigates the roles of sustainable agricultural practices in crop yields, household food security and livelihoods. Use of agricultural practices, for example, soil and water conservation measures, use of animal manure and retention of crop residues have significant positive effects on crop yields, income, assets and food security. These outcomes have improved for farmers who have adopted these practices compared to those who have not adopted them. In addition, the proportions of smallholder farmers who are food secure are relatively higher among those who have adopted these agricultural practices. Moreover, farm households who have adopted these agricultural practices have significantly higher yields, incomes and assets than they would have if they had remained non-adopters.

Furthermore, most farmers in the area have perceived the existence of climate change. They have usually experienced high temperatures and extreme weather events. They have also clearly observed the adverse impacts of climate change on crops, livestock, biodiversity, water and people. As a result, many farmers have made efforts to adjust their farming practices in response to these impacts through the adoption of sustainable agricultural practices, such as the use of soil and water conservation measures, use of agroforestry systems, expansion of irrigation by constructing alternative water harvesting schemes, use of organic fertilizers, use of early maturing varieties, use of drought/disease-resistant varieties, use of varieties with better WUE, and diversification of their livelihood portfolio from agriculture to non-agriculture.

Consequently, these empirical findings confirm that socio-psychological issues, for example, attitudes, social capital, personal efficacy, information and extension services are important factors for improving intentions, reducing aversion (or uncertainty) and promoting adoption of sustainable agriculture. Furthermore, adoption of sustainable agricultural practices has substantial and positive implications for crop production and household livelihoods. Local institutions, capacity building centres and institutional support, therefore, need to receive attention to enhance awareness, provide information and inspire smallholder farmers to adopt sustainable agriculture to address food insecurity and climate change.

However, the results of this doctoral study are subject to some limitations that might require caution in interpreting and extrapolating the findings. The sample size used in this study is relatively small to understand adoption impacts using endogenous switching regression. The survey also covers only six rural villages in Ethiopia. Moreover, the study depends largely on categorical variables, and some data, such as yields, income and assets, are also based on farmer perceptions. Furthermore, cross-sectional data does not capture the true dynamic effects. Apart from these factors, the findings are still valuable to enhance awareness of economic actors, such as researchers, development practitioners and governments on how sociopsychological factors affect the promotion of sustainable agriculture; and also on the role of sustainable agriculture in enhancing agricultural production and livelihoods in dryland and water stressed areas.

Samenvatting

Voedselzekerheid, ondervoeding en armoede zijn problemen die veelvuldig voorkomen in landen gelegen in Sub-Sahara Afrika, zoals bijvoorbeeld Ethiopië. Dit is vaak te wijten aan de lage landbouwproductiviteit en de beperkte aanpassingscapaciteit van lokale systemen. Investeren in het opkrikken van de sectorproductiviteit wint dus steeds meer aan belang binnen het rurale ontwikkelingsparadigma en wordt ook vaak als discussiepunt op de internationale agenda gezet. Alternatieve mechanismen om landbouwproductiviteit op te drijven worden ook gesuggereerd zoals het intensief gebruik van Groene Revolutie technologieën waaronder chemische bemesting, hoge opbrengst variëteiten, pesticiden, mechanisatie en herbiciden, uitbreiding van het gecultiveerde landbouwareaal tot marginale en afgelegen gebieden alsook adoptie van duurzame landbouwmethodes.

De toepassing van duurzame landbouwtechnieken in Sub-Sahara Afrika blijft, tegen alle verwachtingen in, zeer beperkt. Hetzelfde geldt voor de toepassing van Groene Revolutie technologieën. In Ethiopië, bijvoorbeeld, passen een significant deel van de kleine boeren nog geen duurzame landbouwmethoden toe om productiviteit te verhogen en om zich aan te passen aan droogte, klimaatsverandering en andere rampen. Dergelijk lage adoptie is vaak geassocieerd met verschillende uiteenlopende factoren, zoals demografische karakteristieken, socio-psychologische kwesties, biofysische factoren, economische variabelen en institutionele factoren.

Dit proefschrift tracht na te gaan in welke mate socio-psychologische kwesties, zoals attitudes, sociaal kapitaal (formele organisaties en informele instituties), persoonlijke daadkracht, informatie- en capaciteitsopbouw, de gerapporteerde alsook de werkelijke toepassing van duurzame landbouwtechnieken van kleine boeren beïnvloeden. Bovendien evalueert dit proefschrift de impact van duurzame landbouwmethodes op landbouwproductie en ruraal levensonderhoud. Cross-sectionele data werden verzameld aan de hand van een uitgeteste, gestandaardiseerde vragenlijst en focusgroep discussies. Deze primaire data werden aangevuld met secondaire gegevens afkomstig van verschillende bronnen.

De eerste empirische analyse onderzoekt de gedragsintenties van boeren ten aanzien van conserveringslandbouw en hoe dit beïnvloedt wordt door socio-psychologische kwesties. De resultaten van een structurele vergelijkingsmodel en een drie-stadia kwadraten analyse tonen aan dat attitudes ten aanzien van de toepassing, attributen van de toepassing, capaciteitsopbouw training, sociaal kapitaal en gunstige normen ten aanzien van de toepassing, de intentie van boeren beïnvloeden en hen motiveren om conserveringslandbouw toe te passen. Extensie diensten, en de beschikbaarheid van fysische hulpbronnen en rurale faciliteiten, hebben echter geen significante invloed op de gedragsintenties van boeren.

In een tweede luik, vonden we dat de aversiegedachte van kleine boeren afneemt wanneer ze lid zijn van formele organisaties, wanneer ze goede relaties en netwerken hebben met en binnen lokale gemeenschapsgroepen (informele instituties), wanneer ze geletterd zijn, als ze een groot gezin hebben, wanneer ze reeds capaciteitsopbouw training kregen, en wanneer ze positieve attitudes hadden ten aanzien van duurzame landbouw. Bovendien wordt de werkelijke adoptie van duurzame landbouwmethodes, en dan specifiek het gebruik van boslandbouwsystemen, de toepassing van gewasrotatie en het gebruik van compost, significant beïnvloed door het educatieniveau van het gezinshoofd, attitudes tegenover dergelijke praktijken, risico attitudes, sociaal kapitaal en extensie diensten gericht op landbouw.

Dit proefschrift onderzoekt eveneens de rol van duurzame landbouw in de voedselzekerheid en het levensonderhoud van een huishouden. Het gebruik van landbouwpraktijken, zoals bijvoorbeeld bodem- en waterbehoudsmaatregelen, het gebruik van dierlijke mest en het behoud van gewasresten op het veld, hebben een significant positief effect op gewasopbrengsten, inkomen, bezittingen en voedselzekerheid. Boeren die dergelijke landbouwpraktijken toepassen scoren beter op alle 4 de uitkomsten (gewasopbrengsten, inkomen, bezittingen en voedselzekerheid) in vergelijking met boeren die deze technieken niet toepassen.

Bovendien ondervonden de meeste boeren in de onderzochte gebieden de gevolgen van klimaatsverandering. De meesten ervaarden hoge temperaturen en extreme weersomstandigheden. Ze observeerden ook nadelige gevolgen van klimaatsverandering op gewassen, veestapel, biodiversiteit, water en mensen. Veel boeren hebben dus reeds actie ondernomen om hun landbouwpraktijken aan te passen aan deze gevolgen door de toepassing van duurzame landbouwmethodes, zoals bodem- en waterbehoudsmaatregelen, het gebruik van boslandbouwsystemen, het uitbreiden van irrigatie met behulp van alternatieve systemen voor watercollectie, het gebruik van biologische bemesting, het gebruik van droogte-/ziekte-resistente variëteiten, en een uitbreiding van het levensonderhoudsportfolio naar niet-landbouw gerelateerde activiteiten.

Deze empirische bevindingen bevestigen dus dat socio-pyschologische kwesties, zoals attitudes, sociaal kapitaal, persoonlijke daadkracht, informatie en extensie diensten, belangrijke factoren zijn in het verbeteren van intenties, het reduceren van aversie en het promoten van duurzame landbouw. Bovendien hebben de toepassing van duurzame landbouwtechnieken een substantieel positief effect op gewasproductie en levensonderhoud van een huishouden. Lokale instituties, centra voor capaciteitsopbouw en institutionele ondersteuning zijn dus nodig om boeren bewust te maken van reeds bestaande duurzame landbouwtechnieken, hen van informatie te voorzien en hen aan te zetten om dergelijke methodes toe te passen in de strijd tegen voedselonzekerheid en klimaatsverandering.

De resultaten van dit proefzicht zijn echter onderworpen aan een aantal beperkingen en moeten dus met enige voorzichtigheid worden geïnterpreteerd en geëxtrapoleerd. De steekproefomvang van deze studie is relatief klein om de impact van adoptie te begrijpen gebruik makend van endogene schakelregressie. Het onderzoeksgebied beslaat eveneens slecht zes landelijke dorpen in het noorden van Ethiopië. De studie is voornamelijk gebaseerd op categorische variabelen, en sommige data zoals opbrengsten, inkomen en bezittingen, zijn gebaseerd op de perceptie van boeren. Tot slot zijn cross-sectionele data niet in staat om echte dynamische effecten weer te geven. De bevindingen in dit proefschrift zijn echter waardevol om het bewustzijn van academici, onderzoekers, ontwikkelingsmedewerkers en beleidsmakers te vergroten omtrent het belang van socio-psychologische factoren en hun effect op de promotie van duurzame landbouw alsook de rol die duurzame landbouw kan spelen in het opdrijven van landbouwproductie en het levensonderhoud in droge gebieden en gebieden gevoelig aan waterschaarste.

Chapter One
Introduction

1. 1. Background

Climate change, food insecurity and environmental degradation constitute the most important global challenges (Fisher *et al.*, 2015). Recent reports show that more than 0.8 billion people are undernourished and living in poverty. Nearly 60-70% of these people live in rural areas in less developed countries (IPCC, 2014; UNCTAD, 2015). It is further observed that climate change poses a considerable threat to food and water security, public health, human systems, natural resources and biodiversity (Bryan *et al.*, 2009; IPCC, 2014).

These problems are more severe in less developed countries, especially Sub-Saharan Africa (SSA), because of population pressure (Norton, Alwang and Masters, 2010; IFAD, WFP and FAO, 2015), low financial and institutional adaptive capacities for various potential hazards and shocks (FAO, 2010; UNCTAD, 2015; Khatri-chhetri, Aryal and Sapkota, 2016) and high dependence on agriculture and natural resources (Komba and Muchapondwa, 2012).

The Sub-Saharan African countries have frequently been exposed to poverty and environmental degradation because they have poor financial resources. The capacity of their local systems, or institutional settings, are also limited and too weak to cope with the challenges of climate change, drought and other shock (Mbow *et al.*, 2014; FAO, 2015; IFAD, WFP and FAO, 2015).

These countries also have a fast growing population due to high birth rates and a higher proportion of young people. Based on the United Nations' Worldometer projection, it is expected that about 85% of the world's population will be living in less developed countries by 2030 (Worldometer 2018). Another trend is that income, or per capita income has been increasing, especially in emerging countries, such as Brazil, Taiwan and Vietnam.

In South Africa, for example, it has been found that a high population with an increase in income places pressure on natural resources and creates food security issues (Calzadilla *et al.*, 2014). Unless the food demand is addressed, these issues can lead to tensions and instability across the whole economy. The world, especially the developed countries, can also be adversely affected by migration from these countries and other socioeconomic crises (Todaro and Smith, 2011).

Less developed countries, especially SSA countries, are also highly reliant on agriculture. In most of these countries, it is estimated that agriculture accounts for 20-50% of GDP. Around 50-80% of the population also depend on the sector for their livelihoods. In addition, several emerging and existing industries and some service sectors are linked to the sector through value chains, especially inputs and markets (Norton, Alwang and Masters, 2010; Gebrehiwot and Van Der Veen, 2013; IFAD, WFP and FAO, 2015). Therefore, agriculture is vital for livelihoods, the sociocultural system and the overall economy of Sub-Saharan African countries.

However, the sector's productivity is low due to interrelated factors, such as traditional farming practices, environmental degradation and rain-fed subsistence farming (Norton, Alwang and Masters, 2010). Many areas where poor people reside are also marginalized, eroded and degraded (Hoffmann, 2011). Furthermore, susceptibility to climate variability and shifting seasons is another contributing factor (Komba and Muchapondwa, 2012; Gebrehiwot and Van Der Veen, 2013). This could lead to substantial welfare losses, especially for smallholders whose main source of livelihood is agriculture.

With regard to the interlinkage and interplay between agriculture and climate change, however, there are two thoughts. On the one hand, agriculture is a victim of climate change (FAO, 2015). The Intergovernmental Panel on Climate Change stated that climate change amplifies existing risks and creates new risks for natural and human systems (IPCC, 2014). It has the potential to damage the natural resource base on which agriculture depends. For example, high temperatures and inadequate rainfall adversely affect plants, animals, biodiversity, farmers' health, and overall farmers' production decisions. This can lead to food insecurity and also constrain economic development in countries that largely rely on agriculture.

It is estimated that climate change will reduce total agricultural production in the least developed countries by up to 50% in the next few decades (Hoffmann, 2011). In particular, a reduction in rainfall and an increase in temperature have been found to significantly reduce rice, wheat and maize yields, which leads to greater instability in food production (Khatri-chhetri, Aryal and Sapkota, 2016). Low and erratic rainfall in the Sahel zone of SSA leads to harvest failure, severe food shortage and welfare losses (Beddington *et al.*, 2011; Abdulai and Huffman, 2014) and exacerbates the vulnerability of agricultural systems, increasing the burden of climate-related health outcomes (SAI, 2010; IPCC, 2014; Fisher *et al.*, 2015). In Ghana, for example, the productivity of agriculture has declined significantly due to climate change over the last ten years (Egyir *et al.*, 2015).

On the other hand, the atmospheric concentration of greenhouse gases is increasing as a result of human activity (Bryan *et al.*, 2009), with agriculture as one of the main contributors. Globally, agriculture accounts for about 13-15% of greenhouse gas emissions. Emissions from the sector are expected to increase to 30-32% if land use changes, such as land degradation, erosion and deforestation are included. In response to population growth, changing diets towards ruminant meats and dairy products, and the further spread of industrial farming, it is predicted to further increase to 35-60% by 2030 (IPCC, 2007, 2014; Hoffmann, 2011).

Both as an affected party and a source of climate change, agriculture is at the centre of concerns in the context of climate change. For example, it has become a central point in the intergovernmental panel on climate change. The Kyoto Protocol and the Paris Agreement talk about agriculture and climate change. At the UN climate change conference in Paris in November 2015, some of the targets of the sustainable development goal are to eradicate hunger and poverty in all its forms by 2030; conserve and sustainably use the oceans, seas and marine resources; take urgent action to combat climate change and its impacts; and protect and promote sustainable use of terrestrial ecosystems, and halt land degradation and biodiversity loss (United Nations, 2015). These issues are about agriculture, food insecurity, poverty and climate change.

The focal point is not just to highlight the problems, but rather to find alternative ways to improve agricultural productivity, achieve food security, and address global climate change. Put differently, it is how to make agriculture climate resilient and how to make it greenhouse gas efficient, suggesting lower carbon emissions by increasing productivity. An additional issue is how smallholder farmers should not just be food/commodity producers but also advocators/protectors of natural resources and agro-ecological systems (IPCC, 2014).

To this effect, some pragmatic possibilities are suggested in the literature. For example, a need is stated for a holistic approach that focuses on transforming agriculture from being a source of the climate change problem to becoming part of the solution (IPCC 2014, 2007). Khatri-chhetri et al. (2016) identified the adoption of climate-smart agricultural practices, such as soil and water conservation measures, use of drought- disease-resistant varieties, planting of multipurpose trees, reforestation and water harvesting schemes, as a possible strategy for this.

The transformation of current agriculture from uniform and high external-input-dependent models into regenerative agricultural systems is also suggested (Hoffmann, 2011). To restate this, the uniform model of agriculture that applies the same farming practices, technologies and approaches across agro-ecology and countries needs to be flexible to understand specificities across locations and among people. The high external-input-dependent model, which largely focuses on greater use of inorganic inputs to maximize productivity, should reduce the use of these chemical inputs and focus on locally available resources.

Furthermore, improvements to the resilience and adaptation capacities of local systems and communities are recommended (Scherr and Sthapit, 2009). The adoption of more efficient farming practices and technologies is also advised to increase agricultural productivity and promote environmental sustainability (Abdulai and Huffman, 2014). Another alternative is to enrich biodiversity and improve the natural resource base (Juma, Nyangena and Yesuf, 2009).

Here, adopting or promoting sustainable agriculture (*see definition section 1.2.3*) is a win-win strategy for addressing the progressive food insecurity and climate change issues, for instance, due to population pressure, environmental degradation and traditional farming practices. Therefore, these issues inspire this dissertation to conduct research to provide information for policymakers, development actors, and concerned bodies on factors motivating farmers to adopt sustainable agricultural practices and how these practices affect overall livelihoods. Such empirical inputs would help to design effective strategies to advance the adoption of sustainable agriculture to build the resilient capacities of local systems to climate change and shocks.

1. 2. Concepts of mainstream agriculture: at a glance

1. 2. 1. Industrialized Agriculture

The United Nations Economic and Social Commission for Asia and the Pacific defined industrialized agriculture as a farming system characterised by an intensive use of external inputs, such as synthetic pesticides, inorganic fertilisers, antibiotics, agrochemicals, insecticides and vaccines (ESCAP, 2007). It is also defined as the production of livestock, poultry, fish and crops, predominately in large-scale monoculture, using genetic technology, heavy use of chemical fertilizers and pesticides, greater use of farming machinery (e.g. tractors) and confined livestock feeding operations (Nierenberg, 2006). This is the typical form of agriculture from the green revolution and is widely found in developed or emerging countries.

As indicated in different literature, industrialised agriculture has several benefits, such as reduced occurrence of crop and animal diseases. Herbicides help farmers to eradicate wild weeds. Different improved varieties have also been released to increase productivity, such as drought-resistant, disease/pest-tolerant and high-yielding varieties (crops and livestock). Subsequently, the volume of production has increased spectacularly. Farmers who have adopted these external inputs are able to achieve food self-sufficiency and are also able to supply sufficient foods to the world to meet global food demand (Carvalho, 2006; Pingali, 2012).

Moreover, due to surplus production, millions of people have emerged from food insecurity and this has reduced global hunger. Furthermore, the industry that processes and manufactures these external inputs has expanded. Finally, the sector has generated various employment opportunities both on the farms and in industry (ESCAP, 2007; Fazio, Baide, & Molnar, 2014; Pingali, 2012). Consequently, this high input-demanding agriculture has been responsible for increasing productivity, improving global food supply and reducing global hunger.

However, it has had some downsides. The mechanisation and the residuals from the increasing use of agrochemicals have a negative effect on soils and water. For example, pesticide use has negative effects on water bodies and fish, because the chemicals not taken up by the plants are washed away into lakes, oceans and seas. The increased use of chemicals has negatively affected topsoil, water quality, biodiversity, crops, aquatic life, and ecosystem health, causing serious environmental and human health problems (Tucker and Napier, 2001; Carvalho, 2006). Therefore, topsoil depletion, groundwater contamination, increased carbon emissions, water pollution and destruction of natural habitats are some of the irreversible adverse impacts of industrialized agriculture (Van Thanh and Yapwattanaphun 2015; ESCAP 2007).

In addition, not all farmers have access to these inputs. For example, poor and marginalized farmers are unable to purchase expensive inputs. Industrialized agriculture is also unable to cover less favoured and remote areas. Because of these facts, economic inequality among farmers and inter- intra-regional disparities have remained a continuous challenge in these countries (Halbrendt, 2014; Thanh, 1996). Furthermore, industrialized agriculture has mostly targeted certain selected crops, such as rice, wheat, corn, soybeans or specific livestock such as cattle and poultry. As a result, other crops or animals have been neglected, for example, pulses, vegetables, small ruminants and local varieties, leading to their disappearance. Due to poor seedbank systems, genetic diversity is lost (Stevens, 1991; Pingali, 2012). Finally, since most crops are introduced by some donors, governments or researchers, farmers are not happy with the selection process and often prefer indigenous varieties (Pingali, 2012).

Some studies have tried to estimate the negative externalities of industrialized agriculture. For example, the World Watch Institute estimated the ‘hidden costs’ of intensive agriculture to society, including the cost of removing pesticides from drinking water; repairing damage to rivers, reservoirs and roads caused by soil erosion; treating air pollution from emissions; dealing with animal diseases and diminished agricultural biodiversity due to chemicals; and the potential influences of pesticides on human health. The cost was found to be $112/hectare for the USA, $337/hectare for the UK and $274/hectare for Germany (Muir, 2014).

1. 2. 2. Traditional agriculture

The United Nations Economic and Social Commission for Asia and the Pacific defined traditional agriculture as a farming system characterised mainly by intensive tillage with low use of improved inputs (ESCAP, 2007). It is sometimes known as subsistence agriculture and is widely practised in less developed countries. Others have also defined traditional farming as self-contained and self-sufficient farming, where most of the agricultural production is consumed and some may be sold in local markets (Apta *et al.*, 2011). As a result, there is a direct and close relationship between production and consumption (Waceke and Kimenju, 2007). This implies that the goal of traditional agriculture is mostly family survival.

Traditional agriculture is usually rain-fed and characterized predominately by continuous cropping systems, use of family labour, simple technologies and free grazing systems. In addition, it is highly sensitive to unpredictable natural factors, such as rainfall, temperature and other weather events (Abele and Frohberg, 2003). Subsistence farms are small, have a low capital endowment and often have poor access to markets and other physical infrastructure. Labour used per hectare is high, because all family members work on the farms. Furthermore, animals are regularly used to plough, thresh and harvest (Fredriksson, Davidova and Gorton, 2007; Waceke and Kimenju, 2007; Apta *et al.*, 2011).

For these reasons, the production of traditional agriculture is very low and has not been able to fulfil its role of feeding the population and meeting the raw material needs of existing and emerging industries (Apta *et al.*, 2011). Moreover, the local people are often exposed to drought and various shocks due to limited financial and institutional adaptive capacities. Accordingly, food insecurity and starvation have often occurred in traditional agriculture-based economies, especially in Sub-Saharan Africa (IFAD, WFP and FAO, 2015). For example, using a poverty headcount ratio of $1.90 a day, nearly 60% of the people affected by poverty are found in SSA (World Bank 2018).

In traditional agriculture-dominated economies, agriculture and natural resources are the primary sources of income, employment and food for most of the poor households (Apta *et al.*, 2011). With the absence of strong institutions in these countries, people often use existing natural resources improperly or overexploit them, since people often behave out of self-interest. Such activities can ultimately lead to the depletion of natural resources (Jacobsen 2016) and to climate change through the emission of carbon dioxide to the environment. Deforestation, overgrazing, erosion and degradation are among the climate change contributors (IPCC, 2014; Shiferaw *et al.*, 2014; Khatri-chhetri, Aryal and Sapkota, 2016). As a result, traditional farms also have negative implications for food security and climate change.

1. 2. 3. Sustainable agriculture

The concept of sustainable agriculture has received more attention and became popular in the 1980s when Wes Jackson published a book '*New Roots for Agriculture*' in 1985 that asks whether current agricultural practices can be sustained much longer (Kirschenmann, 2004), when environmental movements and the academics have questioned the environmental and social concerns of the green revolution, some NGOs have started to provide sustainable extension services, and research institutes have focused on environment-friendly productivity-enhancing measures (Halbrendt, 2014; Kambewa, 2007; Presley, 2014; Thanh, 1996).

Sustainable agriculture is defined as a farming system that promotes better use of local and on-farm inputs, such as the use of crop residues and biomass as fertilisers and the use of farmers' skills and knowledge in managing agricultural productivity, while improving the resource base. It also discourages the use of external inputs that are harmful to the environment (Thanh, 1996; ESCAP, 2007; Rodriguez *et al.*, 2009; Wauters, 2010; Abubakar and Attanda, 2013; Van Thanh and Yapwattanaphun, 2015). Others also defined it as an integrated system of livestock and crop production that is capable of transitioning industrialized agriculture into an environment-friendly system while maintaining its productivity and competitiveness (Macrae, Henning and Hill, 1993; Foley, 2013; Wezel *et al.*, 2014).

The central concept of these definitions remains the same. They focus on the need to integrate economic, environmental and social dimensions into agriculture. Environmental or ecological sustainability is about maintaining healthy natural services at a suitable level for human needs (Moldan, Janousková and Hák, 2012). However, keeping the environment healthy is not enough unless it has adequate returns to improve livelihoods. Therefore, social sustainability focuses on maintaining inter-generational equity, including social values, relationships, norms, institutions and practices (Van Thanh & Yapwattanaphun, 2015), while economic viability is about the productivity and yields of agriculture and profit or returns that farmers receive from it to sustain their farming operations (Kambewa, 2007). Therefore, the point is to transform industrialized farms into sustainable farms and to make traditional farmers also market-oriented, efficient, competitive and sustainable.

Some examples of sustainable agricultural practices include diversifying crop mixes, use of crop rotations, planting multipurpose trees, use of row-cropping systems, use of cover crops, applying either no or low-tillage, use of rotational grazing and forage management, integrated pest management, use of biological controls, application of green compost, integrated soil fertility management, mulching with crop residues, applying biodegradable pots, use of soil and water conservation measures, use of improved varieties, animal manure application, increased use of irrigation and water harvesting schemes, improved fallow management, and applying biological weed management, including the recycling of farm waste (Fazio et al., 2014; Foley, 2013; Lee, 2005; Wauters, 2010; Wezel et al., 2014).

As indicated in the literature, in comparison to industrialized and traditional agriculture, sustainable agriculture has several economic, environmental and social benefits, for example, improved soil fertility, raised vegetation coverage, increased natural resource base and biodiversity services, improved water table content, reduced labour and fuel costs, reduced carbon dioxide emissions, reduced soil erosion and land degradation, and enhanced adaptive capacity to drought, climate change and other shocks. These, in turn, have the potential to enhance productivity, increase livelihoods, and maintain environmental sustainability and agro-ecosystem resilience (Lee, 2005; Rodriguez *et al.*, 2009; Lichtfouse, 2012; Veisi and Toulabi, 2012; Foley, 2013; Teklewold, Kassie and Shiferaw, 2013; Wezel *et al.*, 2014; Khatri-chhetri, Aryal and Sapkota, 2016).

1. 2. 4. Suitable agricultural practices in the Ethiopian context

The agricultural sector in Ethiopia is currently a mixture of traditional and industrialized farming. Subsistence farming is the way of life for most Ethiopian smallholder farmers. However, due to its low productivity, the sector is still unable to feed the population and to meet the country's food demand (Jaleta, Kassie and Marenya, 2018). The question remains how to improve agricultural productivity to supply sufficient food for the ever-increasing population and ensure food security at household level.

By taking the experience of some Asian and Latin American countries, the government of Ethiopia has given more attention to the introduction of green revolution technologies, especially the steady supply of chemical fertilizers and pesticides to raise agricultural productivity substantially. The government has imported fertilizers, such as urea or diammonium phosphate (DAP), pesticides, insecticides and herbicides, and sold it to farmers (Rashid *et al.*, 2013; Agbahey, Grethe and Negatu, 2015; National Plan Commission, 2017).

Consequently, the volume of inorganic fertilizer used has been increasing in the country. For example, according to the global economy database, chemical fertilizer use (kg) per hectare of arable land in Ethiopia was 5.7 in 2003 but increased to 31 in 2012 (Globaleconomy 2018). Ethiopia imported and used 7 million quintals of inorganic fertilizer in 2014 and this was double compared to 2010. The proportion of cultivated land under chemical fertilizer reached around 41% of the total cultivated cropped area at country level (CSA 2017).

However, we believe that the green revolution is not a viable option for Ethiopia for the following reasons. Nearly 90% of farm households are smallholders and resource-poor (National Plan Commission, 2017). The external inputs that are suggested by industrialized agriculture, such as chemical fertilizers, pesticides, herbicides and high-yielding varieties are unaffordable for them (Agbahey, Grethe and Negatu, 2015). To enable them to participate in food-for-work schemes and receive emergency relief in cases of crisis, smallholder farmers purchase these inorganic fertilizers from the government, but, as (Nyssen *et al.*, 2017) explained, many farmers then sell them on the black market at half the purchase price (on average), mainly to agricultural investors, merchants and some farmers who did not need any government support and rejected buying the inputs from the government.

In addition, the majority of the rural areas, especially in the highlands (temperate and warm temperate zones), which are highly favourable for agriculture and settlement, are predominately characterized by gorges, plateaus, mountains and hillsides. As a result, they are highly susceptible to soil erosion and land degradation, which leads to lower productivity (Haile, Herweg and Stillhardt, 2006; Abebe, Puskur and Karippai, 2008). The high fertilizer purchase prices, low crop yields due to erosion and degradation and the low farm gate output practices have reduced the returns for inorganic fertilizer application and therefore fertilizer-to-output ratio is relatively high (Agbahey, Grethe and Negatu, 2015).

Moreover, animal husbandry is integrated into the farming system in many parts of the country. For example, livestock contributes up to 20% to Ethiopia's GDP and to the livelihoods of 60-70% of the population (National Plan Commission, 2017). Ethiopia produces nearly 24% and 2% of the total African and world honey, respectively (Abebe, Puskur and Karippai, 2008).

However, spraying of some chemicals has negative effects on livestock and water bodies (Carvalho, 2006). As understood from farmers and agricultural experts in the areas, some livestock died when farmers used pesticides, herbicides, fungicides and insecticides to control pests, diseases and weeds. As a result, farmers who have been engaged in small ruminants and apiculture have frequently complained and have even appealed to higher government officials.

Furthermore, there is a lack of information and awareness in many parts of the country on how to use these chemical inputs or about the risks to human health. During the field survey, for example, we observed that some farmers used excess chemicals (overuse and misuse) on some cereals and horticultural crops to protect them from weeds and diseases. They also sprayed without protective clothing. Since there are no proper containers, they dumped the equipment in open areas and then some children played with them. Motivating farmers to use these chemicals before working on awareness-enhancing issues might lead to human and biodiversity losses. Thereby the country could incur a huge cost in terms of reimbursement.

Finally, along with these facts, input markets in the country are either incomplete or missing. Formal institutions are also very weak (Yesuf and Köhlin, 2009). The topographic features, along with small and highly fragmented landholdings, do not encourage the use of machinery and make it difficult for private investors to use capital-intensive inputs, such as tractors. Therefore, to promote inorganic fertilizer use, regardless of the concerns, the government has to do two things (a) strengthen and empower local institutions (including markets) and awareness enhancing centres (c) reduce the fertilizer-to-output ratio significantly by reducing fertilizer purchase prices, reducing soil erosion and land degradation to raise yields, and increasing farm gate output practices. Consequently, considering these grounded facts, industrialized agriculture currently seems less effective and less successful.

In the light of these facts, sustainable agriculture seems more pragmatic for poor and smallholder farmers in Ethiopia. As stated in section 1.2.3, the practices of sustainable agriculture have the potential (directly or indirectly) to improve agricultural productivity, enhance food security and reduce emissions of greenhouse gasses without more investment in agrochemical inputs (Kambewa, 2007; Kheiri, 2015). For example, crop production can be raised through the increased use of irrigation by constructing alternative water harvesting schemes, and the use of organic fertilizers, such as manure, or by crop rotation, intercropping and the use of compost. Construction of physical soil and water conservation measures, such as terracing, stone walls, soil bunds and gully reclamation can also reduce soil erosion and land degradation, as well as improve water holding capacities, thereby leading to increased yields.

Concurrent to these, planting of multipurpose trees, managed pasture lands, and exclosure of communal areas and natural resources have the potential to improve the availability of livestock forage, increase biodiversity and vegetation coverage, and sequestrate carbon dioxide emissions to withstand climate change. In general, sustainable agriculture has the capacity to reduce the risks of climate change, drought and shocks, and enhance the resilience of the local systems. Thus, industrialized farming and traditional agriculture are neither effective nor sustainable for smallholder farmers. They should be transformed and made sustainable.

1. 3. Problem and justification

Ethiopia, like other poor countries, has been severely affected by food insecurity, malnutrition and poverty for many years. Around 25-30% of the population is currently food insecure, which is mostly linked to insufficient agricultural production (National Plan Commission, 2017). In turn, this is associated with the depletion of the natural resource base, low use of improved inputs, low adaptive capacities, reliance on rain-fed subsistence systems, and erratic and unreliable rainfall (Mekasha *et al.*, 2014; Gebregziabher *et al.*, 2016; Jaleta, Kassie and Marenya, 2018).

Notwithstanding this, the economy has been growing by double-digits annually for the last two decades. This growth is primarily due to the growth of the construction sector and the emergence (or expansion) of small and medium industries. However, the insignificant growth in the agricultural sector over the last two decades has been insufficient to address food insecurity (National Plan Commission, 2017). The economic growth has led to an increase in income for many people, which might place additional pressure on agriculture to meet the demand for food.

Since the main source of food insecurity is the low productivity of agriculture, the question is how to improve agricultural productivity. Bryan et al. (2009) argued that understanding (and addressing) how agriculture adapts to shocks is important and is one step forward to ensure food security and sustain a better life for the poor. Two possible options are often suggested: extensive methods and intensive methods. An extensive method is an increase in agricultural production by expanding cultivated areas, even to marginalized and less favourable areas, while an intensive method involves increasing production by improving the productivity of agriculture and production factors (Norton, Alwang and Masters, 2010; Niragira, 2016).

Bearing in mind that food insecurity is exacerbated in mountainous regions (Halbrendt, 2014) and that food insecurity is a common problem in populated areas (Norton, Alwang and Masters, 2010), Ethiopia is listed amongst the most densely populated countries in Africa (17th) with an estimated population of 0.107 billion (Worldometers 2018). Besides, Ethiopia and mainly the northern parts are predominately characterised by a mountainous topography, making the region susceptible to soil erosion and land degradation, causing low productivity. Furthermore, the average landholding size per household is less than 1ha (Haile, Herweg and Stillhardt, 2006). In such a context of population pressure, land relief and small landholdings, the potential for extensification seems questionable and less practical.

Consequently, intensification seems to be the most suitable approach to increase food production and improve livelihoods. As explained above, this can take the form of increasing the reliance on external inputs in a green revolution type of development or can be pursued through the adoption of sustainable agricultural practices. As indicated above, the use of chemical fertilizers, pesticides, herbicides and high-yielding varieties to improve productivity is not economically effective for poor and smallholder farm households. Previously, a similar issue was reported for Honduras, where poor farmers lacked the capital to purchase fertilisers, improved inputs and pesticides to enhance yields (Wollni, Lee and Thies, 2010).

In this light, sustainable agriculture seems the easiest and most effective option for poor and smallholder farmers who live in the (semi) dry environment and who have limited financial capacity. This type of agriculture is mostly carried out by family labour, using farmers' knowledge and skills, and based on locally available resources, while raising productivity and maintaining healthy ecosystems. Also, it does not ban the purchase and use of inorganic fertilizers, but seeks to use them appropriately and not impact society or damage the environment (Moldan, Janousková and Hák, 2012; Halbrendt, 2014; Kheiri, 2015; Van Thanh and Yapwattanaphun, 2015). Therefore, sustainable and industrialized agriculture can coexist to increase productivity.

The government of Ethiopia has focused on both approaches. Farm households are, on one hand, encouraged to use chemical fertilizers, pesticides, high-yield varieties and herbicides (often given in loan form to repay later) to ensure food self-sufficiency. On the other hand, the Climate Resilient Green Economy Strategy has been developed, which focuses on the conservation and management of natural resources, planting of multipurpose trees, expansion of irrigation, reduction of greenhouse gas emissions, and use of soil and water conservation, The intention is also to ensure food security and bring sustainable development (National Plan Commission, 2017).

However, the adoption of sustainable agriculture still remains below expectations (Jaleta *et al.*, 2016; Teklewold *et al.*, 2016; National Plan Commission, 2017; Zeweld *et al.*, 2017). Demographic characteristics, biophysical factors and rural services are found in the traditional literature as influencing factors for the low adoption of sustainable agriculture (Kassie *et al.*, 2010; Gumataw *et al.*, 2013; Teklewold, Kassie and Shiferaw, 2013; Mekasha *et al.*, 2014; Gebregziabher *et al.*, 2016; Jaleta *et al.*, 2016; Teklewold *et al.*, 2016).

However, to our knowledge, research studies on how socio-psychological factors (*see Annexe 2.2 for further detail*) affect the behaviour and decisions of farm households towards the adoption of sustainable agriculture are even scarcer. Since understanding and knowledge of these issues is important for policymakers and development actors working in agriculture and rural development, this PhD examines how these factors, especially attitudes, information, social capital, normative issues, personal efficacy and technical training, affect smallholder farmers' stated and actual behaviours (intentions, risk attitudes and actual adoption) towards sustainable agriculture.

In parallel, the empirical literature that evaluates the impacts of sustainable agriculture on food security and livelihoods is also potentially limited. There are some studies globally, for example, (Amare, Asfaw and Shiferaw, 2012; Asfaw *et al.*, 2012; Kassie *et al.*, 2012, 2013; Gumataw *et al.*, 2013; Teklewold, Kassie and Shiferaw, 2013; Abdulai and Huffman, 2014; El-Shater *et al.*, 2016; Jaleta *et al.*, 2016)**.** However more location-based studies are still needed to understand the impacts of sustainable agriculture spatially. Therefore, this dissertation aims to undertake a research study on a relatively broader spectrum using a rigorous approach to examine the effects of sustainable agriculture on household food security and livelihoods.

Furthermore, according to the global climate risk index (CRI)[1], Ethiopia is ranked 66th in terms of climate-risk exposure in 2017. At first sight, this seems to mean that Ethiopia is not so sensitive to climate change. However, when compared with previous years, the ranking for Ethiopia has deteriorated: it was ranked 125th in 2014 and 89th in 2016 (Kreft, Eckstein and Melchior, 2015). In addition, there are spatial variations within the country, particularly the North, which is our study region and is more sensitive. Therefore, in this PhD, we explore local people's awareness of, and attitudes towards, climate change and evaluate how sustainable agriculture helps farmers to adapt to the impacts of climate change and other shocks.

1. 4. Objectives and research questions

The overall objective of this PhD is to understand how socio-psychological factors influence farmers' behaviour towards sustainable agriculture, thereby investigating its relevance in addressing smallholder farmers' livelihoods. The specific objectives include

1. to assess the impacts of socio-psychological factors on the intentions of smallholder farmers towards the adoption of sustainable agricultural practices
2. to examine the implications of socio-psychological issues on smallholder farmers' risk attitudes
3. to investigate how socio-psychological factors affect the (actual) adoption of sustainable agricultural practices
4. to discuss the roles that sustainable agricultural practices play in smallholder farmers' agricultural production, food security and livelihoods.
5. to explore how smallholder farmers perceive climate change and what strategies they use to adapt to the adverse impacts of climate change

Following the motivation (state of the art and research gaps) and objectives of the study, two research questions are identified. There are also specific sub-questions corresponding to each broad question.

1. How do socio-psychological factors, such as attitudes, social capital, perceived resources, personal efficacy and information influence smallholder farmers' intentions towards sustainable agriculture and their actual adoption?

2. What roles can sustainable agricultural practices play in enhancing smallholder farmers' livelihoods?

In general, policymakers, development actors and other concerned bodies need reliable data to prepare appropriate strategies to improve the productivity of agriculture and build the resilience of local systems. Therefore, the research outputs, which provide empirical contributions, are expected to stimulate policymakers, development actors and other concerned bodies, especially those working in agriculture and rural development, to collaborate and work together towards common goals in promoting sustainable agriculture as a means of addressing food insecurity and mitigating the adverse impacts of climate change on livelihoods and ecosystems.

[1]. *Climate risk index reflects both relative and aboslute climate impact per country and is developed by Germanwatch and Munich Re NatCatSERVICE. It considers who suffers most from extreme weather events, such as flooding, drought, storms, occurrenace of pests and diseases, excess rainfall and so forth.*

1. 5. Theoretical literature review

As stated in the literature, economists, sociologists, anthropologists, psychologists and other scholars have developed and suggested different theoretical frameworks for human behaviour and decisions under risks and other circumstances to adopt, for example, improved systems, new products and technologies (Bickel 2007). According to these theoretical frameworks, human behaviour is defined and conceptualised differently across different disciplines, since it results from the interplay of internal and external forces (Ndah 2008) and also occurs in a social context with a dynamic and reciprocal interaction between an individual and their environment (Rogers, 2003).

Based on how they contextualize human behaviour, these theories can be summarized into three groups (a) economic theoretical frameworks that explain behaviour from economic resources and biophysical endowment perspectives (b) behavioural or cognitive theoretical paradigms that address how social and psychological issues affect behaviour and decisions (c) integrative frameworks that combine both approaches to evaluate how socioeconomic, psychological issues, biophysical and institutional factors influence behaviour and decisions. Depending on the objectives, this study uses the theoretical frameworks below.

1. 5. 1. The decomposed theory of planned behaviour

The conceptual root of this theory comes from the theory of reasoned action (TRA), which assumes human behaviour to be fully volitional and under the control of the subject. The subject has complete control to engage in (or not engage in) a specific behaviour. Accordingly, social behaviour is postulated to be explained by an individual's intention. This, in turn, is an outcome of the combinations of attitudes and subjective norms (Fishbein and Ajzen, 1975).

According to this theory, attitude is defined as the degree to which an individual evaluates the behaviour to be favourable or unfavourable, for example, adoption of an agricultural practice after understanding its benefits and limitations. Subjective norm, on the other hand, is the perceived social pressure (e.g., friends, colleagues, relatives, manager) exerted on an individual's decisions and behaviour resulting from their perceptions of what others think they should, or should not, do and their inclination to comply with these beliefs.

Ajzen (1991) is lately criticised for the assumption of complete volitional control. An attempt to undertake certain behaviour may not necessarily lead to its use, because not all human behaviour is under complete volitional control. A user does not have full control over the operation and some external factors may prevent the intention. Following this, the theory of planned behaviour (TPB) was proposed by adding perceived control to the components of intention and behaviour. The concept of TPB is based on the assumption of unidimensional beliefs.

This newly added factor represents how anticipated obstacles or opportunities, such as user competence, and the availability of resources, including organizations, can hinder or facilitate engagement in the behaviour of interest. It is expected to accommodate the things that are not under the volitional control of the subjects. Therefore, the intention of an individual is explained by attitude, subjective norm and perceived control. In turn, engaging in a behaviour is predicted by intention and sometimes by both intentions and perceived control together.

In a later stage, the monolithic (or unidimensional) structure of belief was criticised by several authors, for example, Taylor and Todd (1995), Bandura (1999), Venkatesh and Davis (2000), and Rogers (2003). The cognitive component of belief cannot be organised into a single conceptual unit. For this fact, Taylor and Todd (1995) proposed the decomposed theory of planned behaviour (DTPB), which formally rejected the concept of unidimensional belief and restructured the concept of belief, for example, in terms of attitude and perceived control.

Following this, the construct for attitude is further split into a relative advantage, perceived complexity and perceived security (*these concepts were proposed earlier by Rogers (1983) in the innovation diffusion theory*). Relative advantage shows a user's perception of the ability of the system (e.g., agricultural practice) to enhance overall performance, such as yields, jobs, efficiency and fertility. Whereas perceived complexity is the degree to which a user believes it is easy to read, understand and learn the system. Similarly, perceived security is the user's perception of whether the system is in line with his/her experience, traditions and needs.

Concurrenetly, Taylor and Todd (1995) also decomposed perceived control into two more constructs of belief, such as facilitating condition and self-efficacy. According to this theory, facilitating condition represents the degree to which a user believes (perceives) that specialized resources (such as time, labour and money), and technical infrastructure exist to support the use and performance of that particular behaviour or system.

On the other hand, self-efficacy is the same as behavioural capability, which was proposed by Bandura (1999) in the social cognitive theory. It is the perception of own actual abilities, skills and knowledge that helps to successfully perform a given behaviour, for example, use of technology. Therefore, subjective norms, attitudes and perceived control, as well as their decomposed components, determine whether an individual user engages in or rejects the behaviour, for example, adopting agricultural practices.

In the empirical literature, TRA has been confirmed through extensively applied research in software uses, knowledge management and consumer behaviour (*See Sheppard et al. 1989, Bock and Kim 2002, Bock et al. 2005, Lin 2007*). Similarly, TPB is one of the most widely cited and applied behavioural theories in health science, marketing and consumer behaviour, natural resource management, and mobile technology and internet banking systems (*See Barberia et al. 2008, Davies 2008, Francis et al. 2008, Arvola et al. 2008, Lobb et al. 2007, Hattam 2006, Zubair and Garforth 2006, Fielding et al. 2008, Lu et al. 2003, Shih and Fang 2004*). It was found that both theories adequately explained intentions and actual behaviour.

There are also some studies that have applied the decomposed approach (DTPB). They found that DTPB predicted a higher percentage of the available variance in intentions and actual behaviour compared to TRA and TPB. Strong correlations have been established between outcome interests (engaging in the behaviour) and attitudes, and with perceived controls. This indicates that DTPB could be a better predictor of intention and behaviour than TRA and TPB. However, some studies have found weak correlations between outcome interests and subjective norms. In some studies, perceived security and perceived usefulness were also found to be highly correlated (*See Kazemi et al. 2013, Ghyas et al. 2012, Sadaf et al. 2012, Velarde 2012*). In general, the decomposed theory of planned behaviour mostly focuses on the multi-dimensional structure of beliefs, instead of unidimensional beliefs.

1. 5. 2. Expected utility theory: decisions under risks and uncertainties

Individuals (=decision makers) normally make decisions under various risks and uncertainties because they do not often accurately know the consequences of their decisions (Norton, Alwang and Masters, 2010). Blaise Pascal (1670) invoked the concept of expected value (historically based on gambles or prospects) to deal with the reasoning underlying individuals' choices and to analyse situations where individuals must make decisions under uncertainty without knowing what outcomes may result from their decisions (Concina, 2014; Hardaker *et al.*, 2015).

This expectancy-value theory holds that people are goal-oriented beings. Accordingly, the behaviour is a function of the individual's expectations and the value of the goal toward which they are working. When more than one behaviour is possible, the behaviour chosen will be the one with the largest combination of expected success and value (Tuliao, 2017).

For example, individuals face a number of alternative actions or prospects (X_i) each of which gives possible outcomes with different probabilities (P_i). Accordingly, the individual has to optimize his or her expected value ($\sum(P_i)(X_i)$). Here, the probabilities are objective. Individuals can make the best decision based on the information available to them at the time of the decision. On this basis, the best outcome can be prescribed and rational choice is for the prospect with the highest expected value (Fischhoff, Goitein and Shapira, 1981).

At a later date, Daniel Bernoulli (1738) criticized the expected value of the gamble and proposed expected utility to optimize the personal utility attached to the value of the prospect. Here, the expected value is adjusted to the expected utility to take into account the aversion behaviour that individuals often encounter in reality. The optimal choice under the expected utility theory is the same as optimizing the expected value after transforming the value (=money) into utilities (Fischhoff, Goitein and Shapira, 1981).

Unlike the expected value theory, individuals have to optimize the expected utility of money or wealth ($\sum(P_i)U(X_i)$). In this standard expected utility theory, utility always increases when the monetary value increases, but with the essential property of diminishing returns or diminishing marginal utility, showing that the utility of money is not necessarily the same as the total value of money (Karni, 2014). The rational choice, therefore, is to choose an action with the highest expected utility – the sum of the products of probability and utility over all possible outcomes.

Similar to the expectancy-value theory, the expected utility theory is based on the existence of objectively known probabilities, as well as an ordinal preference (initially cardinal favour) with completeness, transitivity, independence and continuity axioms (Shanteau and Pingenot, 2009).

In both expectancy value and expected utility theories, individuals assign probabilities to the various outcomes that are equal to the objective probabilities (measured as relative frequencies). However, they may not have the necessary accurate information so they are forced to depend on their perception, which often differs from person to person. Therefore, they may have different probabilities and so there is no guarantee of objective probabilities and optimal decisions (Karni, 2014; Hardaker *et al.*, 2015; Tuliao, 2017). In the literature, it is stated that risks are not measurable and are subjective experiences of threats and insecurity (Van Winsen, 2014). Accordingly, decisions under risk are often subjective and their consequences unknown (Addey, 2018)

Because of this, Savage (1954) proposed subjective expected utility theory to include situations where probabilities are subjectively determined by the decision makers. This theory combines subjective concepts (personal utility or preference function and personal probability distribution) and integrates some crucial premises of risky decision making (a) personal preferences about possible outcomes (b) personal degrees of belief in the occurrence of possible outcomes (c) personal responsibility and accountability for whatever decision is taken via the use of own personal preferences and probabilities (Shanteau and Pingenot, 2009; Tuliao, 2017).

This implies that decision making under uncertainty and subjective probabilities is a process involving the evaluation of possible outcomes associated with alternative courses of action and the assessment of their likelihoods. Evaluation of outcomes and the assessment of their likelihoods are also quantifiable by utilities (decision makers' tastes) and subjective probabilities (decision makers' beliefs). The ingredients of the decision-making process can be inferred from observed patterns of choice and are integrated to produce a criterion of choice (*see more Anscombe and Aumann 1963, Wakker 1989, and Karni 2007*).

A rational decision maker believes that an uncertain event has (an exclusive and exhaustive list of) possible outcomes for each action (X_i) with a utility of ($U(X_i)$). The choice of decision arises from the utility function combined with the subjective belief (subjective probability of each outcome) (P_i) and prefers a decision with the highest subjective expected utility, i.e., ($\sum(P_i(X_i)U(X_i)$). This justifies that different individuals make different decisions because they have different utility functions or different beliefs about the probabilities of different outcomes, which may originate from, or be guided by, beliefs, values, social circumstances or psychological needs (Fischhoff, Goitein and Shapira, 1981; Shanteau and Pingenot, 2009).

With this in mind, in less developed countries such as Ethiopia, smallholder farmers usually have no access to reliable information on agricultural and climatic conditions. They have often made farming decisions with limited or imperfect information (Yesuf and Köhlin, 2008). They may not have accurate knowledge of the consequences of their decisions (Jaleta, Kassie and Marenya, 2018). They, more often, intuitively place perceived probabilities on actions and outcomes. Their beliefs concerning the consequences of the actions are based on a subjective probability distribution which they instinctively assign to each action.

Consequently, expected utility theory, especially subjective probability, is a useful theoretical framework to make farming decisions primarily in an imperfect environment. It overtly acknowledges these subjective components of important decisions – the farming decision is an evaluation of the actions under consideration and the perceived probabilities associated with them. Because of the differences in context, experience and other factors, individuals may have different estimates both of the value and probability of outcomes.

For example, with regards to the adoption of agricultural practices, the difference in evaluation (subjective utility and subjective probability) is not only among farmers but also among stakeholders, such as extension agents and development actors. Therefore, there is no one correct choice with optimal outcome in farming decisions. In most cases, farmers are required to compare their (subjective) expected utility (outcomes) between adopting the agricultural practice and not adopting it, or using the traditional practices and then having to decide to adopt if the expected utility from adoption exceeds the expected utility from non-adoption. Therefore, farmers are expected to decide to adopt sustainable agriculture under the framework of expected utility theory.

1. 6. Conceptual framework

In less developed countries such as Ethiopia, farm households live in uncertain environments and frequently face asymmetric information. Therefore, they have often been engaged in mixed farms to minimise risks and shocks, as well as to maximize yields (more or less to maximize their expected utility in terms of yields and risks). Accordingly, they have been making farming decisions and investments in farms by taking into account multiple, interrelated and complex factors (Bacha *et al.*, 2011; Teklewold, Kassie and Shiferaw, 2013).

Considering these facts, we use the conceptual framework below (Figure 1.1) to adequately define and conceptualize the behaviour of farm households towards the adoption of sustainable agriculture and to internalize the consequences of the adoption of agricultural practices on the outcome of interests. Figure 1.1 integrates the decomposed theory of planned behaviour and the expected utility theory to address the research objectives of this dissertation. Therefore, this conceptual diagram is an extension of the decomposed theory of planned behaviour.

As shown by the conceptual framework, the intention of farm households towards the adoption of sustainable agriculture is expected to be adequately explained by attitude, normative issues and perceived controls directly, and their decomposed components indirectly. This is because variables such as attitudes, normative issues and perceived control are predicted by other decomposed variables. In this way, this study explains how these socio-psychological factors affect farmers' intentions towards the adoption of sustainable agriculture (Q_1). The interactive effects of these predictors have also been shown (*see detail chapter three*).

After evaluating the sole effect of these socio-psychological variables on behavioural intentions, we mix them with conventional factors, such as demographic characteristics and biophysical contexts to assess the subsequent objectives. These research objectives require both socio-psychological and socio-economic factors to some extent. For example, how these socioeconomic-psychological factors affect smallholder farm households' risk attitudes (Q_2), and also how they influence (actual) adoption of sustainable agriculture (Q_3).

Furthermore, this overarching conceptual model reveals the expected outcome of adopting sustainable agriculture, because the main target of adoption is to realize the outcomes. Hence, this study explores how the adoption of sustainable agriculture affects the outcome of interest, such as yields and income (Q_4). In this way, this conceptual framework adequately illustrates the input, process and outcome of the adoption of sustainable agriculture (*see detail latter*).

In general, this integrated framework incorporates various theories to explain smallholder farmers' decisions to adopt sustainable agriculture. Various factors, such as economic variables, sociocultural dimensions, biophysical factors, psychological factors, and institutional aspects are used, which are useful in understanding human behaviour and adoption decisions. Therefore, Figure 1.1 combines the traditional economic literature and social psychological literature to better explain smallholder farmers' behaviour and decisions in the recent literature.

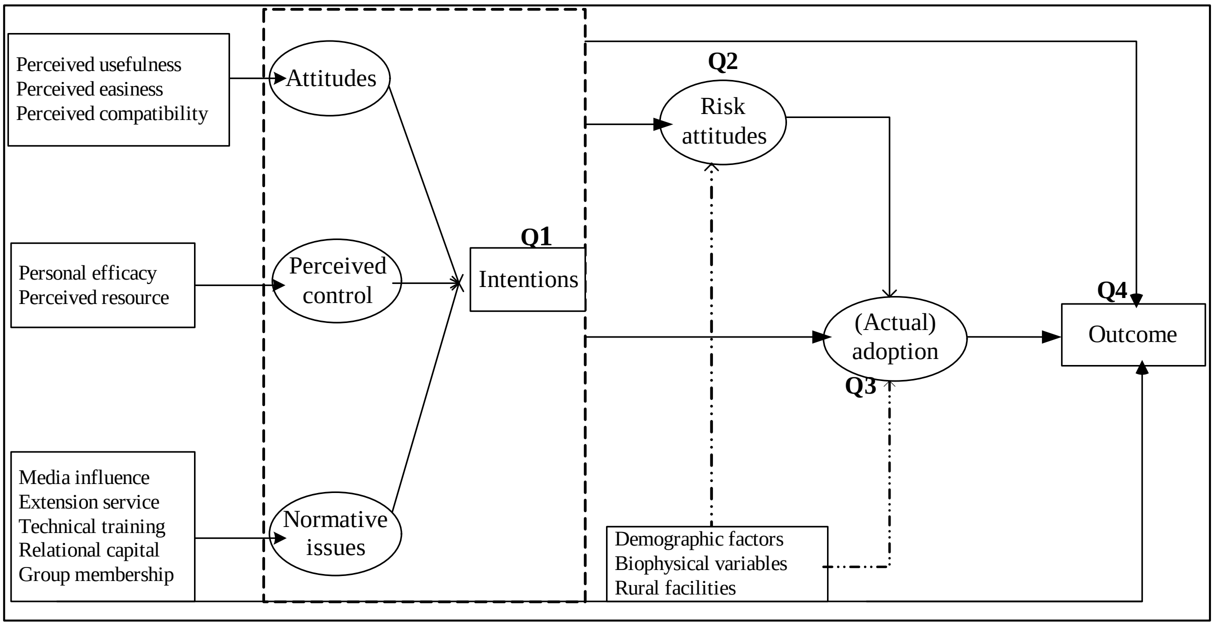

Figure 1.1. Conceptual framework for adopting sustainable agricultural practices at farm level

1. 7. Outline of the dissertation

As shown below (Figure 1.2), this doctoral study is a compilation of eight chapters. The research rationale and objectives of the study are introduced earlier. The current agricultural practices are also discussed, focusing on sustainable agriculture vis-à-vis mainstream agriculture from the viewpoint of smallholder farm households. The theoretical and conceptual frameworks are also briefly reviewed and formulated in the same section.

Following this, the study area, with its biophysical and socioeconomic conditions, is described in chapter two. This chapter also presents the sampling framework and survey design. Moreover, the variables in the study are defined and measured. It also explores how latent variables are constructed. Furthermore, ways used to reduce sampling and nonsampling errors are explained. Eventually, the chapter also assesses the summary statistics for the variables.

Chapter three is all about behavioural intentions. It shows whether farmers in the area have a desire to adopt sustainable agriculture, particularly minimum tillage systems. Additionally, it explores how socio-psychological issues, such as attitudes, normative issues, information and perceived controls affect farmers' intentions towards the adoption of sustainable agriculture.

The relationship between socio-psychological issues and the risk attitudes of smallholder farmers is presented in chapter four. Specifically, the past and current risk behaviour of farmers is assessed. In addition, this chapter explores how socio-psychological factors influence the aversion or uncertainty behaviour of smallholder farmers.

Chapter five looks at the actual adoption of sustainable agricultural practices. Viz., farm households who are currently adopting and planning to adopt sustainable agriculture are identified and assessed. Furthermore, the chapter also investigates how socio-psychological factors affect the actual adoption of sustainable agricultural practices.

Concurrent to the stated and observed behaviours, this doctoral study also investigates the impacts of adoption of sustainable agriculture, for example, chapter six examines the impacts of sustainable agriculture on yields, food security (approximated by expenditure and the household food insecurity access scale) and household welfare (by income and assets).

Chapter seven assesses the smallholder farmers' awareness of climate change and its adverse impacts on livelihoods and ecosystems. Specific strategies adopted by farmers to adapt to the impacts of climate change are also identified and explained. Furthermore, this chapter identifies the determinants of the propensity-to-adapt to the perceived impacts of climate change.

The final chapter presents general conclusions, based on the main findings, and draws policy implications, which may help decision-makers and development practitioners give more focus to the promotion of sustainable agriculture to address food insecurity, environmental degradation and climate change. Some limitations and future research points are also reported.

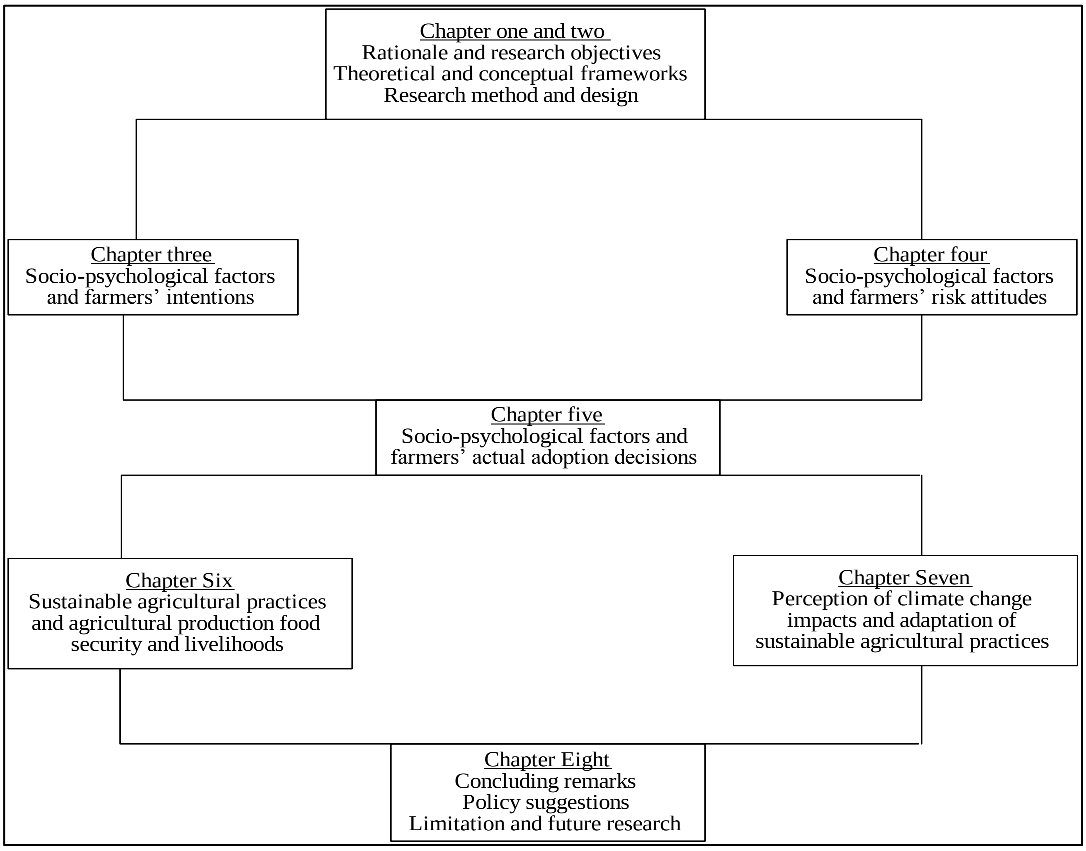

Figure 1. 2. Diagram outline of the dissertation

Chapter Two
Study area, research methods and data

Overview

This chapter describes the areas where this study was undertaken, focusing on the topographic and socioeconomic conditions. The chapter also elaborates the research methodology, including the sampling framework, data collection method and analytical framework. Furthermore, the variables used in the subsequent chapters are defined and their construction and measurement are explained. Finally, the chapter presents summary statistics for some variables.

2. 1. Description of the area

2. 1. 1. Geopolitical location

The study was conducted in Atsbi-Wemberta district, which is geographically located in the eastern administration zone of the Tigray region in Ethiopia, 71km northeast of Mekelle, the regional capital city. It is situated between 13°40′ to 14°0′ N and 39°40′ to 40°0′ E (*see map Figure 2. 1*). It shares a border with the Afar region to the east, Enderta to the south, Kilte Aulaelo to the south-west, and Saesi Tsaeda Emba to the north-west and north. The district is composed of 18 administrative villages or tabias – the lowest strata of government organisation, responsible for political, economic and social matters. Atsbi (Endasilassie) is the administrative centre of the district, while Derra, Haiki Meshal, Kelisha Emni and Habes serve as its sub-centres (Misgina et al. 2016; Asheber 2010; Berhane 2010; Abebe, Puskur, and Karippai 2008).

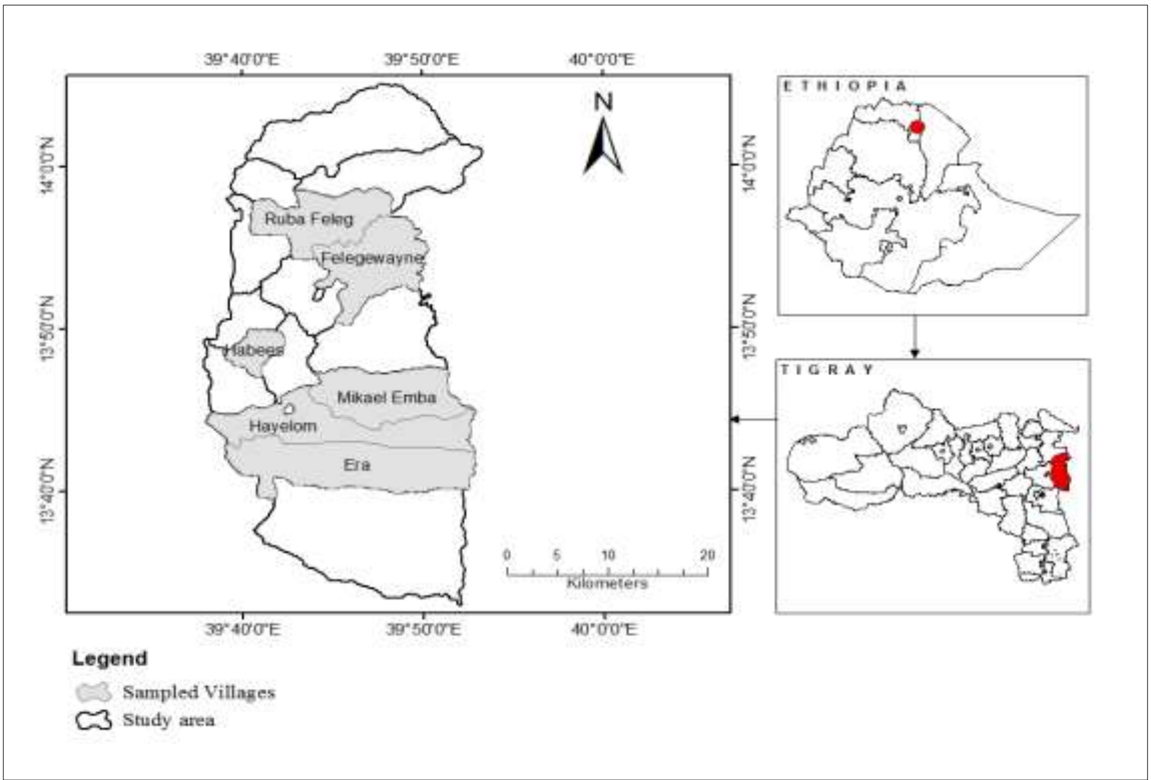

Figure 2. 1. Overview of a map of the study area within Ethiopia, Tigray and the district

2. 1. 2. Biophysical conditions

The physiographic setting of the area is predominantly characterised by mountains and hills. With regard to the land use system for the landmass of 1140km^2, 65% is arable land, 4% is used for animal grazing, 9% is covered with natural forests, woodland, bushes and shrubs, 0.5% is covered with water, and the remaining land is used for other purposes. The district, which lies in three agro-ecological zones[1] (Mengistu 2006) has an elevation ranging from 1003 to 3069 meters above sea level, where 55% of the area is found in the temperate zone, 36% is in the warm temperate zone and 9% is in the dry temperate zone. The soils are mainly Cambisols (80%), followed by Leptosols (14%), while 6% comprising other soil types. However, the land is highly eroded and infertile. Erosion and degradation adversely affect farm productivity.

The district is one of the coldest areas in the country, with a climate ranging from warm to cool. This leads to high variability in rainfall and temperature. The average temperature is around 18°C and mean annual rainfall ranges from 300mm to 700mm with an estimated coefficient of variation of 34%, based on 33 years data (1983-2015). The area receives bimodal rainfall. The rainy seasons are called the Belg season (February-May) and the Meher season (June-August). This typically results in two cropping seasons. But the Belg rainfall has failed entirely for the last decade. As a result, recently, there has only been a single annual rainy season (June-August). The problem with the rainfall is its distribution, which is unpredictable and variable. Viz., rains are usually intense at the beginning of the rainy season, but lately these have been insufficient and of very short duration.

2. 1. 3. Demographic characteristics

In Ethiopia, a census survey is undertaken every ten years by the Central Statistical Agency of Ethiopia. The most recent census survey was carried out in 2007 and this has been used to predict the demographic characteristics of the district. Based on this census, the size of the population in 2017 is estimated to be approximately 144000, of whom, about 87% are rural dwellers, about 51% are women, and about 97% are Orthodox Christians. The population density in 2017 is estimated to be more than 120 (person/km^2), which is greater than that for the eastern administration zone, which has an average of 70 people per square kilometre. The average landholding size per household head is about 0.50 hectares and the average household size is around five people. The population lives in the warm temperate and temperate climatic zones, but herders sometimes move to the dry temperate zone to search for pasture and water for their animals and usually stay there from one to three months.

2. 1. 4. Infrastructure and institutions

Roughly speaking, the area has good access to social and physical services and institutions compared to two decades ago. For example, it has 32 primary schools, three secondary schools,

[1]. *Based on the traditional typological or agro-ecological zones, the district is classified into three, as follows (a) dry warm temperate or lowland that lies between 1003 and 1500 meters above sea level (b) warm temperate, midland or woina dega that lies between 1500 and 2300 meters (c) temperate, highland or dega lies between 2300 and 3069 meters above sea level.*

one preparatory school, 14 health posts, one clinic, four veterinary clinics, 16 multi-purpose cooperatives, and three financial institutions (two formal banks, and a microfinance institution). Nearly half of the population are able to read and write and around 40% have at least completed first-grade education. About half have good access to a rural health post. Approximately two-thirds of the population have access to loans, either from a local microfinance institution or formal banks. Slightly more than half have access to veterinary services, livestock drugs and extension services (*Annual Report of District Agriculture and Rural Development Office 2017*).

The report also indicates that villages in the district are connected to each other and with neighbouring districts by all-weather roads. However, about 70% of the households have no road leading to their house from the all-weather roads. The average time taken to the nearest gravel road is about 60 minutes and to the main input-output (district) markets it is estimated more than 60 minutes. Access to safe drinking water, toilet facilities, electricity, road and sanitary facilities in the district is still very limited, even though there has been a gradual improvement, especially since the middle of the 1990s.

2. 1. 5. Economic activities

Agriculture is the main livelihood source, with around 75% of the population entirely dependent on it. The major crops grown in the area are wheat, barley, broad beans, chickpeas, lentils and field peas. These are important food crops and some have recently become cash crops, especially due to the emergence and expansion of agro-processing industries in the country. Livestock, especially small ruminants and apiculture, is an integral part of the farming system. Oxen provide almost all traction and threshing power (draught power). The district is very well known for its apiculture. It is an important supplier of shoat meat (sheep and goat) and honey to the nearby towns, such as Wukro, Freweyni, Edaga Hamus, Adigrat, Mekelle and others.

However, the sector's productivity remains low and, because of the sloping terrain, the district is highly susceptible to erosion and land degradation. The use of traditional farming practices, along with overgrazing and long-term settlement, also aggravate erosion and degradation and, in turn, lead to low productivity. Deforestation is another severe problem. Consequently, about 25-30% of the population are now unable to satisfy their basic needs on a day-to-day basis (*Annual Report of District Agriculture and Rural Development Office 2017*). The issue of food insecurity is still an important development agenda in the area, and for the country as a whole.

In comparison with the past, the situation relating to environmental rehabilitation and living conditions, however, has been improving (at least at a slow pace) since the 2000s, when the government, nongovernmental organisations, civil society and local communities started working intensively on community-based development programmes. Most of these have been targeted on the introduction of improved technologies and the implementation of improved agricultural practices under the integrated watershed approach, for example, soil and water conservation, application of organic fertilizers, planting of multipurpose trees and construction of alternative water harvesting schemes. These are expected to increase agricultural productivity, and reduce the degradation of natural resources, in turn, tending to mitigate drought and climate change, overcome poverty and bring economic growth.

2. 2. Sampling technique and sample size

The study has two sampling units: predominately farmers and sustainable practices. In addition, the study site can sometimes be considered as a sample unit. Accordingly, the point is how these sampling units are selected and how large the sample size needs to be.

2. 2. 1. What motivated the selection of the study site?

The study area was purposively selected for the following reasons. The district is one of the drought-prone areas in the country. Due to its topographic features (mountains and hills), the area is also highly susceptible to erosion and land degradation. Besides, traditional continuous farming practices and overgrazing can aggravate this. Furthermore, the district is located very close to the Afar depression, one of the hottest and lowest areas on the earth. As a result, the local people have often been exposed and vulnerable to its adverse climatic effects.

In line with these issues, farmers are expected to adopt different agricultural practices or strategies to reduce and mitigate the adverse effects of drought, desertification, climate change and other shocks, and to improve agricultural productivity and maximize yields.

Although this was not a requirement, it can be seen as positive for our analyses that the overall population in the district is quite homogenous. For example, most farmers adhere to orthodox religion. Most are also engaged in a mixed farming system. Most farmers are smallholders and relatively poor. In a heterogeneous population, a larger sample size is required because the influencing factors are multiple, complex and difficult.

In the light of these grounded facts, the study area seems appropriate to undertake this research focusing on decisions and behaviour with regard to the adoption of sustainable agricultural practices, and their consequences on livelihoods. Finally, the district can also represent other areas in the country that have very similar agro-climatic conditions and agricultural practices.

2. 2. 2. Sampling of farm households

Sample selection was undertaken using a multistage procedure. The villages in the district were grouped into two categories based on agro-ecology or agro-climate. Of these villages, 16 are located in the temperate zone, and two in the warm temperate zone (Eira and Kelisha Emni). Certain parts of some villages, especially Gebrekidan, Haresaw, Ruba Feleg, Felege Weyni, May Mesanu, Mikael Emba, Hayelom, Eirra and Kelisha Emni are characterised by the dry temperate agro-climatic zone, but they were not considered because there was no permanent settlement there. Some herders moved sometimes to search for water and pasture and stayed there for some days or months. Haikimeshal and Endaselassie were also excluded from the sampling process because they are more urbanised.

Subsequently, five villages: Felege Weyni, Habes, Hayelom, Michael Emba and Ruba Feleg from the temperate zone and Eirra village from the warm temperate zone were selected using a simple random sampling method. This means that the study covered only six rural villages in northern Ethiopia. In order to achieve a desirable level of precision and a representative sample from these villages, the approaches by Yamane (1967) and Cochran (1993) for sample size determination were followed.

During the survey, these six villages had around 9230 households. Considering the margin of error (level of significance) of 5%, a sample size of approximately 380 farmers is then required when Yamane (1967) formula is applied. To use Cochran (1993) sample design effect, suppose 95% level of confidence (95 out of 100 samples have the true population within the range of precision) with 5% of the desired level of precision or sampling error. Assume again that the degree of variability[2] in the population is also 35%, i.e., adoption level of sustainable agricultural practices in the district to be about 35% while 65% of the population are still not adopting. Therefore, the required sample size would be 348.

However, this calculation of sample size is theoretical or hypothetical. It does not consider the nature of variables and the number of parameters, even if sample size can also be determined by the characteristics and nature of the variables. However, it is not possible to determine these variables in advance. This suggests that our sample size, which is determined following this formula, is a theoretical sample size. Practically, for example, we found that some variables are highly correlated, but we did not take this into account. Therefore, our theoretical sample size was 370, which would be sufficient to account for missing data and possible non-response.

Of this sample size, 10 farmers were allocated to the pilot survey. They were later removed from the dataset for this study. 360 farmers took part in the final survey. The sample size was proportionate to each sample village. Next, the local administrators and extension workers in each village were required to bring a recent list of household heads. From the sampling frame, smallholder farmers were selected using a systematic random sampling method.

Table 2.1 presents the sample size before and after the survey across villages. Prior to the survey, a sample size of 360 was specified (excluding the sample size allocated to the pilot survey) and 360 questionnaires were collected from the field areas. After the survey, 10 questionnaires were found to be incomplete and relevant information was missing for some target variables. These were then discarded or dropped from the analysis. Therefore, the actual sample size for the study was 350 smallholder farmers, with a 97% effective response rate.

Table 2. 1. Distribution of sample respondents across sampled rural villages

Villages	Population	Household head	Prior sample	Actual sample
Hayelom	7066	1800	71	70
Michael Emba	7757	1265	50	48
Eirra	6694	1283	51	50
Felege Weyni	9119	2143	83	82
Habes	4164	1200	46	43
Ruba Feleg	7300	1540	59	57
Total	42100	9231	360	350

[2]. *The degree of variability refers to the distribution of attributes in the population. The more heterogeneous a population, the larger the sample size required to obtain a given level of precision. The less variable (more homogeneous) a population, the smaller the sample size needed.*

2. 2. 3. Selection of sustainable agricultural practices

Smallholder farmers in the area have implemented several sustainable agricultural practices independently or in combination to improve productivity and maximise yields, which tends to enhance livelihoods and promote healthy ecosystems. With the help of agricultural officials in the region, especially Bureau of Agriculture and Rural Development, several agricultural practices that are widely applied in the region as a whole were identified.

Subsequently, in consultation with the agricultural extension workers and development practitioners in the district under consideration, these agricultural practices were categorized into two groups: those agricultural practices that have been commonly applied in the district and those agricultural practices that have been newly introduced (established) and rarely adopted in the district. The groups will be used for different research objectives of this study.

Following this, biological control of diseases or pests, minimum conservation tillage, microbial (botanical) pesticides, biodegradables[3] and row cropping systems (row planting) are categorized as farming practices that are in the process of being promoted. These agricultural practices have recently been promoted by agricultural extension agents and NGOs through short-term training and arranging exposure visits in the areas where they are widely practised. The local governments and development practitioners are expecting to widespread these practices in the district very soon.

Other agricultural practices have already been widely implemented, for example, crop rotation, soil bunds, stone walls, bench terracing, forage planting, cultivation of improved varieties, zero-grazing, rearing new livestock breeds, use of animal manure, use of green compost, integrated soil fertility management, agroforestry systems, expansion of irrigation through construction of alternative water harvesting schemes, pasture management, exclosure, conservation tillage, crop diversification and area enclosure.

Consequently, we randomly selected some agricultural practices from each group, depending on the study research objectives, but without purposeful reason. For example, minimum tillage was selected to explore the impacts of socio-psychological issues on the intentions (desire) of smallholder farmers towards this practice (chapter three). In addition, agroforestry systems, use of compost and application of crop rotation (temporal diversity of crop sequences) were chosen to explore the correlation between socio-psychological factors and actual adoption behaviour for these agricultural practices (chapter five).

Furthermore, retaining crop residues, use of soil and water conservation, particularly soil bunds and stone walls, and application of animal manure were selected to investigate the impact of these agricultural practices on agricultural production, food security and household welfare (chapter six). The reason for changing these agricultural practices simply depends on the research objective of the study, as well as to avoid repetition. Table 2.2 indicates the selected agricultural practices and how they are defined in the local areas.

[3] *Disintegration of substance (capable of being decomposed) by bacteria, fungi or other biological means.*

Table 2.2. Selected sustainable agricultural practices and their definition from local context

Minimum Tillage	Farming practice that involves less ploughing than used normally to reduce soil disturbance	Chapter Three
Agroforestry systems	Planting of multipurpose trees on private field plots (forage trees, perennial fruit (apples, oranges), moringa trees, silkworm trees, acacia trees, olive trees, eucalyptus and other trees	
Crop rotation	Use of different types of crops one after the other in the same area in sequenced seasons, for example, legume crops (beans, chickpea or peas) following cereal crops (wheat, barley or maize)	Chapter Five
Compost	Use of organic materials (weeds, farm waste, straw/hay leftovers, dry leaves, ash and food wastes) as organic fertilizer to increase yields	
Soil & water conservation	Use of stone walls, soil bunds and bench terracing on private field plot levels. This is sometimes known as contour bunds.	
Animal manure	Application of animal faeces, such as cattle dung, chicken manure, shoat droppings or other waste as organic fertilisers on private field plots	Chapter Six
Crop residues	Retaining grain production leftovers on the field plots, such as stalks, straw, stems, leaves, cobs, seed pods, stubble and others	

2. 3. Data collection method

In terms of the source of data used in this dissertation, both primary and secondary data were used to understand the nature of the subject matter. Cross-sectional data were gathered using a standardised questionnaire, field observation and focus group discussions. Secondary materials were also reviewed as a complement to identify and evaluate existing gaps. The different types of data collection methods helped to ensure the reliability of the data. In general, a sequential mixed method was used. First, preliminary discussions were undertaken with concerned bodies. Subsequently, pre-testing the survey and reviewing the relevant literature to obtain a better insight into the subject, and gain a better understanding of terms that fit the objectives. Finally, a detailed survey was undertaken.

2. 3. 1. Questionnaire survey

The questions used in the household survey passed through several iterations. A preliminary discussion was undertaken with purposively selected agricultural officials in the region to understand the agricultural practices in the region. Some previously validated empirical studies (*see detail in each chapter*) were also reviewed, which helped in obtaining some descriptive terms that were used to measure the research objectives. Subsequently, a discussion was undertaken with some agricultural extension workers in the study area to understand specific agricultural practices and overall socioeconomic conditions in the district.

Next, a draft questionnaire was prepared and its adequacy and language issues were assessed. A pre-testing survey was arranged with ten randomly selected farm households to contextualise the questionnaire, especially the clarity and discourse in the local language. Those farmers who participated in the pilot survey did not participate in the final survey. Based on the reflections during these pre-assessments, some questions were removed, especially questions that were ambiguous for the farmers, and many questions were modified according to the local language.

After following these points, the final version of the questionnaire was developed. It included relevant information, such as demographic characteristics, village variables, institutional factors, rural services, socio-psychological factors, welfare indicators, risks and agricultural practices. In general, the data was collected and administered by experienced enumerators, who speak the local language, under the close supervision and follow-up of the research team.

2. 3. 2. Focus group discussion

Another data collection tool was focus group discussion, which is used to elicit broader reasoning and argumentation and enables us to gain a deeper understanding of farmers' behaviour. After preparing a guided checklist, a focus group discussion was held in each sample village to obtain general information about issues relating to risk behaviours, food security, livelihoods, the potential and constraints of sustainable agricultural practices, and climate change. In the focus groups, the participants, who were accessed by using a purposive sampling method, were representative of different social strata and rural organisations.

They included, for example, the agricultural extension offices, farmers' associations, women's associations, cooperative societies, religious institutions, non-governmental organisations working in the villages, early warning and preparedness committees, local governments, model farmers and elder farmers. The composition of the focus groups was not random, but pre-determined and purposively selected by extension workers from the respective villages.

For specific questions, respondents were given 50 stone counters for ranking purposes. After identifying the reasons, for example, for non-adoptions of sustainable agricultural practices and also summarizing these into some clusters, each participant was asked to rank them according to certain criteria. After the participants had done the same thing, they finally discussed each ranking and reached a consensus for a group rank that represented their village. The focus groups were conducted in the local language and every participant was also given a chance to speak on each discussion point. In general, the discussion was participatory and open.

2. 3. 3. Personal observation

In reality, since people may have some issues that are observable personally but are unlikely to be expressed in words to others, visiting the field can help to understand the behaviour, habits, needs, and feelings of the local people. This can give unique information about the situations without any verbal interpretation. In this study, for example, such field observations helped to identify whether farm households have actually adopted sustainable agricultural practices.

2. 3. 4. Secondary data

In this study, books, government reports and scientific articles in relation to adoption behaviour, sustainable agricultural practices, climate change and livelihoods were reviewed to supplement or complement the primary data that were collected using a structured household survey. Literature review helped to identify the existing gaps and understand what had already been done and what was still left to do. Thereby a conceptual framework was constructed for this study. In addition, this enabled evaluation of the study in relation to other previously validated empirical studies. The desktop survey (or literature review) was also used to learn and develop theoretical and methodological frameworks vis-à-vis the research objectives.

2. 4. Data management and analysis

2. 4. 1. Defining, explaining and measuring variables

The study uses both continuous and categorical variables, where the former represents a variable that has standard measurement units and does not require operationalization, for example, income, landholding size and age of the household head. The categorical variables, on the other hand, do not have standard measurement units, for instance, modes of transport such as train, bus, ferryboat, and aeroplane. They require operationalization using measurement scales, such as nominal, interval, ordinal, ratio and composite scale. This scale often helps to overcome distortion, check the precision of the data, for example, reliability and validity, and to undertake a statistical analysis, for example, factor analysis and statistical test (Bickel 2007).

Concurrent to this, the study also contains observed and unobserved (latent) variables in the dataset. While observed variables refer to variables that explicitly exist in the dataset collected via the survey (Schumacker and Lomax 2010), latent (unobserved) variables refer to variables that are not directly observed in the survey or are not measured using the standard unit (Wauters 2010). In this study, landholding size, expenditure and income are examples of observed variables, whereas attitudes, intentions and risk attitudes are latent variables.

In this study, latent variables are expected to be derived or constructed from statements or questions that are directly observed in the dataset. Each observed statement is graded or anchored by a five-point Likert item, ranging from completely disagree to completely agree, from very bad to very good, and from very low to very high. A number is assigned for the scale measurement, for instance, from one (negative implication) to five (positive implication).

To make this explicit, although most questions are labelled at the endpoint, some questions are directly assigned a number, for instance, 1 for strongly disagree, 2 for disagree, 3 for undecided or uncertain, 4 for agree and 5 for strongly agree. However, the opposite is also possible for some variables, to keep the counterbalance and understand the response consistency. We used this even if we reversed it later in the analysis to maintain the consistency of the dimensions.

In this dissertation, there are target and control variables regardless of whether they are latent or observed and continuous or category. Some target variables are, for example, household size, education, extension service, technical training, attitudes, intentions, risk attitudes, perceived resources, social capital and credit access, while other demographic variables, rural services and farmland conditions are examples of control variables in this study (for detailed definitions and explanation of these variables in the study see Annexe 2.1, Annexe 2.2. and Annexe 2.3). The variables will be defined and discussed in more detail in the following chapters.

2. 4. 2. Data analysis and estimation procedures used

The raw data collected from the field was coded, cleaned, processed and managed using MS Excel. The same procedure was used for the secondary data collected from existing databases, for example, rainfall and temperature data. Different estimation methods were used to analyse the data. In general, the steps below were undertaken or followed hierarchically, especially in constructing the latent variables, in order to produce and generate sound research output.

Step 1: Exploratory factor analysis[4], specifically a maximum likelihood extraction method was used to construct latent variables for the study with a homogeneous structure from multiple observed statements with heterogeneous structure in the dataset (see Annexe 2.2; Annexe 2.3).

Step 2: Reliability and validity of the derived latent variables were checked using Cronbach's alpha, factor loading and variance extracted. These show whether the observed multi-response statements adequately explain the respective latent variables.

Step 3: The value of the latent variable is computed from the corresponding observed statements in different ways, for example, factor score technique, Herfindahl-Hirschman index, expected value (mean) method, actual-optimal-value index, and total (sum) approach. In this study, mean and total methods are applied to determine the value of each latent variable from the corresponding statements that are observed in the dataset of the study.

Step 4: In the literature, there are no uniform ways that are used to regroup categorical variables into other categorical variables. There is also no universal threshold level to classify respondents into different groups. Various studies have used different ways, for example, cluster analysis, mathematical certainty equivalent calculation, equivalent interval principle and similarity-based regrouping. In this study, these except mathematical certainty equivalent calculation are used to classify variables or respondents into different groups (if necessary) based on specifically predefined characteristics.

Step 5: The assumptions of normality, multicollinearity and heteroskedasticity (including endogeneity in possible cases) are checked using different techniques.

Step 6: The estimation research objectives were undertaken using various methods, depending on the nature of the response variables, for example,

a) Structural equation model, which sees and estimates the interdependence effect of the predictor variables, is used to explore how socio-psychological issues influence the intention of smallholder farmers to adopt sustainable agricultural practices. In this model, there are two steps: measurement model, which is tested by confirmatory factor analysis, shows the overall goodness-of-fit model and structural model or path analysis shows the interrelationships between the latent variables. This model is supplemented by three-stage least squares that adjusts the correlation of error terms across equations.
b) (Generalized) ordered probit model with a heterogeneous choice model is applied to investigate how the socio-psychological issues affect the risk attitudes of farmers.

[4] *For many observed statements, the lowest value often indicates negative implication while the highest value has a positive implication (1=more unlikely, 2=unlikely, 3=uncertain 4=likely and 5=more likely), but sometimes we use a reverse option (counterbalance) for some variables to check the accuracy of the responses. In this case, the lowest value indicates positive implication (1=more likely, 2=likely, 3=uncertain 4=unlikely and 5=more unlikely). Since these variables are required to be in a uniform or similar dimension to use in further analysis, the latter option should be transformed in a way that the lowest value shows a negative implication.*

c) Multivariate analysis with the ordered probit model is used to examine the impacts of socio-psychological issues on simultaneous (actual) adoption (probability and intensity) of multiple sustainable agricultural practices.
d) Endogenous switching regression with treatment effect (inverse probability weighted regression adjustment, regression adjustment, etc.) is utilized to estimate the potential effect of sustainable agricultural practices on agricultural production, food security and rural livelihoods of smallholder farmers.
e) Descriptive statistics and percentile ranking scale are applied to understand smallholder farmers' awareness of climate change, to investigate the impacts of climate change and to assess the strategies they have adopted in response to climate change.

2. 5. Possible ways of reducing errors

It is well-known that there are sampling and nonsampling errors in any behavioural research. Recognising this, the following procedures were considered to reduce (avoid if possible) these errors. Following these procedures helped us to collect reliable and unbiased data, thereby generating relatively good research outputs.

At the inception, the draft questionnaire was pre-tested by randomly selected farmers and was revised or improved based on the feedback from the pre-testing survey. With regard to the data enumerators, they had a bachelor degree, good experience in data collection, and were conversant with the local language and customs. They also attended two days of training about the questionnaire, research ethics and response recording. Such training helped enumerators to internalize the questions and to have a uniform verbal interpretation of the questionnaire.

Concerning the sampling procedure, farmers were identified using the probability sampling method, which helped to ensure representativeness and also to reduce heterogeneities and selection bias in the sample. Along with this, face-to-face interviews gave the advantage of a high response rate, and the opportunity to clarify any unclear questions. While the structured questionnaire reduced recording and interpreting errors from enumerators, we believe that these points could partially contribute to the reduction of errors in sampling and data collection.

Additionally, since it was expected that some respondents might not be available during the survey and some might also be unable to provide information because of personal characteristics, we held a list of reserves who were chosen according to the same procedure, after excluding the farmers who had already been selected. Having a list of reserves helped to manage non-response and to replace unavailable respondents.

In practical terms, we could not find four selected household heads at the time of the survey. Accordingly, they were replaced from the reserve lists. For one farmer who was not available during the survey, information was taken from his wife and elder son (20 years old and attending grade 11) since they were ready to give us the necessary information. Consequently, we believed that the attrition rate was not such a big concern for this study.

In parallel, the researcher and enumerators met every evening to brief each other and to make immediate corrections for misunderstandings, misinterpretation or any major errors in the responses, although it was not possible to fully cross-check the responses for each questionnaire and every question daily. The researcher entered the data directly into an Excel spreadsheet on a computer to avoid or reduce recording or typing errors.

Furthermore, the study has a relatively adequate sample size. Following this, ten questionnaires that were incomplete or contained inconsistent data (relevant information was missed) were discarded completely. This could reduce the impact of missing data.

With this, a consent agreement was included on the first page of the questionnaire. This introduced the purpose of the survey, including ethical considerations, and requested the voluntary participation of respondents, encouraging them to remain anonymous. Each enumerator was asked to read and explain this to respondents before starting the questionnaire.

In many parts of the questions, a choice of '*I do not know or I do not want to respond*' was also present. This gave respondents the freedom whether or not to respond. We believe that these points helped to minimize sampling and non-sampling errors, at least partly, even if it is not possible to avoid them completely.

2. 6. Descriptive statistics: demographic variables

The data used for this research originates from a household survey that was conducted in August-October 2015, during the off-harvesting period in northern Ethiopia. Table 2.3 presents the socioeconomic and biophysical characteristics of respondents (*see definition and explanation in Annexe 2.1*). About 58% of the farmers were from male-headed households and about 59% were married, while the proportion of single household heads was about 2% and about 39% were either widowed or divorced. Of the latter figure, two-thirds were female-headed households. As indicated in the focus group discussions, and commonly believed in the area, the Ethio-Eritrea war and the migration of young people to Arab countries might have contributed to the high proportion of widowed or divorced household heads.

Another demographic feature is the age of the farmers, which ranges from 30 to 71 years, with a mean age of 48 years. During the survey, they had a farming experience ranging from five to 44 years, with mean farming experience of 23 years. About 86% were followers of orthodox religion while the remaining were Muslims, Catholics and Protestants. The mean household size was slightly greater than four people (4.3) with a labour supply of 3.5, which represents the adult-equivalent-based household size[5] and a better likely indicator of labour supply for production and technology adoption. This figure was roughly less than that for the Tigray region as a whole (Bureau of Agriculture and Rural Development report 2017).

With regard to the educational level of the household head, about 54% of smallholder farmers could not read and write, about 10% were literate from religious education and illiteracy campaign programs, while about 36% had attended formal education in primary and upper schools, with an average educational attainment of 2.2 years of schooling. This illiteracy rate is

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[5]. *Here, adult equivalence scale only captures age (but not gender) difference in household size, because it is not possible to disaggregate the data collected from the field. Household size based on adult labour equivalent is computed as adult male and female (15-60 years) is assigned 1; older males and females (above 60 years) is 0.70; children both boys and girls is 0.50.*

very similar to the corresponding figure for the Tigray region (*Annual Report of Bureau of Finance and Economic Development 2017*).

In the area, agriculture is found to be a primary source of livelihood for about 67% of the farmers, while it is not a primary activity for the remaining farmers. This means that there are some farmers who have been engaged in non-agricultural activities, for example, small businesses, petty trade, casual labour, and the sale of charcoal and firewood. About 41% of respondents indicated that they have special skills, such as masonry, carpentry, plumbing, weaving, spinning, pot/basket-making, hairdressing, traditional healing or blacksmithing. Since these activities could generate additional and higher returns than agriculture, they might often spend time engaged in them. Because some rural towns in the area are flourishing, some farmers might also be involved in small business activities.

Livestock ownership presents farmers with the flexibility to adopt strategies, and also use them for traction or transportation. The majority of the farmers (92%) own livestock and the mean livestock asset is 2.40TLU[6], although livestock assets vary significantly between farmers (i.e. from 0.25TLU to 5.92TLU). The remaining farmers have no livestock. All farmers have cultivated farmland, even if it is small and fragmented. This ranges from 0.19ha to 0.98ha, with a mean landholding size of 0.56ha. The number of field plots per individual farmer varies from three to seven field plots, with a mean of four field plots. As indicated in the focus groups, the distance from the house to field plots is, on average, estimated from 2 to nearly 80 minutes.

The quality of the farmland is measured using soil fertility, the gradient of the farmland and soil depth, and all of these are captured through farmers' perceptions. Based on the perceptions of the farmers, the quality of the cultivated farmland varies significantly from flat to steep slopes, from very fertile to infertile soils and from shallow to deep soils. While evaluating the field plots, on average, about 25 and 40% of the field plots are perceived by the farmers to have flat and moderate slopes. About 30 and 37% of the field plots are perceived to have fertile and moderately fertile soils. About 32 and 40% of the field plots have shallow and moderate soil depth. About 35% of the field plots have steep slopes, and 33% have infertile soils.

Evaluating the availability of, and accessibility to, infrastructure facilities, about 45% of the farmers have access to input-output (district markets) within a radius of 80 minutes walking distance[7] and about 60% have access to all-weather rural roads within a radius of 6 km. In every village, there is a farmers' training centre (farmer-school). These centres usually have demonstration field plots for new technologies (centre for training). Farmers can also access inputs such as chemical fertilizers, pesticides and improved seeds from the government supplies held at the centres. About 47% of the farmers have access to these inputs or a training centre within a distance of 6 km. About 39% of the farmers have either received short-term training or participated in agricultural field days and farm demonstrations about agricultural practices.

Concerning access to credit, which is important to resolve liquidity constraints, there are three possibilities: farmers who want credit and obtain it, farmers who want credit but are unable to

[6]. *The Tropical Livestock Unit (TLU) equivalence is used to determine livestock density from many and various types of animals, and calculated as follows: 1 TLU=1 camel, 0.7 cow, 0.8 ox, 0.1 shoat, 0.5 donkey, 0.45 heifer/bull, 0.75 mule/ horse, 0.2 bee colonies or 0.01 chickens.*
[7]. *Using the Wikipedia encyclopedia a walking event is translated into km at various fitness-walking paces: 7 minutes per km for fast, 10 minutes per km for moderate, and 12 minutes per km for easy walking. In this study, a moderate fitness-walking pace is used.*

obtain it and farmers who do not want credit. At the time of the survey, about 45% of the farmers had received credits from either a local microfinance institution (Dedebit) or a formal bank, while about 18% did not require any credit because they are either wealthy or credit averse. Furthermore, 37% had no access to credit due to collateral and other constraints.

In terms of information channels, about 12% of the farmers have a television or radio through which they are more likely to obtain timely agricultural information. In each village, there are extension agents, who are assigned by the government to assist farmers technically in the application of technological innovations. To this effect, many farmers can frequently visit and contact agricultural extension agents to obtain information on climatic and agricultural conditions. However, about 60% do not have confidence in the competence, skills and knowledge of these extension agents. There are also different formal organizations, for example, credit and saving associations, farmers' associations, resource users' groups and cooperative societies. Many farmers are members of these organizations.

As stated above, the area is very susceptible to erosion and degradation. About 35% of the farmers indicated that the area has been affected by frequent (moderate and severe) droughts and other shocks, at least four times during the last two decades. About 53% of the farmers have also reported that their crops and livestock are frequently affected by the prevalence of pests, diseases, and shocks. Consequently, about 55% of farm households are highly dependent on government and nongovernment support in times of drought, crop failure and other crises.

For variables listed in Table 2.3, we used Spearman's rank correlation for continuous variables and contingency correlation coefficients for dummy variables. Some are found to be highly correlated statistically (age with experience, marriage with gender, education with marriage) and some are weakly correlated, whereas most variables in this study are found to be statistically uncorrelated. Highly correlated variables were excluded from the estimation models. Therefore, multicollinearity cannot be a serious threat for this study (*explained in the following chapters*).

Table 2.3. Summary statistics for socio-economic variables in the study (mean for continuous variables and proportion or share for dummy variables)

Variables	Value	Variables	Value	Variables	Value
Gender	0.58	Experience	23.0	Special skills	0.41
Age	48.0	Religion	0.86	Occupation	0.67
Livestock	2.40	Marriage	0.59	Family size	4.30
Farmland	0.56	Gentle slopes	0.40	Credit access	0.45
Flat slopes	0.25	Fertile soil	0.30	Medium soil	0.37
Shallow Soil	0.32	Drought	0.35	Extension confidence	0.40
Agroecology	0.82	Market proximity	0.45	Government support	0.55
Education	0.46	Farmer schools	0.47	Road accessibility	0.63
Stress	0.53				

Chapter Three
Understanding smallholder farmers' intentions towards conservation agriculture

Abstract

The paper investigates smallholder farmers' intentions towards the adoption of conservation agriculture, particularly, minimum tillage. The decomposed theory of planned behaviour is used as a theoretical framework while structural equation model along with three-stage least squares regression as an analytical model. The findings reveal that attitudes and normative issues positively explain smallholder farmers' intentions to adopt conservation agriculture. Perceived usefulness is a significant positive predictor of smallholder farmers' attitudes, while it is negatively affected by perceived compatibility. It is also found a normative issue to be affected positively by social capital, which is captured by group membership and relational capital. In addition, it is positively influenced by technical knowledge and capacity building training. Furthermore, the availability of resources and rural facilities has direct impacts on perceived control, while personal efficacy has indirect effects on smallholder farmers' intentions. This justifies that when the intentions are formed, smallholder farmers are expected to carry out their intentions when the opportunities arise, such as positive attitudes and favourable normative issues. This study confirms that social capital, personal efficacy and attributes of agricultural practices play significant roles in behavioural intentions towards the practices. However, agricultural extension services and mass media have no direct and indirect effects on farmers' intentions. Therefore, attention should be given to social-psychological issues such as enhance awareness, build positive attitudes and strengthen formal and informal institutions to positively push intention of farmers towards the adoption of sustainable agricultural practices, especially minimum tillage.

Keyword: *Smallholders, intentions, minimum tillage, the decomposed theory of planned behaviours, structural equation model.*

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3. 1. Introduction

The application of improved technologies and sustainable agricultural practices has successfully improved the productivity of the agricultural sector, and thereby reduced food insecurity and poverty significantly in some Asian and Latin American countries, for example, Brazil, India and Vietnam (FAO 2014; Kelsey 2013; Todaro and Smith 2011; Dillon 2011; Norton, Alwang, and Masters 2010; Hanjra, Ferede, and Gutta 2009; Bhattarai, Barker, and Narayanamoorthy 2007; Huang et al. 2006; Hussain and Ashfaq 2006).

To this effect, the adoption of improved technologies and sustainable agricultural practices has been considered an important agenda in the development policy of the Sub-Saharan African countries since the 1980s (FAO 2014; Gumataw et al. 2013; Dillon 2011; Norton, Alwang, and Masters 2010; Hanjra, Ferede, and Gutta 2009; Bhattarai, Barker, and Narayanamoorthy 2007). The governmental and nongovernmental organizations, especially those working in agriculture and rural development, have given attention to introducing and/or expand technological innovations and improved agricultural practices.

However, as indicated in the literature, the adoption of technologies and sustainable agricultural practices in these countries still remains below the expectations. Several demographic, institutional and socioeconomic factors were identified as reasons for the low adoption (Mbow et al. 2014; Foley 2013; Gumataw et al. 2013; Kassie et al. 2013; Kelsey 2013; Teklewold, Kassie, and Shiferaw 2013; Asfaw et al. 2012; Reimer, Weinkauf, and Prokopy 2012; Norton, Alwang, and Masters 2010; Bhattarai, Barker, and Narayanamoorthy 2007; Lee 2005).

In an earlier time, the primary focus was on how demographic characteristics, economic resources and biophysical factors affecting adoption of innovations, particularly technology and new products. More recently, social and psychological variables such as beliefs, psychological factors, institutions, information sources and relational capital have been receiving attention in adoption decisions and human behaviour. This is for the fact that it is believed people differ in cognitive ability, subjective norms, social traditions and attitudes, which are directly reflected in people's behaviour and farm management decisions (Power, Kelly, and Stout 2013).

The available empirical literature on social and psychological factors includes, for example, (Menozzi, Fioravenzi, and Donati 2015; Erwin Wauters and Mathijs 2014; Yazdanpanah et al. 2014; Foley 2013; Martínez-García, Dorward, and Rehman 2013; E. Wauters and Mathijs 2013; Yamano, Rajendran, and Malabayabas 2013). They are, however, limited in amount to sufficiently capture overall impacts of socio-psychological behaviour and alternative information sources, especially considering the variability of studies across location and among people. This is why it is stated that there is still a lack of clear evidence to understand what motivate farmers to adopt improved technologies and sustainable agricultural practices (Yazdanpanah et al. 2014).

In addition to the limited availability of empirical studies in socio-psychological impacts, there are rare studies that explore in a disaggregated way how attitudes, normative issues, personal competence, social capital and alternative information influence behavioural intentions, especially in agriculture and rural development. In Ethiopia, smallholder farmers' intention towards sustainable agricultural practices still remain unexplored in the literature interface, which however could provide more insight into actual adoption behaviour. Currently, minimum tillage is not popularised in northern Ethiopia (Araya 2012) even if various efforts have been undertaking recently to promote the adoption of this practice.

Therefore, this chapter aims to understand farmers' attitudes and intentions toward adopting sustainable agricultural practices in the area. With this regard, it has twofold objectives. The paper determines the attitudes and intentions of smallholder farmers to use minimum tillage on their field plots in the future. The chapter also investigates the influence of socio-psychological factors, for example, attitudes, social capital, and perceived controls on the intentions of farmers to adopt this conservation practice. However, the effect of socio-economic and institutional factors that are often mentioned in the traditional literature are excluded because the main purpose is to evaluate how those socio-psychological factors influence farmers' intentions.

While addressing these objectives, the research results provide insight and empirical evidence for governments and development practitioners to design specific initiatives to promote positive intentions or to readjust the current strategies (if necessary) to stimulate the adoption of sustainable agricultural practices. This paper also contributes to the existing limited literature on sustainable agriculture. Finally, the decomposed theory of planned behaviour is tested whether it can adequately explain smallholder farmers' intentions towards sustainable agriculture, especially in less developed countries.

The remainder of this chapter is organised as follows. After introducing and justifying this chapter above, section two reviews the theoretical and conceptual frameworks of the study. It also establishes a hypothesis and explains the model. Subsequently, the research design that includes sustainable agricultural practices selected and ways of elicitation of intentions is described. The assumptions of the structural equation model are also evaluated in this section. The fourth section analyses and discusses the main findings while the last section provides conclusions and draws implications.

3. 2. Review of literature

3. 2. 1. Theoretical and conceptual framework

The theory of planned behaviour is the most commonly used behavioural theoretical framework in the literature to explain human behaviour and adoption of technological innovations. But this theory provides an insufficient basis to understand farmers' intentions and actual adoption behaviour. Accordingly, the decomposed theory of planned behaviour is used as a theoretical basis to better explain farmers' intentions towards agricultural practices.

This decomposed approach (Figure 3.1) has been received significant attention recently. Like the theory of planned behaviour, intention, which is captured by three motivational factors, such as attitudes, subjective norms and perceived control, plays a central role in performing a given human behaviour and adoption decision (Ajzen 1991). As indicated in Figure 3.1, smallholder farmers' intention to adopt sustainable agricultural practices is explained by attitudes, perceived controls and normative issues.

The conceptual framework shows that attitude is further decomposed into three dimensions, such as perceived usefulness, perceived compatibility and perceived easiness of agricultural practices using the innovation diffusion theory (*see definition in Table 3.1 section 3.2.2*) (Rogers 1983). Those characteristics are also expected to influence intention indirectly. Therefore, those perceived attributes of agricultural practices seem to provide sufficient information about attitudes and intentions towards sustainable agricultural practices.

Concerning the perceived control, it indicates the beliefs about the presence of external and internal factors that could be opportunities and constraints in influencing the performance of the behaviour (Zschocke et al. 2013; Sadaf, Newby, and Ertmer 2012). Here, it is further decomposed into personal efficacy using the self-identity theory[1] and into perceived resource using economic theory in order to provide comprehensive information and explanations about intentions (*see definition in Table 3.1 section 3.2.2*).

In this situation, perceived control indicates how smallholder farmers have the confidence and ability to control the behaviour and social environment. Therefore, perceived economic resources, personal motivations and understanding of the specific attributes of sustainable agricultural practices are important for intention decisions. However, attributes of the practices, personal efficacy and perceived resources may not sufficient conditions for behavioural intentions.

According to the innovation diffusion theory, communication channels and social system are other factors that significantly influence human behaviour and adoption decisions (Rogers 1983). In the social identity theory[2], adoption also occurs in a social context with a dynamic and reciprocal interaction between a person and the environment (Venkatesh, Thong, and Xu 2012; Reckwitz 2002). This implies that intention can go beyond the context of the attributes of the practices and perceived controls.

Following those facts, we decomposed normative issue, which indicates the degree to which the farmer believes how important groups for him, for example, reference groups, external forces and information channels affecting his decisions and behaviour, into five different structures, such as media influence, extension service, technical training, relational capital and group membership (*see definition in Table 3.1 section 3.2.2*). Those dimensions help to capture the overall influence and pressure of information and external forces on intentions towards sustainable agricultural practices.

[1]. *Self-identity theory refers to relatively permanent self-assessment, such as personality attributes, knowledge of one's skills and abilities, one's occupation and hobbies, and awareness of one's physical attributes. Who are you? Norm activation theory shows awareness of the environmental problem, awareness of behavioural relevance and awareness of abilities explain personal norm, this, in turn, predicts behaviour. Thus, self-identity theory and norm activation theory are interchangeable.*

[2]. *Social identity theory explains person's sense of who they are based on the group membership (intergroup behaviour), i.e., describes and predicts certain intergroup behaviours on the basis of perceived group status differences, the perceived legitimacy and stability of those status differences, and the perceived ability to move from one group to another. Groups such as social class, family and others are important sources of pride and self-esteem.*

As explained by Rogers (2003), the normative issue can serve as a proxy for innovation, social capital[3] and uncertainty. Mass media, friends, families, training, extension workers and neighbours play important roles in making users aware of or form attitude to sustainable agricultural practices (knowledge), to evaluate the attributes of the practices (persuasion), which can reduce uncertainty about their advantages and disadvantages (decision) and enable them to adopt the practice in own farm environment (implementation) and to reinforce the decision already made and influencing other groups (confirmation).

The conceptual framework of this chapter forms synthesises the theory of planned behaviour with other theories, such as social identity theory, economic constraint theory, self-identity theory and diffusion innovation theory to form an extended decomposed theory of planned behaviour. Furthermore, it targets a multidimensional belief, which produces sound findings and may have a better explanatory power than that of a monolithic belief. Finally, this framework allows the possibility of establishing crossover interrelational (interaction) effects among the intention predictors.

These behavioural theoretical models, for example, theory of planned behaviour and decomposed theory of planned behaviour have been commonly applied in consumer behaviours, manufacturing industries, information technologies, and software sciences, for example, in the use of internet and mobile banking (Kazemi et al. 2013; Kyere-Duodu 2011), online shopping and e-commerce in business enterprises (Iqbal and El-Gohary 2014; Sentosa and Mat 2012; Velarde 2012), e-learning in agricultural higher education (Zschocke et al. 2013; Ghyas, Sugiura, and Kondo 2012), sharing knowledge and files using P-2-P networks (Kyper and Blake 2012) and Web 2.0 virtual community technologies on various activities (Horng, Lee, and Wu 2012; Sadaf, Newby, and Ertmer 2012).

In the field of agriculture, natural resource management and rural development, there are limited empirical studies, even if there are some, for example, Menozzi et al. (2015), Yazdanpanah et al. (2014), Martínez-García et al. (2013), Power et al. (2013), Yamano et al. (2013), Sharifzadeh et al. (2012), Läpple & Kelley (2010), Wauters (2010), Wollni et al. (2010), Läpple & Kelley (2010) and Fielding et al. (2005), particularly limited studies using the decomposed theory of planned behaviour.

These existing behavioural studies in the literature have produced mixed findings even if most studies found positive and significant effects of attitudes and subjective norms in predicting intentions and actual behaviour towards adopting technological innovations and sustainable agricultural practices. Consequently, this disaggregated conceptual framework or decomposed approach (Figure 3.1) is expected to allow for better understanding of smallholder farmers' behavioural intentions towards sustainable agriculture in general and conservation agriculture in particular.

[3]. *Farmers can form two types of social network (informal and formal networks) with people with different socio-economic status. Such networks exhibit distinctive forms of internal trust and is driven by values and voluntary efforts with strong ties. Such family relations, kinship and formal group formation provide social safety nets (help each other) to individuals or groups and protect members from external invasion (Granovetter 1985). Here both relational capital and group membership are known as social capital. Therefore, social capital captures a spillover effect of personal and group networks*

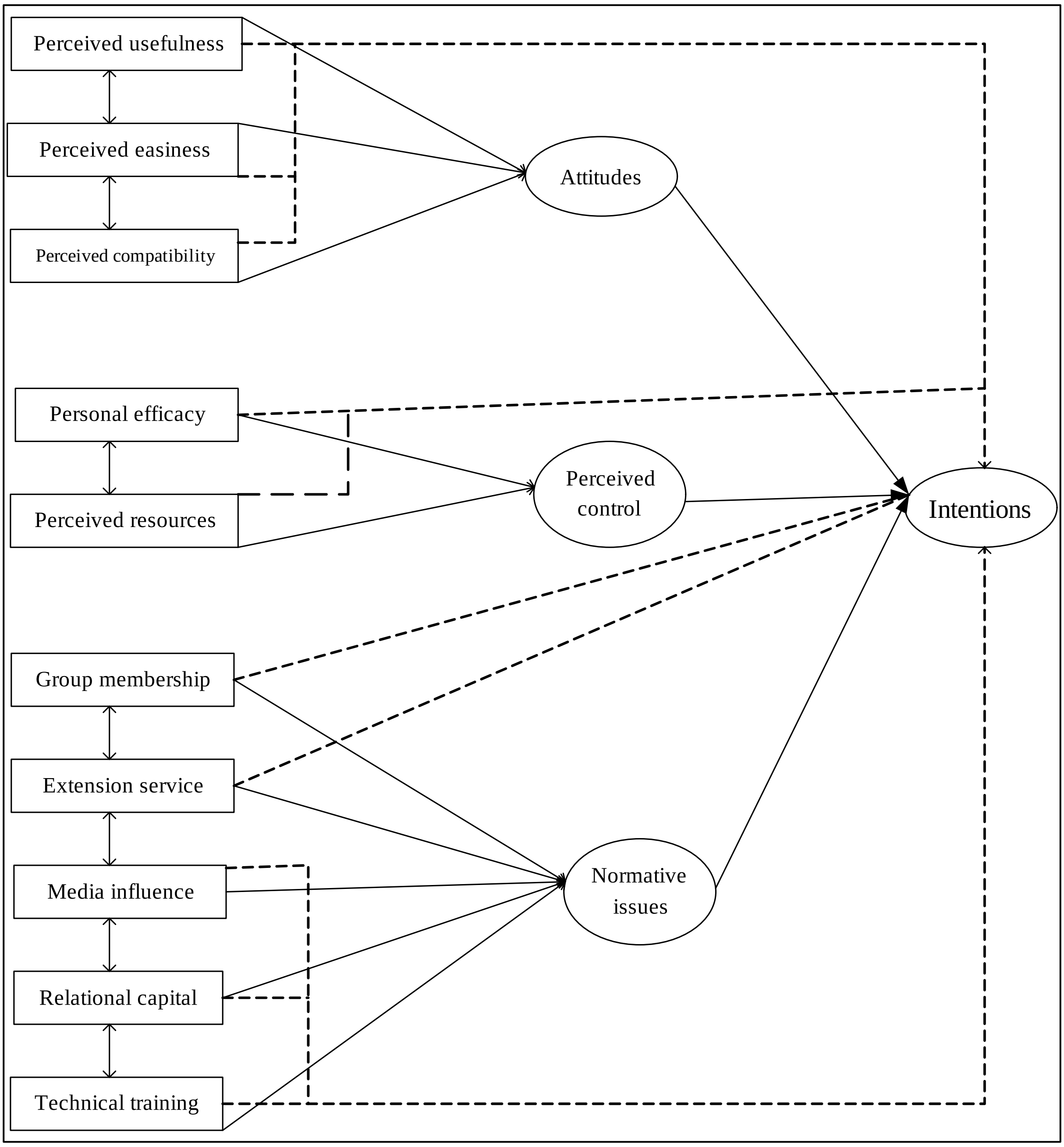

Figure 3. 1. The conceptual framework of behavioural intentions towards agricultural practices: conservation agriculture (solid line for direct effect while broken line for indirect effect)

3. 2. 2. Explaining variables and establishing hypotheses

As indicated in the conceptual framework (Figure 3.1), the study has four endogenous latent variables (intentions, attitudes, normative issues and perceived control) and several exogenous latent variables (media influence, extension service, technical training, relational capital, personal efficacy, group membership, perceived resource, perceived usefulness, perceived easiness and perceived compatibility). Those variables are latent (or unobserved) in the dataset of the study. Table 3.1 presents the definition and explanation of these latent variables.

As stated in chapter two, multiple observed indicators or statements are used to construct and measure these latent variables. In turn, each statement is anchored or responded by a five-point Likert or predefined scale, for example, completely disagree - completely agree, very low - very high, definitely false - definitely true, very bad - very good, and more unlikely - more likely. These are labelled either at the endpoint or at each point, with detailed, such as strongly disagree, disagree, not sure about, agree and strongly agree (detailed see chapter 2 section 2.4 or Annexe 2.2).

In this chapter, the endogenous latent variables are dependent variables, which are influenced by the exogenous latent variables (explanatory variables) in the model either directly or indirectly. Accordingly, based on the conceptual framework, research objectives and prior empirical studies, the following hypotheses are proposed:

H1: proportion

Half of the smallholder farmers in the area under consideration are hypothesized to have positive attitudes and intentions towards conservation agriculture, particularly minimum tillage

H2: direct effect

H_2A: Attitude is positively and directly related to intentions

H_2B: There is a significant direct relationship between normative issues and intentions

H_2C: Perceived control is hypothesized to positively affect intention

H_2D: Attitude has a positive and direct relation with perceived usefulness/ perceived easiness/perceived compatibility

H_2E: There will be a significant positive relation between normative issue and its decomposed components (media influence, extension service, technical training, relational capital and group membership)

H_2F: Personal efficacy or perceived resources is expected to have a statistically significant positive effect on perceived control

H3: indirect effect

H_3A: Attitude will mediate significant effects of its decomposed components towards intentions (perceived usefulness, perceived easiness and perceived compatibility)

H_3B: Through the mediation of normative issues, intention is significantly affected by media influence, relational capital, group membership, technical training and extension service

H_3C: Perceived control mediates significant effects of its decomposed components on intentions (personal efficacy and perceived resources)

Table 3. 1. Definition and explanation of target variables of the study

Variables	Description and explanation of these latent variables
Attitude	The level to which a farmer feels to adopt agricultural practices after understanding and evaluating their positive and negative consequences.
Personal efficacy	The level in which a farmer evaluates own competencies, skills, knowledge and capabilities whether those help him to successfully perform agricultural practices.
Perceived resource	The extent of perception of a farmer on how necessary economic resources and rural facilities facilitate or impede the adoption of sustainable agricultural practices.
Media influence	The level of influence on a farmer's behaviour and decisions from formal mass media, like television, radio broadcast, mobile phones, newspapers and magazines.
Technical training	Perception of a farmer on how capacity building schemes, like attending short-term course training, attending on-farm trials or agricultural field days and participating workshop exposure affects his decisions and behaviours
Extension services	The level of how access to agricultural advisory services, such as agricultural experts and development agents influence a farmer's decisions and behaviours
Relational capital	Perception level on how reference groups or informal institutions (friends, families, neighbours and endogenous clubs, like Equb and Idir), who are important for the farmer, affect his decision and behaviour (also interpersonal contact=social pressure)
perceived usefulness	Level of perception of a farmer to the contribution of agricultural practices to perform his expected outcomes, such as yield, fertility, income, nutrition and other benefits
Group membership	A farmer's feeling on how formal organizations (farmers' association, saving and credit association, resource users' groups and cooperative societies) influence his behaviour and decisions. This is also sometimes known as group pressure.
perceived easiness	A farmers' perception of the level of simplicity or non-complexities of sustainable agricultural practices to understand, learn and adopt.
perceived compatibility	The degree to which whether agricultural practices are fitted with a farmers' previous experience, existing traditional values, social norms and current needs

3. 2. 3. Model explanation and estimation

As it is indicated in the literature, structural equation model (SEM) consists of two parts; a measurement model and structural model. The measurement model specifies the relationships between the latent variables and their constituent indicators. It is similar to a procedure of exploratory factor analysis, which is used to reduce the number of variables. The structural model designates the causal relationships between the derived latent variables; a procedure similar to linear regression (Toma and Mathijs 2007).

Factor analysis is used to determine the number of underlying factors (latent variables) with homogeneous structure from the several heterogeneously observed indicators or statements in the dataset. These latent variables are assumed to be proportional to a linear combination of the observed statements contributing to the latent variables (Lobb, Mazzocchi, and Traill 2007; Taylor and Todd 1995). Subsequently, it can be expressed as follows:

$$LV_j = w_t \sum_{t=1}^{n} \xi_t \tag{3.1}$$

Where, LV_j is a latent variable 'j' for example, intentions and attitudes derived from the different and multiple observed statements (ξ_t) in the dataset, which are collected from the sample size (n) through a household survey; and w_t is the weighted index or factor loadings of each observed statement 't' that is loaded in the corresponding latent variable. The desired factors or latent variables are specified based on the rule of Eigenvalue, scree plot and Kaiser-Meyer-Olkin principle[4]. The value of the latent variables from corresponding statements is computed by a sum or mean approach (see section 2.4.2) (only if necessary).

These derived latent variables have indirect interactions (or endogenous relationships) to each other and then confirmatory factor analysis is used to take into account the direct and indirect interlinkage among these latent variables. Accordingly, the relationships between these latent variables are estimated in order to account for interdependence and endogenous relationship (Lobb, Mazzocchi, and Traill 2007). Accordingly, the generic system is given by:

$$LV_s \propto f(LV_k) \quad if\ s \neq k \quad s = 1, 2, ..., m; \quad k = 1, 2, ..., m \tag{3.2}$$

Where latent variable 's' (LV_s) interacts with latent variable 'K' (LV_k).

While determining and computing the endogenous relationships, the path coefficients of these latent variables on intentions are estimated using the structural model, which is a (direct and indirect) linear function of the derived latent variables. A linear structural model that captures potential causal dependency between the derived endogenous and exogenous latent variables is used to estimate intentions and is given as follows:

$$IB_i = \sum_{i=1}^{n} \beta_i LV_{ih} \qquad where, LV_{ih} = \sum_{i=1}^{n} \alpha LV_{iv} \quad h \neq v \tag{3.3}$$

Where IB_i represents the behavioural intentions of farmers 'i' towards sustainable agricultural practices. This is explained linearly and directly by the derived latent variables (LV_h) and explained linearly and indirectly by other decomposed latent variables (LV_v). This structural model tests and accounts for both direct and indirect causal relationships between the derived latent variables and our response variable, behavioural intentions.

In the structural equation model, it is assumed that the data follow a multivariate normal distribution. Accordingly, a maximum likelihood estimation method is applied. In addition, it also indicates whether there is simultaneity problem, especially verifies misspecification problem and reversal cause-effect relationships between these latent variables. Furthermore, it is good for testing complex hypothesis involving multiple equations.

Toma and Mathijs (2007) stated that structural equation model helps to depict model from an empirical point of view (feasible relationships) because it is possible to run an alternative model (hypothetical model) and compare them with the proposed model. However, the structural

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4. *For Eigenvalue, it is often taken one and above, while for Kaiser-Meyer-Olkin (KMO) value, it is above 60%. Scree plot uses determining the number of factors to retain in a factor analysis when the slope of the curve is clearly levelling off.*

model does not capture bias from unobserved factors because does not consider random disturbance. This nevertheless may generate inefficient results, which leads to a drawing wrong policy implication.

Following this, three-stage least squares (3SLS)[5] is complemented to account for selection bias problem that exists in the equations. This model combines a system of equations to estimate all coefficients simultaneously and improves the efficiency when it compares with equation-by-equation estimation. It also accounts and permits correlation of unobserved disturbances across those equations. Both SEM and 3SLS methods can produce the same result if the structural disturbances have no mutual correlations across equations (Zellner and Theil 1962)**.**

$$DV_{im} = IV_{im}\vartheta + EV_{im}\varpi + \varepsilon_{im} \qquad (3.4)$$

Where DV_{im} is the column vector of observations $'i'$ on one of the jointly dependent variables (endogenous latent variables) $'m'$ occurring in that equation; IV_{im} is the column vector of explanatory dependent variables (if any for example demographic variables); EV_{im} is the vector of exogenous latent variables; and ε_{im} is the column vector of structural disturbances while ϑ and ϖ are the corresponding coefficient vector for explanatory dependent variables and exogenous latent variables, respectively.

Consequently, structural equation model (SEM) and three-stage least squares (3SLS) are used to explore the impacts of social and psychological variables, such as attitudes, normative issue and perceived control, and their decomposed components on behavioural intentions of farmers towards adopting sustainable agricultural practices, especially conservation agriculture.

3. 3. Research method and data

3. 3. 1. Conservation agriculture: minimum tillage

Minimum tillage is selected to understand and investigate the influence of socio-psychological variables on farmers' intentions towards this practice (Table 2.2). It is amongst the three principles of conservation agriculture, like diverse crop rotation, reduced (no) till systems and maintenance of surface cover (Kirkegaard et al. 2014; Gonzalez-Sanchez et al. 2015). It is defined as the minimum possible of cultivation or soil disturbance done to prepare a suitable seedbed for successful crop production and other environmental benefits. It does not place any restrictions on farmers but the soil should be physically not inverted (Araya 2012).

Previous studies found that this farming system reduces energy consumption and labour costs, especially reduce the cost of pesticides, inorganic chemicals and fossil fuel. It also promotes the ability of the soils to store or sequester carbon, stabilize the soil surface to wind and runoff erosion and evaporation, minimize the release of dust and other airborne particles, improve the amount of organic matter in the soils, increase soil moisture retention, and enhance productivity and yields (Kirkegaard et al. 2014; Ekeberg and Riley 1997; Hobbs, Sayre, and Gupta 2008).

[5]. *We would like to thank participants in the ICSD 2017 'Sustainable Development' 19-23 October, Skopje, Macedonia, who advised us to use three-stage least squares to account for unobserved bias while identifying factors influencing intentions.*

An example of conservation agriculture, zero conservation tillage is also found to conserve soil moisture and increase organic matter content, which leads to higher yields and net returns (El-Shater et al. 2016). Therefore, minimum conservation tillage helps to conserve soil, water and energy resources, which has direct and indirect effects on agricultural yields, income and overall household welfare.

3. 3. 2. Elicitation methods of attitudes and intentions

In the literature, there are no clear approaches that help to elicit attitudes and intentions. As stated above, these two latent variables with the help of factor analysis are explained by and constructed from observed statements in the dataset (Annexe 2.2). The values of attitudes and intentions can be derived from those statements using factor score, sum method and mean approach (see section 2.4). In this study, mean approach is used to compute the value of attitude as well as the value of intention from the multiple observed statements (see detail section 3.4.1). The mean approach states that the value of the new derived latent variables is an average value of the corresponding observed statements loaded on it, whereas sum approach states that the value of the newly constructed variable is the total values of the statements that are used to construct it.

It is obvious that farmers are expected to have different attitudes and intentions towards conservation agriculture. As stated in section 2.4.2, there are some ways that help to categorize respondents into groups based on specific characteristics. Accordingly, cluster analysis and similarity-based regrouping are used to group smallholder farmers based on their intentions and attitudes towards conservation agriculture, especially minimum tillage. The principle in similarity-based regrouping is that categorical variables or farmers can be categorized from larger levels into smaller levels based on their similar characteristics or entities, for example, very bad and bad can be in one group because both indicate negative implications.

One-way ANOVA analysis is also performed to check whether those socio-psychological variables differ significantly between different attitude and intentions typologies or levels in the sample. The post hoc test is examined which group has significant differences in mean scores and what is the size of the difference. Since the choice for the best post hoc test depends on the equal variance assumption, a priori Levene's test is performed. When this test revealed equal variance, a Tukey post hoc test is used, otherwise a Dunnett's T_3.

3. 3. 2. Constructing latent variables

As it is stated above, our target variables are latent, which are constructed from observed statements. The Bartlett factor analysis with oblique target rotation[6] on the correlation matrix of the multiple statements is applied to determine the statements underlying the latent variables.

[6]. *With extraction method of maximum likelihood, OLS regression method is used when there is correlation between latent variables while Bartlett and Anderson-Rubin method when they are uncorrelated. The exact choice of rotation method depends on whether the underlying latent variables are related. If there are theoretical grounds to think that they are independent or unrelated, the orthogonal rotations (e.g. varimax) are chosen. The oblique rotations (direct oblimin or promax) are used when theory suggests that the variables might correlate* (Kline 2011; Schumacker and Lomax 2010). *In this paper, it is assumed that those latent variables are theoretically related and then oblique rotation with Bartlett method is applied*

This frequently helps to reduce multiple and heterogeneous observed statements into some underlying latent by scrutinising their commonality structure.

Accordingly, the value of Kaiser-Meyer-Olkin (KMO)[7] is 0.73 with Bartlett's test of Sphericity ($P(\chi^2)=0.001$) and therefore the sample size is satisfactory to undertake factor analysis. Of the total statements in the dataset that are expected to explain and measure the socio-psychological behaviour of farmers, 13 factors or latent variables are retained based on the retention threshold of above one Eigenvalue (*see which statements loaded to which latent variables Annexe 2.2*).

These underlie multiple statements explained about 73% of the available total variance in conservation agriculture. The intention factor explains about 11% of the total variance while the other variables explain the remaining. For example, the second factor (attitudes) also explained about 9% of the available total variance.

Based on factor analysis, four observed statements are loaded into attitude while six statements are loaded into intention (*See detail Annexe 2.2 and section 3.4.1*). In a similar way, the normative issue is constructed from and measured by five statements. The remaining latent variables of the study are also loaded by three or more observed statements (see Table 3.2).

Having the descriptive statistics, the mean score for most latent variables lies above three points, i.e., agree and strongly agree on response scale. For example, half of the farmers have favourable (favour and/or strongly favour) attitudes towards conservation agriculture. The standardised dispersion of these latent variables is nearly unity, except for personal efficacy, which is about half. Thus, more positive responses indicate more likely of farmers to adopt conservation agriculture in the future, whereas more negative response, for example, disagrees and strongly disagree shows farmers are less likely to adopt conservation agriculture.

Table 3. 2. Summary statistics of major latent variables for conservation agriculture

Latent variables	Observed statement	Mean	Standard deviation	Latent variables	Observed statement	Mean	Standard deviation
Intentions	6	3.27	0.95	Attitudes	4	3.46	1.06
Perceived usefulness	3	2.73	1.08	Perceived easiness	3	3.30	1.07
Normative issues	5	3.69	0.95	Perceived compatibility	3	2.81	1.03
Perceived control	3	2.87	1.19	Technical training	4	3.35	0.91
Extension service	3	3.22	1.03	Group membership	3	3.78	0.82
Media influence	3	2.67	0.83	Personal efficacy	5	3.38	0.57
Relational capital	5	3.55	0.82	Perceived resource	3	3.21	0.75

[7]. *The KMO measures the adequacy of the sample size to run factor (principal component) analysis and its value between 1.0 and 0.90 is marvellous or superb; 0.90 and 0.80 is meritorious or great; 0.80 and 0.70 is good or middling; 0.70 and 0.60 is mediocre; 0.60 and 0.50 is miserable; and below 0.50 is completely unacceptable* (Kline 2011; Schumacker and Lomax 2010). *For this paper, KMO is about 73% and hence it is good.*

3. 3. 4. Evaluating assumptions of structural equation model

As stated in the literature, a structural equation model (SEM) is sensitive to sample size and type of variables as well as normality, and multicollinearity assumptions. The variables, which are used in the structural model are required to be reliable and valid (Kline 2011; Schumacker and Lomax 2010; Wauters 2010). Consequently, these assumptions or requirements are reviewed and assessed below.

3. 3. 4. 1. Sample size and nature of variables

A large sample size is required to maintain power or to obtain stable parameter estimates. The estimates are unstable and biased for small sample size. As a rule-of-thumb, Schumacker and Lomax suggested 150 as a minimum acceptable sample size (Schumacker and Lomax 2010) while Kline endorsed 15 times the number of parameters to be estimated (Kline 2011). Our sample size for less than 15 estimable parameters is sufficient for individual parameters to be stable and unbiased.

Additionally, variables that are used in a structural equation model, are required to be either continuous or interval scales. Any latent variable is needed to be measured by two or more statements. Furthermore, variables in interval scale form should be graded by at least two-point multiplicative scales (Kline 2011; Schumacker and Lomax 2010; Erwin Wauters 2010).

Following these, the variables in this chapter are in ordered form. However, they can be regarded as interval scale or continuous since they are graded by using a five-point Likert item, for example, from strongly disagree to strongly agree. even originally, these variables have Likert scale forms. In turn, interval scale[8] can be frequently considered as continuous variables. Furthermore, these variables are constructed by at least three observed statements in the dataset. Thus, these points make our variables appropriate to a structural equation model.

3. 3. 4. 2. Normality and multicollinearity assumptions

There are several ways to check for normality assumption. Here Skewness[9] is used to check whether or not the variables are normally distributed. As indicated in Table 3.3, the value of the Skewness for each latent variable does not deviate from the univariate normality assumption. Using the Shapiro-Francia normality test, which is believed as the best statistic test in detecting

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8. *Measurement scales include nominal, ordinal, interval and ratio. In literature, ordinal response scale that has more than three response scale can be considered as interval scale and therefore compute mean and standard deviation. Unless this is not considered as interval scale, it is mathematically only possible to compute percentile and median. Indeed, our variables are measured by five-point response scale and can be viewed as interval scale to compute central tendency and dispersion.*

9. *Skewness is used to check probability distribution of random variable while Pearson correlation coefficient shows whether there is multicollinearity. There is no official rule about cut-off criteria to decide how large skew value must be to indicate non-normality and what value of correlation to indicate multicollinearity because zero skewness and zero correlation practically rarely possible. However, as a general rule of thumb, value of skewness between -1.0 and 1.0 is often acceptable for normality even if highly preferable values between -0.5 and 0.5. There is no correlation statistically between variables if value of correlation coefficient or contingency coefficient lies between -0.09 and 0.09. The variables are highly correlated that indicates presence of multicollinearity if the coefficient lies outside of -0.12 and 0.12* (Kline 2011; Schumacker and Lomax 2010; Greene 2003; Field 2013). *In this study, it is preferred value of skewness between -0.40 and 0.40 for normality, and correlation coefficient between -0.08 and 0.08 for complete absence of multicollinearity.*

deviation from normality among others detectors for all sample size (Mbah and Paothong 2015), it fails to reject the null hypothesis and the variables meet the normality assumption.

Along with these points, the Doornick-Hansen test for multivariate normality (*Chi-square statistic=1.465 and* $P(\chi^2)=0.127$), which is more powerful than univariate normality, does not lead to a rejection of the null hypothesis of normality. In addition, the multivariate central limit theorem confirms this. The variables do not seriously violate the normality assumptions (normally distributed) and are therefore fitted for subsequent estimation and standard inference.

In a similar way, 2-tailed Pearson moment correlation analysis is used to check the presence of multicollinearity between the variables. The result demonstrates that the variables are statistically uncorrelated to one another except for some variables, for example, a strong correlation between technical training and perceived easiness (coefficient =0.11 and $P(\chi^2)=0.05$) and perceived compatibility and perceived resources (coefficient =-0.14 and $P(\chi^2)=0.01$). Relational capital is also found to very weakly correlated with perceived usefulness (coefficient =-0.06 and $P(\chi^2)=0.10$) (See Annexe 3.1). Nevertheless, these variables are kept because they are found not in the same equations (rather cross-equations) and dropping them does not also bring a significant change in the overall performance of the intention model. Furthermore, the large sample size can offset the problem.

3. 3. 4. 3. Evaluating reliability and validity of variables

Both content and statistical methods are used to verify the qualities, such as reliability and validity. As stated above, statements in the survey are adapted from previously validated studies, for example, Venkatesh et al. (2012), Wauters (2010) and Taylor & Todd (1995). The conceptual framework has also a theoretical foundation, which is a decomposed theory of planned behaviour. This theoretical framework is empirically validated in software, new products and technological innovations even if it is scarcely verified in agriculture, natural resource management and overall rural development.

In addition, the language clarity and content of the questions after translating into the local language (Tigrigna) is cross-checked. Furthermore, the questionnaire is pretested by some randomly selected farmers. Based on the feedback or reflections, several questions are removed and improved. Such content assessments are believed to ensure logical flows of the questions and significantly improve the quality of the questions, for example, clarity.

With regard to the statistical method, the average factor loading[10] and average variance extracted are used to test the convergent validity of the observed statements. The coefficients of the average factor loadings for the variables of the study are acceptable (factor loading≥0.60). The average variances extracted for all variables is found exceeding the minimum

[10]. *In factor analysis, factor loading is the degree to which multiple items to measure the same concept in agreement while variance extracted is the overall amount of variance in the indicators accounted for by the latent variables. The Cronbach alpha shows how well a set of indicators measures a single factor (internal consistency or reliability of variables) and a higher value of alpha indicates higher reliability. For factor loading, variance extracted and Cronbach alpha, indicators should use the same metric and have the same response scale otherwise should be reversed. As a rule-of-thumb, the minimum value for alpha, average factor loading and average variance extracted in behavioural research studies is 0.70, 0.60 and 0.50, respectively* (Kline 2011; Schumacker and Lomax 2010; Toma and Mathijs 2007).

recommended criteria (variance extracted≥0.50). The values of the factor loadings and variance extracted for media influence are a bit lower than the other variables (Table 3.3).

The Cronbach alpha (α) is also used to check the reliability or internal consistency of the observed statements, which are loaded into a latent variable. The coefficients of the Cronbach alpha indicate that all these latent variables are found to be higher than the minimum recommended level (α≥0.70). While evaluating the values, perceived compatibility is most reliable whereas extension service is least reliable. Therefore, the remainder variables lie in between these reliability values.

Table 3. 3. Normality, reliability and validity of the latent variables of the study

Variables	Cronbach alpha	Factor loading	Variance extracted	Skewness
Intentions	0.85	0.73	0.66	0.07
Attitudes	0.83	0.79	0.67	-0.32
Normative issues	0.85	0.79	0.72	-0.40
Perceived control	0.86	0.87	0.81	0.19
Perceived usefulness	0.72	0.76	0.63	0.31
Perceived easiness	0.77	0.81	0.74	0.20
Perceived compatibility	0.92	0.75	0.75	-0.30
Media influence	0.74	0.75	0.57	-0.07
Technical training	0.81	0.78	0.68	-0.14
Relational capital	0.81	0.75	0.66	-0.19
Extension service	0.71	0.76	0.59	0.35
Personal efficacy	0.82	0.77	0.62	0.13
Perceived resource	0.78	0.74	0.62	-0.05
Group membership	0.73	0.80	0.72	0.27

3. 3. 4. 4. Model indices and decisions

As indicated in section 3.3.4.1-3, each statement in the questionnaire that corresponds to the derived latent variable has common parts. They are reliable and valid, and hence are acceptable. All statements in each latent variable can adequately be loaded onto a single derived variable using, for example, mean or summated scale method. These are part of the measurement model or confirmatory factor analysis, which shows unmeasured covariance between each possible pair of latent variables, and basically assesses whether the proposed statements or indicators are good indicators for their respective latent variable.

The structural model, which is the set of endogenous and exogenous variables together with the effects connecting them, the correlation among the exogenous variables or statements and the disturbance terms for these variables (Wauters 2010), captures any heterogeneity and endogeneity problem in the model. For example, in the STATA command, like *lmhsem (*overall system heteroscedasticity tests after SEM Regression) in the structural equation modelling help to detect to heterogeneity and *lmnsem* (overall system non-normality tests after SEM Regressions) to detect normality.

Similarly, *mindices or jrule (*detect model misspecifications in SEM) help to detect and readjust for endogeneity misspecification problems. Therefore, the data of the study do not exhibit the problem of non-normality, multicollinearity, and heteroscedasticity. Misspecification is also not a problem. The data are suitable for what we are interested to do for further exploration.

3. 3. 4. 5. The goodness-of-fit and stability of measurement model

The goodness-of-fit is tested and checked to capture the discrepancy between observed values and the values expected under the model hypothetically. This is used to estimate and determine the overall significance of the model fit (Kline 2011) rather than to examine the significance of individual variables (Wauters 2010). Based on the results, it is possible to retain or reject the specified model, and also helps to build the model, which draws remarks and implications.

There are several indices for goodness-of-fit depending on different criteria *(for more see Kline 2011, Schumacker and Lomax 2010; Wauters, 2010; Tutkun, Lehmann and Schmidt, 2006*), for example, see below directly copied from Wauters. The use of different goodness-of-fit indices is generally recommended to test how well the observed data fit the model

- Goodness-of-fit tests based on predicted versus observed covariance (absolute fit indices) - comparison between the observed covariance matrix and the estimated covariance matrix under the assumption that the model is true, such as the model chi-square, the normal chi-square, the Minimum Value of Discrepancy F (FMIN), the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI) the Root Mean Square (RMS) residuals and the Hoelter’s critical N.
- Information theory goodness-of-fit measures -used to compare models, not to be interpreted for a single model, example, the Akaike Information Criterion (AIC), the Bayes Information Criterion (BIC), the Cross Validation Index (CVI) and the Consistent Akaike Information Criterion (CAIC)
- Non-centrality based goodness-of-fit measures- shows chi-square is greater than zero, rather than the hypothesis that chi-square is equal to zero, example, the Non-Centrality Parameter (NCP), the Relative Non-Centrality Index (RNI), or the Centrality Index (CI)
- Goodness-of-fit tests comparing the model with a null or alternative model – compare the proposed model with another model, usually the independence model (assumes that all relationships are zero), such as the Comparative Fit Index (CFI), the Normed Fit Index (NFI), the Non-Normed Fit Index (NNFI) and the Relative Fit Index (RFI)
- Goodness-of-fit measures penalizing for lack of parsimony –indicate the most parsimonious model (the simplest one) as possible but most goodness-of-fit measures will indicate better fit when the model becomes more complex, all other things being equal, examples, the Parsimony Ratio (PRATIO), the Parsimonious Normed Fit Index

(PNFI), the Parsimonious Comparative Fit Index (PCFI) and the Root Mean Square Error of Approximation (RMSEA).

In parallel, the stability index for non-recursive models is computed because the unstable model can cast questions about the validity of the model. It is believed that the recursive models (one-way or unidirectional relationships) are by design stable (Kline 2011). Furthermore, we have checked whether the present model needs a change or improvement in the interdependence of the variables using modification indices or Lagrange multiplier test.

Table 3. 4 indicates most goodness-of-fit indices are within the recommended ranges. Consequently, the observed model is not significantly different from the hypothesised model. The fit of the model indicated in Figure 3.3 is adequate and no need modification. The overall stability index is below unity. This implies that the estimates yield a stable model. The causal relationships between the variables in the structural equation models are statistically significant and the model is, therefore, efficient and stable.

Table 3. 4. Summary statistics for goodness-of-fit and stability indices

Model-fit criteria	Omnibus cut-off point	Values obtained
Normed Chi-square per degree of freedom	<3.00	1.52
Bollen-Stine P-value	> 0.05	0.09
Normed fit index	> 0.90	0.96
Comparative fit index	> 0.90	0.92
Goodness-of-fit index	> 0.90	0.95
Adjusted goodness-of-fit index	> 0.90	0. 89
Root mean square error of approximation	< 0.08	0.03
PCLOSE	>0.05	0.10
Stability index of modulus	< 1.00	0.01

Source (Kline 2011, Schumacker and Lomax 2010, Wauters 2010; Tutkun et al. 2006)

3. 4. Results and discussion

3. 4. 1. Smallholder farmers' attitudes and intentions to conservation agriculture

This section aims to understand and examine the attitudes and intentions of smallholder farmers towards conservation agriculture. As it is indicated above, six statements are loaded into intention while four different statements to attitude. The responses to these statements are graded by a five-point Likert response scale with endpoints, for example, definitely false-definitely true, and more unlikely-more likely (*see detail Annexe 2.2*).

Indeed, these six statements include intend to adopt minimum tillage next year; intend to encourage neighbours to adopt minimum tillage next year; how strong is the farmers' readiness to adopt minimum tillage in the future; whether they are targeting to use less of chemical fertilizer, pesticides, herbicides and insecticides that have adverse environmental impacts; whether they think that minimum tillage would improve farm productivity and yields; and how likely do farmers believe that adoption of minimum tillage will increase farm income.

In a similar way, attitude consists of four different statements, such as use of sustainable agricultural practices on private field plots next year would be a wise idea (very bad-very good); it is important to use sustainable agricultural practices to improve agricultural productivity and yields (very unimportant - very important); sustainable agriculture is effective farming system to improve the fertility and quality of the soils (very disadvantageous - very advantageous); and sustainable agriculture is finally necessary farming system to improve farm income indirectly (very unnecessary - very necessary).

While noticing the average variance extracted (Table 3.3), the average variance extracted for intention is 0.66. This suggests that these six observed statements that are loaded to the intention factor explained about 66% of the available total variance in intention, while the remaining proportion is explained by other statements. Similarly, the corresponding figure for attitude is about 67% of the available variance. This implies that the loaded statements in each latent variable have a shared variance and captured a significant portion of each observed statement.

It has been shown above that, these variables are graded by a five-point response scale, for example, strongly disagree, disagree, uncertain, agree and strongly agree. Since there is no clear way for regrouping categorical variables (see section 2.4.2), we use similarity-based regrouping and farmers are grouped into three levels based on their attitude or intention towards conservation agriculture. These include positive or high that includes agree and strongly agree, neutral or undefined (for those who responded not sure about), and negative or low that includes disagreeing and strongly disagreeing response options.

Figure 3.2 presents smallholder farmers' attitudes and intentions to use conservation agriculture. About 54% of the farmers have positive attitudes towards minimum tillage and the percentage of farmers who have a negative attitude towards this practice is about 7%. The remaining farmers have a neutral attitude towards minimum tillage. The remaining farmers are indifferent. Therefore, most smallholder farmers have positive attitudes towards sustainable agriculture practices, particularly minimum tillage.

With regard to behavioural intentions, as it has been shown in the same figure (Figure 3.2.), about 61% of the farmers in the area have positive intentions to use minimum tillage. About 31% of the farmers have undecided or uncertain intentions while the remaining farmers have negative intentions for the adoption of conservation minimum tillage. Therefore, the number of positive intenders is relatively higher than that of the negative and neutral intenders.

Consistent findings were reported by previous studies. Nearly half of the farmers had positive attitudes towards adoption of sustainable agricultural practices in Italy (Menozzi, Fioravenzi, and Donati 2015); to use improved grassland management practices in Mexico (Martínez-García, Dorward, and Rehman 2013); to use climate information for technological innovations in Iran (Sharifzadeh et al. 2012); and towards implementing environmental practices in rural Haiti (Bayard and Jolly 2007).

In addition to similarity-based regrouping, k-means (non-hierarchical) cluster analysis (sometimes known as partitioning method) is used to classify farmers into three clusters based on their attitudes and intentions towards sustainable agricultural practices. The algorithm is described by assigning each statement to the cluster having the nearest centroid or mean (Field 2013). Following the four statements in attitudes and six statements in intentions, farmers were grouped as positive, uncertain and negative attituders or intenders. Very related results were found as it was reported earlier. The finding based on these two approaches are highly correlated. Therefore, about 55% and 59% of the farmers have positive attitudes and positive intentions towards conservation agriculture, respectively.

Coinciding with this, many farmers in Iran had positive intentions to use improved natural grassland management practices (Yazdanpanah et al. 2014) and to use climate information for adoption of agricultural practices and improved technologies (Sharifzadeh et al. 2012). Many farmers in Italy and Haiti had positive intentions to adopt agricultural practices that had both the environmental and economic benefits (Bayard and Jolly 2007; Menozzi, Fioravenzi, and Donati 2015) and to use improved grassland management practices in Mexico (Martínez-García, Dorward, and Rehman 2013).

The result of Figure 3.2 supports proportion hypothesis (H_1), which suggests half of the farmers in the area under consideration are expected to have positive intentions (and also attitudes) towards conservation tillage even if some farmers have also negative implications. Therefore, it can be concluded that the overall attitudes and intentions of smallholder farmers for conservation agriculture, particularly, minimum tillage seems relatively good.

One-way analysis of variance is also used to understand the social and psychological variables across different intention and attitude levels (Annexe 3.2). Farmers with positive, neutral and negative attitudes recorded statistically significant differences, for example, for perceived easiness, technical training, personal efficacy and group membership. The Tukey post hoc test reveals that the mean of these variables is higher for farmers with positive attitudes than that of farmers with neutral attitudes and negative attitudes.

Along with this, the F- statistic test (one-way ANOVA) also shows that there are significant differences in perceived easiness, normative issues, technical training, relational capital, personal efficacy and group membership among negative, neutral and positive intenders. The mean scores of these variables are relatively higher for positive intenders than others, such as farmers who have negative and neutral intentions.

In the remaining social and psychological variables, smallholder farmers with different attitudes or intentions do not significantly differ in perceived usefulness, perceived compatibility, media influence, extension service and perceived resource. This simple analysis, however, does not enable us to conclude and suggest.

As indicated in Figure 3.2, there are some farmers who have negative or uncertain implications to conservation agriculture. Even if it was not specifically to minimum tillage, there was a dialogue in the focus groups to identify or mention reasons for non-adoption of sustainable agriculture in the area. The participants have mentioned several factors, for example, lack of information (awareness) about the benefits of the practices, preference of farmers to adopt other commonly known agricultural practices, shortage of labour supply to execute the practices, shortage of financial resources and absence of institutional support. We believe that some of these constraints could be served as reasons for unwillingness of smallholder farmers to adopt conservation agriculture.

In general, many smallholder farmers in the area have positive attitudes and intentions towards sustainable agricultural practices, like conservation agriculture. Consequently, the focus of concerned bodies should be given to specific strategies that are expected to enhance awareness of smallholder farmers and also to solve their liquidity constraints because these could help farmers in the areas and encourage them to adopt conservation agriculture.

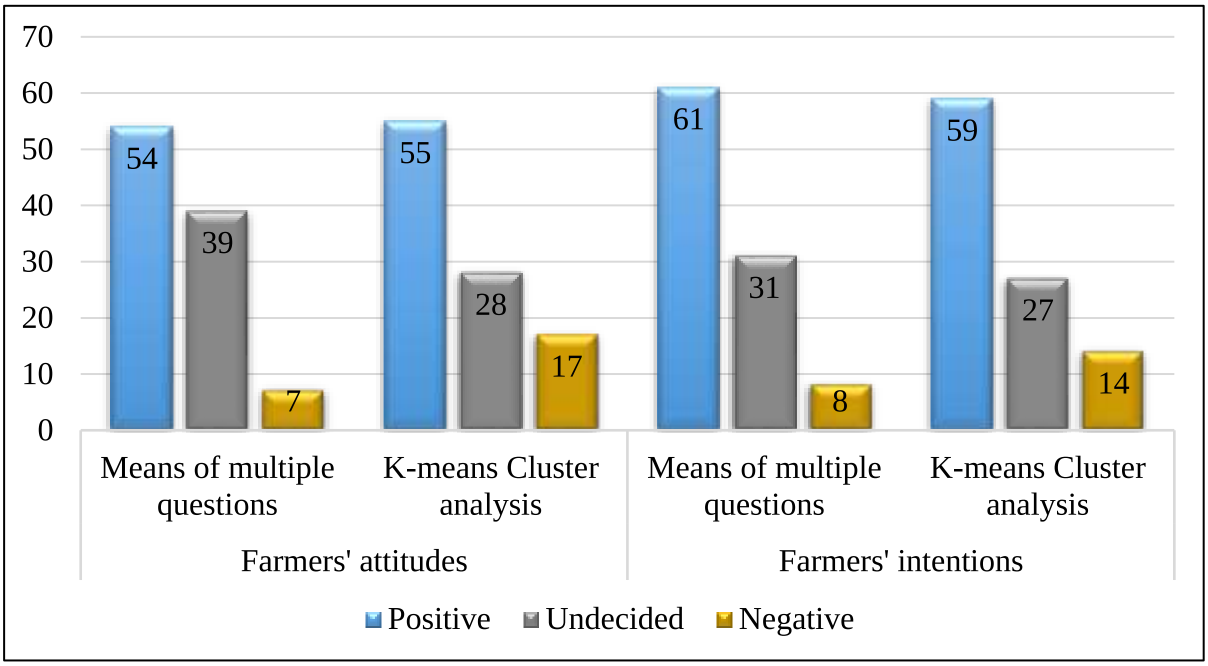

Figure 3. 2. Attitude and intention of farmers toward conservation agriculture (percent)

3. 4. 2. Socio-psychological effects on farmers' behavioural intentions

This section examines factors influencing smallholder farmers' intentions towards minimum tillage using the robust maximum likelihood estimation method of structural equation model. Here, socio-economic and biophysical variables, like age and educational level of the farmers, quality of field plots and rural services are excluded because the principal purpose of the study is to assess and evaluate how socio-psychological factors affect farmer intentions.

In the previous sections, we confirm that the study has no a serious problem of non-normality, multicollinearity, and heteroscedasticity issues. In the structural equation model, the Breusch-Pagan LM test ($\chi^2=0.86$ *and* $P(\chi^2)=0.99$) confirms that the overall system is free from heteroscedasticity. The Jarque-Bera LM test ($\chi^2=0.765 - 3.86$ *and* $P(\chi^2)=0.682 - 0.145$) proves that each equation has the value of this range and shows they are normally distributed.

As it has been shown in the conceptual framework (Figure 3.1), the intention of the farmers is explained by three different variables, namely, attitudes, perceived controls and normative issues. By using the modification index, we tested other equations to explore different kinds of interrelationships or interdependence, example, a direct relationship between personal efficacy and intentions, between social capital and intentions, and between social capital and attitudes.

Following the Lagrangian multiple test, it is found a direct new path from perceived easiness, relational capital and technical training to intentions. This suggests that it is necessary to modify the old conceptual framework (Figure 3.1) based on this result. The best model fit with good performance is what has been indicated in Figure 3. 3 because we could not find significantly a better model than this model. Thus, the practical framework of this chapter is Figure 3.3.

Additionally, this practical or adapted conceptual framework (Figure 3.3) has the lowest the Bayesian information criterion (BIC) and Akaike information criterion (AIC) compared to hypothetical model; the goodness of fit statistics represented the hypothesised model (Price and Leviston 2014). Furthermore, the modification index does not show a reversal direction (opposite directions) from the response (intentions) to explanatory variables. This suggests that there is no, at least, a perverse problem of endogeneity or simultaneity.

The findings of the structural equation model (Figure 3.3) include goodness-of-fit (*see 3.3.4.5*), predictive (explanatory) power[11], path coefficients and their significance. The predictive power of the endogenous equations includes intentions (R^2=0.71 and $P(\chi^2)$=0.008), attitudes ((R^2=0.68 and $P(\chi^2)$=0.038), normative issues (R^2=0.74 and $P(\chi^2)$=0.027), and perceived control (R^2=0.79 and $P(\chi^2)$=0.004). The predictive power and Wald test of these equations (overall models) are statistically significant even if there are many non-significant paths. We have retained them to ensure that the model is not overfitted to the data (Price and Leviston 2014).

With regard to the results of the structural model, these social and psychological drivers are able to predict about 71% of the available variance in intention towards minimum tillage. Attitudes and normative issues are statistically significant predictors that influence intentions of farmers in the area to adopt this practice. However, the perceived control fails to reach a statistical significance.

Farmers who have positive or high attitudes have higher intentions to adopt minimum tillage (by the standardised coefficient of 0.08) compared to other farmers. The normative issues positively and significantly enhance intentions of farmers to the adoption of this practice with a standardised coefficient of 0.10. This suggests that as the values of attitudes and normative issues increase to their optimal values (=5), it is more likely for smallholder farmers in the area to have a higher intention towards conservation agriculture.

The findings support hypothesis H_2, which proposed a significant direct effect of attitudes (H_2A), and normative issues (H_2B) on smallholder farmers' behavioural intentions. However, perceived control fails to support this hypothesis (H_2C), showing perceived control has no significant and direct effects on farmers' intentions. The higher the attitudes towards minimum tillage and the more favourable the normative issues towards this practice as well, the intentions

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[11]. *It is the coefficient of determination (R^2), which is the amount of variance of the models that is explained by the prevailing independent variables or a summary measure of the overall in-sample predictive power of the estimator. As a rule-of-thumb, structural equation with above 0.67, between 0.67 and 0.33, and between 0.33 and 0.19 values of coefficient of determination are respectively considered as models that have substantial, moderate and weak predicating power. However, models with coefficient of determination less than 0.19 is undesirable and unacceptable* (Kline 2011; Schumacker and Lomax 2010).

of the farmers towards conservation agriculture would be more likely and sufficiently larger, which motivates farmers to actual adoption of sustainable agricultural practices.

Essentially, three attributes of agricultural practices, such as perceived easiness, perceived usefulness and perceived compatibility predict attitudes and capture 68% of the available variance in attitudes towards minimum tillage. Perceived usefulness is a significant positive determinant of attitudes, while perceived easiness has a negative effect on attitudes while perceived compatibility does not affect attitudes. When farmers perceived minimum tillage to be useful for them, their standardised attitudes to this practice significantly improved by about 4%. In contrary, if farmers perceived that conservation agriculture is easy to understand and adopt, their attitudes declined by 8 percentage points. This suggests that farmers often prefer to attempt as such not so simple and easy agricultural practices.

Previous studies found mixed results. Consistent results were reported by some previous studies while others unrelated results. It has shown that technologies, which are perceived to be easier to use and are also useful, have a higher probability of acceptance and usage by potential users (Shih and Fang 2004). Also, the perceived difficulty was found to significantly influence intentions towards buffer strips although not towards reduced tillage in Belgium (Wauters 2010). In addition, lack of complexity was amongst the main determinants for adoption of grassed waterways, filter strips, conservation tillage, and cover crops in the United States America (Reimer, Weinkauf, and Prokopy 2012).

Normally, farmers often can easily accept and adopt technologies that are consistent with their existing values, past experience, social traditions, current farming systems and needs. For this fact, perceived compatibility is included in the model. However, it was not significant to affect attitudes of farmers towards minimum tillage (but significant using 3SLS). Based on this result, it is unlikely to conclude whether minimum tillage is related to the existing personal and social traditions. In other countries for example in the US, perceived compatibility was found as a main determining factor of the intended and actual adoption of grassed waterways, filter strips, conservation tillage and cover crops (Reimer, Weinkauf, and Prokopy 2012).

Interestingly, no matter the sign, the characteristics of sustainable agricultural practices are, henceforth, essential factors for smallholder farmers to have positive attitudes towards conservation agriculture. The joint effect of these variables is statistically significant. The direct effect hypothesis (H_2) was supported by perceived usefulness and perceived easiness but failed by perceived compatibility. Significant and direct effects of perceived usefulness and perceived easiness on attitudes were found (H_2D) but not perceived compatibility on attitudes. Therefore, attributes of agricultural practices need more attention to positively contribute to intentions.

The normative issue is another factor in the intention model. This variable is explained by media influence, extension service, technical training, relational capital and group membership. The available variance in it that captured by these variables is about 74%. Technical training and social capital (relational capital and group membership) have significant positive effects on normative issues. Farmers have favourable standardized normative issues when they have received capacity building training, they have strong social ties and relations with local community groups, and when they are members of formal organizations, such as resource users' groups, farmers' associations, and cooperative societies.

In literature, a similar finding was reported in Switzerland in a way that communication through diverse information channels was found to positively influence the intention of farmers to convert from conventional farming to organic farming (Tutkun, Lehmann, and Schmidt 2006). In a similar way, Georgian farmers who exhibited higher levels of social capital had higher intentions to adopt agricultural practices more often than those who exhibited lower levels of social capital (Jordan 2005).

Agricultural extension service is hypothesised to positively influence normative issues because the agricultural advisory services build positive and favourable normative beliefs (Opara 2008). However, it has an insignificant effect on normative issues. Farmers who have frequently acquired information and guidance from agricultural experts and extension workers have no substantial effects and are unlikely to affect their intentions to adopt conservation agriculture. The same also holds true for mass media. This might be due to a limited accessibility (coverage) to television or radio, while the former might be due to lack of confidence on the competence of extension workers (as stated in chapter two).

The direct effect hypothesis (H_2E) is partially supported. A significant and direct path is found from group membership, relational capital and technical training to normative issues. However, there is no significant and direct relationships between normative issues and media influence, as well as normative issue and extension services. Therefore, the relevance of mass media and extension agents seems questionable unless otherwise the result is influenced by the affordability of television and radio, as well as competence of extension agents.

In concurrent, perceived control that shows the influence of internal and external forces is explained by personal efficacy and perceived resources. Those variables are able to predict 79% of the available total variance in the perceived control. The path from perceived resources to perceived control is negative and statistically significant. This indicates that the presence of barriers, for example, bureaucratically problem, shortage of family labour and lack of money might retard the adoption of conservation agriculture.

The finding coincides with other previous studies. Technology and per capita resources were found to highly affect people's perception of the benefit of good environmental quality (Bayard and Jolly 2007). The availability of financial resources along with the perceived advantage of the practices, such as economic and environmental benefit, was found as the main determinant factor for farmers to have positive intentions and to the adoption of grassed waterways, filter strips, conservation tillage and cover crops in the US (Reimer, Weinkauf, and Prokopy 2012).

Personal efficacy, which is a farmer's self-judgment of his capabilities, knowledge and skills to accomplish minimum tillage, is expected to positively affect the behavioural perceived control. But it is found that it does not have a significant impact. This means that smallholder farmers who have satisfactory competence are indifferent to farmers who lack knowledge and competence. The competence of farmers is unknown whether it can affect perceived control of farmers towards conservation agriculture. Hence, based on these results, a perceived resource supported direct effect hypothesis (H_2F) but personal efficacy failed to support this hypothesis.

As per the newly established conceptual framework through Lagrangian multiplier test (Figure 3.3), perceived easiness, technical training and relational capital are found to significantly influence behavioural intentions. The standardised effect of technical training and relational capital on smallholder farmers' intentions is positive and about 25% and 12%, respectively. The intention of farmers to use conservation agriculture tends to decline if it is perceived easy to understand, learn and adopt, and if farmers do not receive capacity building training nor attending agricultural field days. The intended behaviour towards conservation agriculture is most influenced by technical training because it has the highest loading estimate than others.

In line with the direct effect, the structural model substantiates an indirect effect of different exogenous variables on farmers' intentions (indirect effect hypothesis H_3). The idea is that the variables that have positive and indirect effects can improve the predictive power of the behavioural intentions. For example, perceived usefulness, group membership and personal efficacy have significant and indirect positive effects while it is found technical training to have an indirect negative effect on smallholder farmers' intentions.

Hypothesis H_3 is validated and confirmed by the results of the indirect effects. It is partially supported. For example, attitudes mediate a positive effect of perceived usefulness on smallholder farmers' intentions towards conservation agriculture (H_3A). Nonetheless, it fails to support perceived compatibility. In addition, an indirect significant effect of perceived easiness to intentions could not find to establish.

Similarly, H_3B is partly supported, where normative issues mediate significant and indirect effects of group membership and technical training on intentions. However, it fails to support the mediation of media influence, relational capital, and extension services to intentions. Because media influence, relational capital and extension service do not have significant and indirect effects on behavioural intentions.

With regards to H_3C, it is supported partly as well. Perceived control mediates a significant and indirect positive effect of personal efficacy on behavioural intentions. Even if an indirect effect of perceived resources on intentions through the mediation of perceived control hypothesized, there was no significant and indirect impact on intention. Therefore, perceived control failed to mediate perceived resources and intentions.

The direct and indirect effect hypotheses give lessons that some socio-psychological variables can better explain intentions directly and indirectly than others, which are mainly insignificant. In addition, technical training has a positive direct effect on intentions (coefficient=0.25) but it has also a negative indirect effect on intentions (coefficient=-0.005) so that the net effect seems positive. Furthermore, perceived usefulness, which indicates perceptions of farmers whether the practices have the potential to improve performance, such as yields, returns and fertility, has indirect and positive impacts on intentions and then financial return, therefore, seems to have indirect implication to introduce minimum tillage.

In parallel, the results of the three-stage least square regression (Annexe 3.3), which captures correlation of random disturbances across equations, also confirm mostly the findings of the structural equation model. As indicated in Annexe 3.3, both models generated consistent and very similar results. Unlike in the structural model, the results of the 3SLS show that perceived compatibility negatively influence attitudes as well as personal efficacy has a significant positive effect on perceived control. Therefore, conservation agriculture is perceived to violate the existing traditions and norms, and the knowledge and skills of farmers significantly matter to the adoption of conservation agriculture, specifically minimum tillage. However, this might be due to lack of awareness of minimum tillage since it is newly introduced.

Having the results of both estimation models, capacity building training and social capital can help farmers to enhance their awareness and understanding of sustainable agricultural practices. Formal and informal institutions should be strengthened to organise frequent capacity building sessions and agricultural field day visits to inspire smallholder farmers to adopt sustainable farming practices. However, the availability of different sources of information, such as radio, television and extension agents are less likely to build positive attitudes and intentions.

The worthy point is that findings of both models indicate that the target variables (socio-psychological) factors, such as relational capital, formal organisations, attributes of sustainable agricultural practices, perceived resource conditions and personal competence jointly explain smallholder farmers' intentions, even if not all these variables are statistically significant. They are important factors that positively intend farmers to adopt sustainable agricultural practices.

In general, those impacts, especially through social capital and personal efficacy, would be high if they are complemented with necessary resources condition and infrastructural facilities. Thus, information heterogeneity, attitudes, relational capital and formal organisations do have great impacts on smallholder farmers' behavioural intentions and decision-making process related to the adoption of sustainable agricultural practices, particularly conservation agriculture.

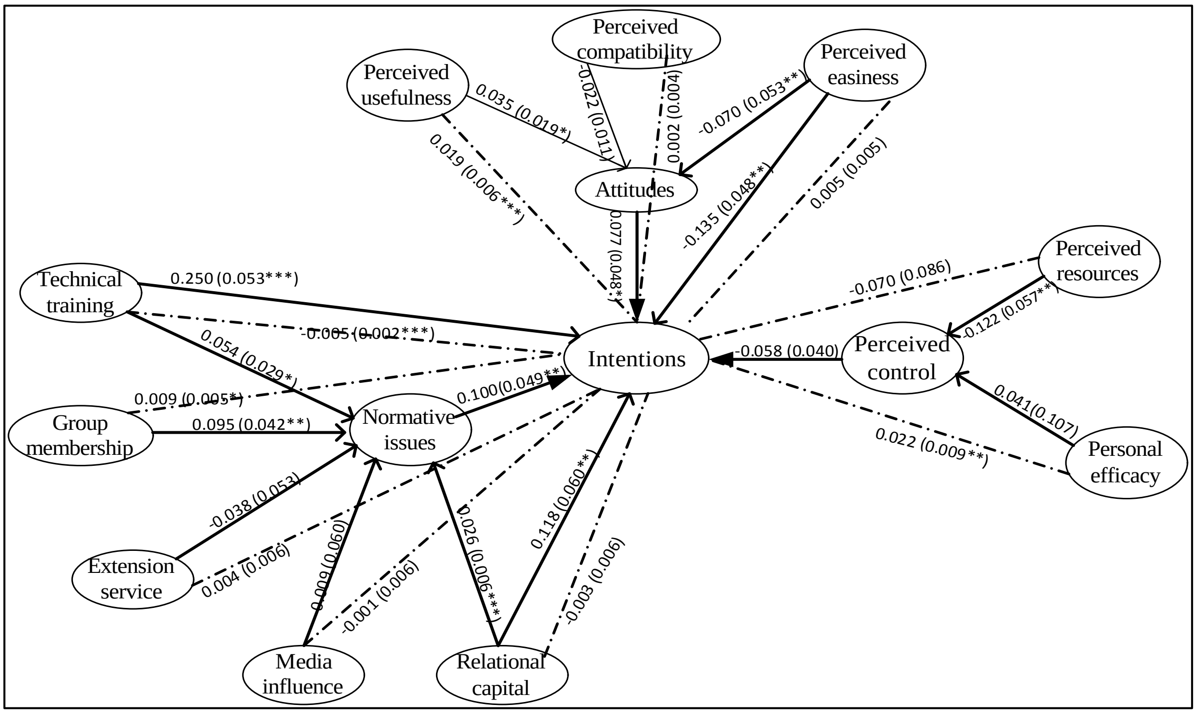

Figure 3. 3. *Standardised coefficients of explanatory variables for conservation agriculture: minimum tillage system (solid line shows direct effect while the broken line indicates indirect effect. *, ** and *** shows statistically significant at 10%, 5% and 1% levels, respectively)*

3. 5. Conclusion and implications

This study examines how socio-psychological factors affect smallholder farmers' behavioural intentions to adopt conservation agriculture in Ethiopia. The decomposed theory of planned behaviour is used as a theoretical basis, and cross-sectional data is analysed by a linear structural equation model in complement with three-stage least squares regression. The findings reveal that more than half of the local farmers have positive (high) attitudes and intentions towards conservation agriculture, particularly minimum tillage.

The finding also indicates that positive attitudes and favourable normative issues are found to lead to stronger intentions to perform conservation agriculture. The greater the attitudes and the more favourable the normative issue, the stronger is the smallholder farmers' intentions to adopt minimum tillage. Besides, an intention is formed if farmers have obtained capacity building training and participated in agricultural field days, if local community groups who are important for the farmers have good views on minimum tillage and motivate the farmers to adopt, and if conservation agriculture is perceived not easy to implement.

Capacity building, informal institutions and formal organisations are the main drivers for normative issues, while perceived usefulness and perceived easiness are attitude drivers. Mass media influence and agricultural extension services do not have both direct and indirect significant impacts on intentions to adopt conservation agriculture, especially minimum tillage.

In addition to a combination use of structural equation model and three-stage least squares, the novelty of this study is the way of disaggregating these socio-psychological issues, especially the normative issue, which is naturally an active and catalysts throughout the stage of adoption of sustainable agriculture, such as knowledge, persuasion, decision, implementation and confirmation (Rogers 2003).

The implication of the findings is that the attributes of agricultural practices, informal relationships and interactions between local community groups, and formal organizations are essential factors for smallholder farmers to have positive attitudes and intentions towards sustainable agriculture. The availability of economic resources and rural facilities can also constrain adoption decisions. Therefore, the focus should be given to enhance understanding of smallholder farmers on the benefits of sustainable agriculture, empower informal institutions and strengthen formal organizations to improve adoption and widespread of sustainable agriculture in the country.

Chapter Four
Implications of socio-psychological issues for risk attitudes of smallholder farmers

Abstract

Because of scarce literature on how socio-psychological factors affect smallholder farmers' attitudes towards risk, the paper investigates the role of socio-psychological issues in smallholder farmers' risk attitudes. This study utilises data from a cross-sectional household survey and analyses it by using an ordered logistic regression complement with the generalized ordered logit model. The findings show that the main sources of risk and worries in the area under consideration include natural hazards, input and output price volatility, technological risks, financial shocks and human security including personal health issues. About 45% of smallholder farmers are less risk averse, while about 30% are more risk averse and the remaining are risk indifferent. Furthermore, education, relational capital, attitudes, group membership, technical training and household size are found to be the main significant and influential factors in smallholder farmers' risk attitudes. Farmers who can read and write, who have strong social capital and who have received capacity building training are, at the least, less risk averse. Finally, this study confirms the importance of positive attitudes, strong social capital (group membership and relational capital) and satisfactory competence to reduce uncertainty and motivate farmers to take risks related to technologies and others. Therefore, attention should be given to specific initiatives to enhance their awareness, build their adaptive capacities, provide timely information, and improve their skills and knowledge. These would help to revert the risk aversion of smallholder farmers, who are usually thought to be risk averse in low-income economies, and to stimulate them to adopt sustainable agriculture and technologies, which are expected to improve agricultural productivity and enhance the resilient capacity of local systems and rural communities.

Keywords: *Attitude, information, social capital, risk attitudes, (generalized) ordered logit*

This chapter is compiled from

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4. 1. Introduction

Agriculture in less developed countries carries more risk than non-agricultural sectors (Mosley and Verschoor 2005). This is because it is highly sensitive to unpredictable natural factors (Todaro and Smith 2011; Akcaoz and Ozkan 2005) and it often faces shocks, such as crop failure, lack of rainfall, human illness and price fluctuations (Brauw and Eozenou 2011; Haile 2007). An unfavourable environment and frequent drought are also challenges faced by this sector (Ward and Singh 2014). As stated in chapter one, compared to developed countries, less developed countries have limited financial and institutional capacities to adapt to shocks.

Accordingly, these adverse impacts affect not only the livelihoods of rural people but also the whole economy in these countries, including the non-agricultural sectors. For example, it has been reported that natural disasters that adversely affect agriculture have led to losses of about 13% of the gross domestic product in Cameroon (Balgah and Buchenrieder 2011). Several risks, especially natural disasters and financial shocks, were also found to deplete household assets (Pandey and Bhandari 2009) and resulted in livestock deaths and reductions in yields, income and assets (Ağir et al. 2015; Van Winsen et al. 2011; Berg, Fort, and Burger 2009; Haile 2007).

This suggests that risks and uncertainties negatively affect farmers' production decisions. Farmers make decisions in an environment full of complexities and with factors beyond their control (Bandiera and Rasul 2006). The decisions of producers in Canada and Ethiopia relating to the adoption of technologies are overshadowed by risks. However, the risks could be different with different adaptations (Haile 2007; Yu, Hailu, and Cao 2014) but they have also prevented farmers from investing in improved technologies and improved farming practices that have the potential to enhance productivity and yields (Liu 2013; Ward and Singh 2014).

In the literature, such adverse impacts on livelihoods and farmers' unwillingness to invest in technological innovations are often connected to lack of information (or market imperfections) and resource constraints (Haile 2007), because uncertainties and worries are often sourced from lack of information or knowledge, while risks result from uncertain consequences (Hardaker et al. 2015). Information asymmetry has been a serious threat to economic growth and overall development (Balgah and Buchenrieder 2011). In addition, imperfect knowledge has made individuals reluctant to use new technologies (Yu, Hailu, and Cao 2014). Furthermore, relevant information was also found to build positive attitudes and reduce uncertainties about technological innovations (Wauters et al. 2014; Van Winsen et al. 2011; Haile 2007; Marra, Pannell, and Abadi Ghadim 2003).

The implication is that smallholder farmers are reluctant to adopt or invest in improved technologies and sustainable agriculture because of the risks and uncertainties, which are sometimes associated with a failure in the provision of sufficient information. However, when they obtain adequate information through different sources, such as television, radio, formal associations, extension agents, families and neighbours, they are more likely to invest economic resources, such as time, labour and money in improved agricultural practices and technological innovations, although this may not work for those who do not have an information problem.

Empirically, for example, a positive effect of information on risks and adoption is evidenced in the literature. Self-learning allowed farmers to make better decisions about new technologies and improved their implementation ability (Marra, Pannell, and Abadi Ghadim 2003). In Tanzania, access to information helped Tanzanian farmers to adopt agroforestry systems (Hillbur 2014). A positive effect was also reported for social interaction on Canadian farmers' risk attitudes towards adopting genotyping in dairy production (Yu, Hailu, and Cao 2014). In addition, extension services had a significant effect on motivating farmers to adopt chemical fertiliser, improved varieties, and soil and water conservation practices (Yu et al. 2011).

Apparently, the existing studies on information, risks and adoption are limited (Sakib, Afrad, and Ali 2015; Wauters et al. 2014; Wuepper et al. 2014; Schwartz et al. 2013; Huffman et al. 2007), especially those studies that address how different sources of information affect decisions under risk conditions. For example, some have focused on television (radio) while others have used extension services separately. Such an approach is insufficient to take into account information effects on risks or adoption. Use of alternative information sources simultaneously, such as television, radio and extension services can show which source has the highest impact and is most effective in reducing risk aversion and advancing the adoption of sustainable agriculture. Therefore, more studies are needed to understand which alternative information sources need to be prioritized.

Additionally, the results of the existing studies vary spatially. The perceptions of farmers towards risks, for example, drought, crop failure, climate change and other shocks, are also variable across location. The same holds true for ways of responding to, and handling, potential risks. Van Winsen (2014), explained that risk averse farmers tend to deal with risks reactively (ex-post curative measures) while farmers who are more willing to take risks will adopt a pro-active approach towards risk (ex-ante risk management). Furthermore, in economies dominated by mixed farming, risk is an important factor. Both crop production and animal husbandry are highly susceptible to various risks (related to shocks, disasters, uncertainties and hazards). Understanding the major sources of risk is pertinent to enhance farmers' awareness and to encourage them to choose the right risk management strategies[1] (reactive and proactive) to deal with risks. Therefore, specific studies are still important to better understand how farmers react to risks and how they protect themselves against risks.

In parallel, the presence of formal organizations, relationships with local community groups, and the specific knowledge and skills of farmers are essential inputs in the production decision system under risk and uncertainty. They can help farmers to scan the internal and external environment in which they are operating to gain better knowledge and awareness, to prepare a strategic plan in advance (e.g., risk mitigation strategies) and to easily evaluate the performance of improved sustainable agriculture. These are opportunities for farmers. However, the impact of these variables on farm households' risk attitudes remains under-researched.

As stated in the literature, the attitudes of farm households towards risk have a significant effect on the propensity to implement any risk management strategies, even if the risk management

[1]. *Reactive risk strategies refer to crisis management, or firefighting, when event has happened, whereas a proactive risk management strategy represents preparation in advance to avoid the occurrence of the risk or minimize severe outcomes. In other classifications, a risk reduction strategy is a measure to reduce the probability of adverse impacts by using, for example, technology; risk mitigation is a measure that allows the risk to happen but reduces its impact, for example, off-farm income, insurance and diversification; and risk coping is to restore the damage after it has happened, for example, reducing expenses, and selling assets* (Frankwin Van Winsen 2014). *These are like adaptation (response to challenge) and orientation (thinking about new systems).*

strategy is found to be unaffected by the perception of farmers towards risk (Van Winsen 2014). This suggests that adaptations for risk management are guided by the type of risks faced and by the attitude towards those risks. Moreover, farm household's choice of different risk management strategies is complex and varies significantly between individuals (Holzmann, Sherburne-Benz, & Tesliuc, 2003). Therefore, understanding the determinant factors of risk attitudes would help local people to handle and respond to shocks and hazards.

Therefore, this paper has two objectives. Primarily, it assesses the past and current risk behaviour of smallholder farmers, which helps in understanding the attitudes of farmers towards risks and uncertainties. Subsequently, the paper examines the roles of those socio-psychological factors, such as attitudes, social capital and information in predicting self-reported risk attitudes (SRRA) of smallholder farmers. However, this does not mean that the socio-economic and institutional variables are overlooked. They are included as control variables, because the main intention of the chapter is to see how these socio-psychological variables affect risk attitudes.

Accordingly, the objectives help to address two research questions: what is the general attitude of farmers towards risks? What factors affect the risk attitudes of smallholder farmers? While addressing these questions, other concerned bodies (for example development actors) can obtain empirical information to craft different ex-ante and ex-post risk management targets and strategies to deal with the risk of shocks, uncertainties and worries. Therefore, the findings of this chapter may have policy relevance and contribute to existing literature from wider contexts.

This chapter is organised into five sections. Section two reviews the concepts and measurement of risk behaviour, including explaining and estimating the model. Section three indicates how risk-related variables and other socio-psychological variables are measured and constructed. The major findings are presented and discussed in section four, while the final section provides concluding remarks and identifies policy implications.

4. 2. Review of literature

4. 2. 1. Conceptions of risks and uncertainty

Risk and uncertainty are important factors for individuals. They often face countless risks in their everyday lives and economic activities (Addey 2018). The words risk and uncertainty were used interchangeably until the 20th century. In the early 1920s, Knight differentiated risk from uncertainty by introducing the concept of risk in decision-making as dimensions of subjective uncertainty and its consequences (Knight 1921). After the 1960s, risk has been used extensively in several disciplines, such as economics, finance, marketing, health, agriculture, and other decision sciences (Hillbur 2014; Bohm and Harris 2010; Legesse and Drake 2005).

Apparently, risk is a combination of the probability of an uncertain event happening and the incidental impact. It increases when the probability increases, the magnitude of the impact increases or both increase (Van Winsen 2014). Hardaker et al. (2015) identified uncertainty as imperfect knowledge and risk as uncertain consequences. Risk is also defined as the probability of occurrence of a negative outcome or event, such as injury, damage, loss of wealth, deterioration in health and loss of field crops (Addey 2018). This shows that both are defined by a state of mind for a specific action, where the potential outcome is unknown and unquantifiable for uncertainty, whereas for risk it is known and measurable based on different probabilities. Thus, uncertainty is a necessity for risk but does not always lead to risk.

As stated in the literature, risks can be grouped into different types: idiosyncratic and covariant or systematic and non-systematic. Risk is idiosyncratic if it is uncorrelated and affects a specific person, for example, illness, disability, unemployment and death. Conversely, it is covariant if it is frequently correlated across sectors and affects more people, such as drought, war, inflation and epidemics (Holzmann, Sherburne-Benz, & Tesliuc, 2003). In addition, risk is systematic if the event is repeated in a pattern of probabilities over time, while non-systematic risk is recognized by imperfect records of occurrence and where no pattern can be identified in the distribution of the outcomes (Bezabih and Sarr 2013; Crosetto and Filippin 2013; Van Winsen et al. 2016).

With regards to the epistemological foundation of risk, there are two views: constructivists argued that risk or uncertainty does not objectively exist and cannot be objectively measured if there is perfect information (Sjöberg, Moen, and Rundmo 2004). The realist perspective stated that risk is a real event and a real threat, and is objectively measurable as a multiplication of the probability of the risk event happening and the impact of the risk or the potential unwanted consequences (Zinn 2008). Therefore, risks are not universally uniform (Bishu 2014; Holzmann, Sherburne-Benz, and Tesliuc 2003; Addey 2018).

Indeed risks can vary between individuals, over time and across locations and so do risk attitudes and risk management, especially across different economic groups (Bishu 2014; Holzmann, Sherburne-Benz, and Tesliuc 2003; Addey 2018; Van Winsen 2014). While attitude is the choice of response process to a situation, risk attitude[2] is a chosen state of mind with regard to the uncertainty about a specific action that could have a negative effect on a specific objective, for example, fertility and yields. Risk attitude is sometimes known as risk preference, risk aversion or risk propensity, and varies across different economic groups, such as consumers or producers (Hillbur 2014; Bohm and Harris 2010; Haile 2007).

Empirically, various studies have identified different determinant factors for risk attitudes. Risk aversion was found to be insignificantly correlated with age, gender, education and income, but significantly correlated with perceived vulnerability and physical assets (Mosley and Verschoor 2005). In Haile (2007), neither age nor the household size and education influence farmers' risk behaviour even if the value of livestock and rainfall significantly correlated with risk aversion. It has been reported that farmers who were wealthier were more willing to take risks than poorer farmers (Yesuf and Bluffstone 2009). Education, per capita expenditure, media influence and label information were found to be highly determinant of risk preference and risk perception (Brauw and Eozenou 2011; Angulo and Gil 2007). Farmers' perceived risk attitude index was determined by income, education, cattle size, livestock package and zero-grazing (Bishu 2014).

[2]. *Risk behaviour is the process of how to react or act in relation to uncertain events, including identifying the shock or hazard (event), evaluating and sensing (perceived risk), deciding (risk attitudes) and taking risk measures. Risk attitude is personal orientation towards taking or avoiding risks, while perceived risk is the level of uncertainty regarding the outcome of the events and is calculated by multiplying the perceived probability of the event happening (unlikely-likely) and the impact of the different risk sources (small to large impact). Risk attitude is found to positively or negatively determine the intended or stated risk behavior, which is expressed by the implementation of risk reducing or management strategies, but not perceived* (Frankwin Van Winsen 2014)

4. 2. 2. Elicitation methods for risk attitudes

The concept of risk attitude is different in economic and psychological literature. In economic literature, risk attitude is defined based on the expected utility framework, which rests on the assumption of diminishing utility (see section 1.5.2). It can be measured as the curvature of the utility function - to what extent an increase in value is considered an equal increase in utility. It is regarded as stable over time, different domains and contexts (Dohmen et al. 2011).

However, in psychological literature, risk attitude is assumed to differ over domains and time because decisions makers can simultaneously be risk seeking and risk averse in different domains. Therefore, risk attitude is a personal orientation towards taking or avoiding risk, which is persistent and stable but evolves over time (Hansson and Lagerkvist 2012).

In traditional economic literature (expected utility theory), risks are assumed to be well-defined, independent, quantifiable, comparable and static (rational decision possible). In reality, however, they are interdependent, interlinked, limited in their rationality and dynamic (bounded rationality theory). Accordingly, farmers' orientation towards risk varies because the subjective interpretation of the risks differs (Van Winsen 2014). Farmers' decisions under risk and uncertainty involve a combination of multiple factors that are bounded to uncertain outcomes with different probabilities (see section 1.5.2).

Bearing this in mind, there are many approaches that have frequently been applied to explain and measure the risk attitudes of individual actors, for example, ordered lottery selection (Eckel and Grossman), multiple price list or lottery test (Holt and Laury), the investment Game of Charness, Gneezy and Potters (CGP), the Balloon Analogue risk task (Balloon), the Bomb Risk Elicitation Task (BRET), and the questionnaire method (DOSPERT and SOEP) (Addey 2018; Crosetto and Filippin 2013; Dohmen et al. 2011). Depending on the data used, these different elicitation methods are often summarized into survey approaches and experimental approaches[3] (Hillbur 2014; Bohm and Harris 2010; Ding, Hartog, and Sun 2010).

In an experimental approach, actual data and hypothetical data are used more frequently. In economics, this approach is based on an expected utility framework with an assumption for the constant relative risk-utility function. Von Neumann and Morgenstern, and choice experiments are some examples of certainty equivalence techniques. Under the psychometric approach, risk attitude is based on a subjective response to either general or specific indicators. There are often two methods: self-elucidation general (direct) method, and domain specific-context method[4]. This was commonly applied in sociology, psychology and social studies, while it has been applied more recently in economics, agriculture, health, managerial science, consumer studies and other behavioural studies (Weber, Blais, and Betz 2002; Weber and Milliman 1997).

In the empirical literature, there are several studies that have used an experimental approach to explore the risk behaviours of economic agents, such as producers and consumers, for example,

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[3]*As indicated, these are from economic and psychological paradigms so that the survey approach is sometimes known as a psychometric, self-assessment, qualitative or normative approach, while the experiment approach is named as an objective, quantitative or positive approach.*

[4]*. Self-elucidation general and direct question method refers to the use of a single question to indicate to what extent farmers, or other decision makers, are willing to take risks, whereas the domain specific-context method is a series of multiple specific questions in which farmers are required to indicate to what extent they agreed with statements about their risk taking behaviours.*

Lönnqvist et al. (2014), Balgah & Buchenrieder (2011), Brauw & Eozenou (2011), Haile (2007) and Binswanger (1981). In a similar way, some studies that have used a psychometric approach to understanding and measuring the risk behaviour of economic agents include Angulo & Gil (2007), Binder et al. (2012), Ağir et al. (2015) and Alam & Wolff (2016). Some studies have also used both approaches jointly, for example, Bishu (2014) and Bourque et al. (2012). Those studies have found that some economic agents enjoyed risks relating to technological innovations or new products while some did not. Others also did not care whether the activities were safe or risky. Therefore, they grouped economic agents into three types based on their attitudes towards risk, namely, risk averse, risk neutral and risk seekers.

4. 2. 3. Model explanation and estimation

Farmers can adopt technological innovations to maximize expected utility, such as yields, profits, costs, losses and risks (Kabunga, Dubois, and Qaim 2012). An individual farmer compares the expected utility from adopting the technology $(U_i^1(\Pi))$ and from non-adopting $(U_i^0(\Pi))$ and decides to adopt it if the net expected utility exceeds zero $(U_i^1(\Pi) > U_i^0(\Pi))$ otherwise not $(U_i^1(\pi) \leq U_i^0(\Pi))$. Accordingly, the expected utility function that shows the farmer's choices between risky or uncertain prospects is given mathematically by:

$$U(.) = MaxU(\Pi) \quad (4.1)$$

Where the expected utility $U(.)$ depends on a vector of constraints (Π), such as resources, wealth and people-specific characteristics, and its shapes vary (convex or concave), because some people may be risk seeking for some prospects while being risk averse for others (Bohm and Harris 2010). The problem here is that expected utility is unobservable while the choice of farmers towards risky events is observable. The unobserved factor can be derived from the observed factors. The normal equation for the choice of farmers towards risks is given by:

$$RA_i^* = \beta X_i + e_i \quad (4.2)$$

Where RA is an observed response variable for farmers' risk attitudes while RA^* is a latent variable of risk attitudes, which depends on a vector of explanatory variables (X_i) and a random error term (e_i). The error term is expected to capture unobserved bias and measurement errors, which are not visible to the researchers but still known to the farmers.

A five-point ordinal Likert scale is used for the responses to the risk-related statements (*see section 4.3*). Therefore, the response to a statement has a meaningful sequential order. After reversing the responses (see section 2.4.2 if any), the highest value indicates the highest willingness or readiness of the farmers to choose and accept risks. This latent variable is, hence, constructed from the multiple observed statements or events with several ordered response categories as follows:

$$\begin{aligned} RA_{ij} &= 1 \quad if\ RA_i^* < k_1 \\ &= 2 \quad if\ k_1 \leq RA_i^* < k_2 \\ &\\ &= j-1 \quad if\ RA_i^* > k_{j-1} \end{aligned} \quad (4.3)$$

Where $RA_{ij} = K\ if \quad u_{k-1} < RA_{ij}^{*} \le u_k;\ for \quad k = 1, 2, ..., j$ and u_k is multiple threshold parameters or cut-points normalised as $u_0 = -\propto; u = 0\ \&\ u_j = \propto$. Following this, risk attitude, which is an ordered variable and constructed from observed statements, is modelled and estimated by the ordered logistic regression method as follows:

$$P(RA > j) = \beta X_{ij} + e_{ij} = \frac{\exp(\alpha_i + X_{ij}\beta_i)}{1 + \exp(\alpha_i + X_{ij}\beta_i)}; j = 1,2,...,k-1 \qquad (4.4)$$

Where RA_{ij} represents the probability that an individual farmer $'i'$ chooses $'j'$ observed ordinal options, for example, one of the five response options for risky questions. Accordingly, the probability likelihood function of each ordinal option of risk attitude is expressed by Eq.4.5, where F(.) corresponds to the cumulative standard logistic distribution function.

$$P(RA_{ij} = k) = P(u_{k-1} < RA_{ij} \le u_k) = F(u_k - X_{ij}\beta) - F(u_{k-1} - X_{ij}\beta) \qquad (4.5)$$

Given this milieu, the ordered logit model, which has the ability to obtain predicted probabilities, is restricted to the parallel lines assumption. It explains that parameters should not change for different categories. This means that parameter estimations do not change for cut-off points (Greene 2003). To make this clear, equation (4.5) is disaggregated as follows:

$$P(RA_{ij} = 1/X) = F(u_k - X_{ij}\beta)\ for \quad k = 1$$

$$P(RA_{ij} = k/X) = F(u_k - X_{ij}\beta) - F(u_{k-1} - X_{ij}\beta)\ for \quad k = 2,...,k = J-1$$

$$P(RA_{ij} = J/X) = 1 - F(u_{k-1} - X_{ij}\beta)\ for \quad k = J$$

Therefore, the cumulative probabilities are given mathematically by:

$$P(RA_{ij} \le k/X) = F(u_k - X_{ij}\beta)\ for \quad k = 1,...,k = J-1 \qquad (4.6)$$

In equation (4.6), the intercept is zero. For each probability, the curve differs only in being shifted to the left or right. They are parallel as a consequence of the assumption that it is equal to each equation. $\beta's$ are allowed to differ across the equations. The parallel regression assumption implies $\beta_1 = \beta_2 = ... = \beta_{J-1}$ and therefore the degree that the parallel regression assumption holds, the coefficient $\beta_1,\ \beta_2, \dots \beta_{J-1}$ should be close (Greene 2003).

However, the assumption may be violated. For example, as indicated in the literature, some continuous variables in a set of mixed variables may be likely to result in a higher proportion of empty cells, which are more likely to lead to violation of the assumption. A relatively large number of variables may also have a slight probability of violating the assumption (Brant 1990).

In case of violation of the assumption, the ordered logit model is needed to complement the generalised ordered logit model. This is not only less restrictive for the parallel lines assumption but also produces more parsimonious results than the ordered model. It also allows interaction terms and cross-population comparison effects if necessary (Williams 2006).

Additionally, the results may have heteroskedastic errors, which show apparent differences in the outcome effects. For example, levels of risk attitudes may be an artefact of differences in residual variability. Although it is known that the robust (bootstrap) standard error estimation can correct for heteroscedasticity, it is safer to also supplement the ordered logit model with a heteroscedastic ordered model[5] to correct unobserved heteroscedasticity or to account for scale differences (response errors) for some variables (Williams 2010).

Therefore, the use of these models can help us to evaluate the results because they are used when the response variable is ordered and when it is aimed to predict the probabilities of choosing each category of the response variable. However, they are quite different in handling assumptions and residual variabilities. Since the generalised ordered and heterogeneous choice models may have downsides, it is necessary to consider these models simultaneously and in parallel. Additionally, caution is needed in model specifications and interpretation of the results, especially where there are contradictory results between the models (Greene 2003; Williams 2006).

Finally, the coefficients in Eq. 4.4 are used to interpret the direction (or signs) and significant effects to determine whether the dependent variable increases (or decreases) with the explanatory variables. However, they do not reveal the size of the coefficients or the impacts on the probability or magnitude effects. The marginal effect indicates by how many units or by what percentage the response variable changes as a result of a unit change in an explanatory variable, while other explanatory variables are held at their mean (proportional value) and this is given by:

$$\frac{\partial P(RA_{ij}^{*})}{\partial X_{ij}} = \frac{\partial P(\beta X_{ij})}{\partial X_{ij}} = \beta_j \{F(u_{j-1} - X_{ij}\beta) - F(u_j - X_{ij}\beta)\} = \beta F(\frac{X\beta}{\delta}) \qquad (4.7)$$

4. 3. Research method and data

4. 3. 1. Measuring and validating risk attitudes

The data used for this chapter originated from a standardised questionnaire that was developed after reviewing previously validated studies (Bishu 2014; Venkatesh, Thong, and Xu 2012; Lewandowski 2010; Wauters 2010; Weber, Blais, and Betz 2002; Taylor and Todd 1995; Van Winsen 2014; Bard and Barry 2001). The questionnaire was also a priori contextualized by extension agents and some farmers in the study areas. These procedures helped to better understand farmers' risk behaviour (identifying shocks that are shared by many farmers) and to prevent us from asking researcher-driven questions.

As stated in section 4.2.2, there are several elicitation methods for risk attitudes in the literature (Crosetto and Filippin 2013; Addey 2018; Bohm and Harris 2010). In this paper, a psychometrical approach, or survey comprising a self-elucidation general and direct risk question and domain specific-context risk questions, was used to elicit and explore self-reported risk attitudes or the risk propensity (SRRA) of farmers.

In this study, a questionnaire survey or psychometric approach was used to explain and elicit the risk attitudes of farmers. It is simple to understand and compute risk attitudes. It also has

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[5]. *We would like to thank participants in the International Conference on Economics and Administration, 3-4 November, 2016, Bucharest, Romania, who advised us to use a heterogeneous choice model to cross-check the validity of the results of the (generalized) ordered logit model. This heteroscedastic choice model verifies and accounts for scale or variance difference from some variables-hide difference in residual variance across the response levels. Thus, it corrects for heteroscedasticity by simultaneously estimating two equations: determinants of risk attitudes (choice equation) and determinants of the residual variances (variance equation). Thus, null hypothesis is risk attitude effects don't differ across transitions by scale or residual variance factors.*

the potential to elicit risk attitudes (risk preference) for a large number of people at a relatively low financial cost over a shorter period. Furthermore, it generates results closely related to others- experimental approaches (Crentsil 2018; Addey 2018; Hansson and Lagerkvist 2012).

However, caution is needed in the interpretation of the results of the questionnaire survey and in making generalizations, because some studies have suggested that a combined use of both experimental and questionnaire methods have produced better results in explaining risks than separate use (Anderson and Mellor 2009; Lönnqvist et al. 2015; Dohmen et al. 2011).

In the general risk assessment, farmers were asked whether they are individuals who generally take or evade potential risks and were requested to rate themselves on a five-point predefined scale, such as extremely unlikely to take risks, unlikely to take risks, not sure, prepared to take risks and very much prepared to take risks.

In addition to this general risk question, 33 specific-context questions relating to shocks, worries and uncertainties (Annexe 2.3) are listed in the questionnaire. These are expected to explain and construct the overall risk attitudes of farmers. Responses are recorded using a five-point scale (whether they are likely to take the specific risk), which ranges from highly unlikely to more likely, from very low to very high, and from extreme dislike to extreme like.

As can be shown from Annexe 2.3, based on the factor analysis with oblique target rotation, 22 statements are loaded into five risk factors (risk domain) (with eigenvalue unity and above), which are named as natural hazard (Factor 1), technology risk (Factor 2), human security (Factor 3), market volatility (Factor 4) and financial shock (Factor 5). Other studies have also found similar groups of risks (Bishu 2014; Drollette 2009; Legesse and Drake 2005).

For example, Hardaker et al. (2015) identified five major sources of risk: production risks, market or price volatility, institutional or policy risks, personal risks and financial risks. Van Winsen (2014) also found price, production and institutional risks to be major concerns or farm business risks for the Flanders region in Belgium. Therefore, there are several concerns in the study areas that worry farmers.

These five risk factors explained about 70% of the available variance in risks. This means that these variables contain 70% of the variation in the 33 original variables. The first factor explains about 20% of the variation and factor 2 explains about 17%. The Kaiser-Meyer-Olkin (KMO), which measures the adequacy of the sample size, is about 76% with Bartlett's test of Sphericity (*chi-square statistic=4071 and* $P(\chi^2)=0.000$). This shows that the sample size is sufficient to run a factor analysis and use the data for further analysis.

With regard to the rotational loading extraction method (see chapter three), six statements relating to natural calamities, such as drought, flooding, shortage of rainfall, late start and early end of rainfall, and diseases/pests are loaded to natural hazard. Five risk statements associated with the use of agricultural practices and improved technologies are loaded to the same latent factor under the name technology risk. Human security is another latent factor, which is loaded with five observed statements relating to risks of social security, personal norms and health.

Market volatility is loaded and explained by three statements relating to markets, such as inadequate market for crops and livestock, change in input cost, fluctuation of output price, and lack of market information. Similarly, three statements relating to financial issues, for example, lack of money (saved or in hand), limited access to financial credit and other financial constraints are loaded into the factor financial shock. As stated in chapter three, other latent variables, like attitudes, relational capital, group membership, personal efficacy and perceived resources are also loaded by some other observed statements in the dataset (see Table 3.2).

4. 3. 2. Evaluating assumptions: reliability, validity, normality and multicollinearity

As exhibited in chapter three, there are various techniques to check reliability, validity, multicollinearity and normality (*see section 3. 3. 2 and 3. 3. 3*). Table 4.1 indicates that these risk-related variables are weakly normally distributed, although market volatility and financial shock are slightly positively skewed (normally distributed: -0.4≤ coefficient of Skewness≤0.4). The Cronbach's alpha explains that these variables are sufficiently reliable (alpha ≥0.70). Financial shock is the least reliable, whereas market volatility is the most reliable.

Based on the average factor loading and average variance extracted, all variables in Table 4.1 are above the minimum recommended value for validity (coefficient of loading factor ≥0.60 and variance extracted ≥0.50). Human security is the least valid, while market volatility is the most valid. Consequently, these risk latent variables are adequately explained by their corresponding observed statements in the dataset.

In addition, the assumption of multicollinearity is checked for each variable using a Spearman's rank correlation or contingency coefficient matrix. The correlation coefficient for target variables is already explained in chapter three (*See Annexe 3.1*). For control variables, a strong correlation is found between age and farming experience (*coefficient=0.70,* $P(\chi^2)=0.00$), gender and marriage (*coefficient=-0.27,* $P(\chi^2)=0.00$) and education and marriage (*coefficient=0.15,* $P(\chi^2)=0.00$). Accordingly, farming experience and marriage are dropped from the model. Robust variance estimates are also applied for correcting heteroscedasticity.

In general, the resulting model has no issues relating to multicollinearity, non-normality and heteroscedasticity and can, therefore, exploit the data for further estimation and inference. The mean score for all risk domain factors exceeds three points, although the mean score for human security is the lowest and the highest for market fluctuation. It seems that farmers are more conservative or pessimistic about issues relating to personal security and health issues, while they are more likely to choose risks relating to market issues.

Table 4. 1. Measuring the reliability, validity, and normality of the variables

Latent variables	Statement	Mean	Standard deviation	Alpha	Loading factor	Skewness	Variance extracted
Natural hazard	6	3.23	1.15	0.88	0.79	0.01	0.67
Technology risk	5	3.15	0.82	0.89	0.82	0.00	0.72
Human security	5	3.10	0.90	0.81	0.75	0.02	0.67
Market volatility	3	3.54	0.91	0.90	0.90	0.08	0.83
Financial shocks	3	3.49	0.83	0.73	0.80	-0.07	0.69

4. 4. Results and discussion

4. 4. 1. Smallholder farmers' risk behaviour: past and current self-reported assessment

This section aims to assess the behaviour of farmers towards risk, i.e., whether (or not) farmers have been involved in risky activities (for example, risk of borrowing money, using new/improved varieties, planting perennial fruit, injury while implementing farming activities). Because risk is domain specific it varies spatially, from person to person and over time. It can occur once or repeatedly. For example, risk activities are self-perceived and farmer-specific based on shocks, hazards, uncertainties and worries. A general direct question and series of multiple (domain specific-context) questions are used to understand the historical and current attitudes of farmers relating to risks and shocks.

In the general risk question, each farmer was asked a general question stating exactly '*how frequently they had engaged in risky activities for the last five years*', which was answered by using a five-point response option, such as 'none', 'rarely', 'sometimes', 'usually' and 'more frequently'. Annexe 4.1 presents the results. 6% of the farmers had rarely engaged, while about 12% were more frequently involved in self-perceived risky activities during the last five years.

Similarly, about 35% of the farmers claimed that they had sometimes participated in risky activities, while the remaining 47% had often been involved in risky activities. However, there were no farmers who responded that they had never been involved in risky activities (none). This suggests that many farmers in the area have already had experience of risky activities resulting from, for example, climate change, drought, calamities and other shocks.

To understand and assess the current willingness of the farmers towards risks, we used a general and specific question. We asked farmers a general question as to '*whether they are a person who takes or evades any risk in agricultural production'.* This means the extent to which they are willing to take risks associated with the adoption of improved farming practices and technologies and other issues. This was answered using a five-point response scale ranging from 'extremely unlikely to take risks', 'unlikely to take risks', 'not sure whether to take or evade risks', 'prepared to take risks' and 'very much prepared to take risks'. This helps us to understand whether farmers are fully prepared to take risks or completely evade risks or fall in the middle of the two options.

We found that about 6% of the farmers are not ready to take any risk at all, while about 16% are extremely willing to take risks. Nearly 30% of the farmers are relatively willing to take risks, while about 26% are not willing to take risks. About 22% of the farmers are uncertain whether to take or evade risks. Their decisions depend on personal characteristics and social factors. This implies that farmers take risks to accomplish day-to-day activities to sustain their livelihoods and their attitudes towards risk are distributed across different categories.

Following the response to this general question, farmers' risk attitudes were grouped into three levels or categories, namely, 'more risk averse' (risk averse), 'risk neutral' (risk indifferent) and 'less risk averse' (risk seekers). Less risk averse includes those farmers who enjoyed risks and are 'prepared' and 'very much prepared' (willing and very willing) to take risks, as long as they have opportunities, whereas more risk averse (risk avoiders) represents farmers who remove any risky events so that they partially and completely avoid risks.

For risk neutral farmers (risk indifferent), they are undecided or uncertain whether to take or avoid risks. They do not care whether the activity is safe or risky. They largely focus on other external factors to select the activity (Haile 2007). Accordingly, about 46% of the farmers are less risk averse (or risk seekers) and about 32% are risk avoiders, while the remaining (22%) are risk indifferent so that they are neither more risk averse nor less risk averse (*Figure 4.1*).

In addition, considering the mean approach (see section 2.4.2), which states the value of the latent variable as the average values of the statements loaded onto it, the value of risk attitude is constructed by taking the average value of 22 statements (known as the risk domain) and the average value of 7 statements loaded onto five technology risks (known as technology risk). The value of risk attitude ranges from 1 (most risk averse) to 5 (least risk averse). Subsequently, the attitude of farmers towards risk is categorized into three levels using the similarity-based regrouping method (see section 2.4.2), for example, more risk averse (=more unlikely + unlikely to take risks), less risk averse (=more likely + likely to take risks) and risk indifferent (not sure about or known as risk-neutral). Accordingly, when we see the results of the 22 statements, about 45% of the farmers are less risk averse (or risk seekers), while about 30% are more risk averse. The remaining farmers are risk indifferent. Similar results are also found using the five statements relating to technology and improved agricultural practices (see Figure 4.1).

In parallel, a k-means (non-hierarchical) cluster analysis (sometimes known as partitioning method) is used to classify farmers into three groups, or clusters, based on their attitudes towards risks. The algorithm is described by assigning each statement to the cluster having the nearest centroid or mean (Field 2013). Following this, we used the 22 risk statements, which have already been confirmed as good indicators of farmers' risk attitudes. Figure 4.1 shows the results of k-means or centroid cluster analysis and nearly 28% of the farmers are more risk averse, while 47% are less risk averse. Other farmers (25%) are undecided whether to accept or avoid risks relating to climatic and agricultural conditions, because their decisions are based on objective evidence, such as demographic issues, instead of on the activity itself.

Furthermore, the total approach and equivalent interval principle are used to compute the value of risk attitudes and classify farmers into groups based on their attitudes towards risks (see section 2.4.2). Accordingly, first, the values of the 22 statements are added to obtain the risk propensity scale or risk-taking index. Second, the sum theoretically ranges from 22 (greatest risk aversion) to 110 (least risk aversion) even if it practically runs from 44 to 94. Third, the attitude of farmers towards risk is categorized into three risk attitude levels, namely, more risk averse (44-60), risk-neutral (61-77) and less risk averse (78-94). Accordingly, about 28% of the farmers have more risk averse behaviour, while 44% have less risk averse behaviour (=risk seekers). Using the same procedure for the five statements relating to technology risks, three levels of risk attitudes are identified, such as more risk aversion (7-13), risk neutral (14-19) and less risk aversion (20-25). Hence, about 44% of the farmers are found to be less risk averse (=risk seekers), about 29% are more risk-averse (=risk avoiders) and 27% are still undecided.

Using these three risk attitude elicitation methods, such as self-elucidation general question, specific-context (mean of multiple questions) and k-means cluster analysis, we evaluated their correlation effect using the contingency correlation coefficient. We found a significant correlation between these risk attitude measures. For example, risk attitude using the self-elucidation assessment is strongly correlated with risk attitude using the mean of the multiple questions (specific-context) method (P(χ^2)=*0.014).* The same also holds true for risk attitudes using self-elucidation assessment and cluster analysis (*P(χ^2)=0.027).* Similarly, the risk attitudes using cluster analysis and the mean of multiple questions are also highly correlated (*chi-square statistic p-value=0.009*). Other studies have also reported similar results. In particular, the general question and psychometric series of questions, as ways of measuring risk attitudes, were significantly correlated (Van Winsen 2014; Maart-Noelck and Musshoff 2013; Nielsen, Keil, and Zeller 2013). Thus, farmers' risk attitudes in the area under consideration differ significantly across farmers, but not across elicitation methods for risk attitudes.

These alternative risk attitude elicitation methods generated similar and consistent results. This suggests that risk attitude measures might be capturing similar characteristics of the farmers in relation to how the farmers respond to risks. The level of smallholder farmers' attitudes towards risks in the area under consideration does not change statistically across different ways of computing risk attitudes. Therefore, we conclude, for further exploration, that 30% of farmers are more risk averse (risk avoiders), whereas about 45% are less risk averse (risk seekers) and other farmers are undecided whether to take or avoid the risks, so they are risk indifferent.

In the literature, some studies have used the same procedures to elicit risk attitudes. Weber et al. (2002) applied 50 statements in five risk domains (financial, health, recreational, ethical and social) and all the statements were rated based on a five-point rating scale. This covered 560 undergraduate students from the Ohio State University. The likelihood of students engaging in risky behaviours (general assessment) was also evaluated using a five-point rating scale ranging from extremely unlikely to extremely likely. More students were found to be more risk averse across all content domains.

Hanoch, Johnson, and Wilke (2006) used a German version of the domain-specific risk-taking (DOSPERT-G) scale to evaluate risk-taking and risk-avoiding behaviours. The study included numerous statements relating to recreational, health, social and ethical risks, and gambling and investment domains. Decisions were made using a five-point Likert item. Others that applied a questionnaire either on its own or in combination with an experimental approach include Crentsil 2018; Bishu 2014; Dohmen et al. 2011; Reynaud and Couture 2012; Anderson and Mellor 2009; Menapace, Colson, and Raffaelli 2016; Lönnqvist et al. 2015; Van Winsen 2014.

These studies examined the association between risk preference, using general question and field experiments, and found a significant positive correlation between the general risk attitude question and the risk attitude obtained through the field experiment with real monetary stakes. The domain-specific DOSPERT scale (specific-context in our case) was found to be a better predictor of risk attitudes than the general risk attitude question. However, risk attitude is measured indirectly from a series of statements that are thought to be influenced by the latent construct and scored on the Likert scale, so this is subject to a number of biases, such as social desirability, strategic motives and other self-serving bias (Dohmen et al. 2011). Since it cannot be measured directly, disentangling it from the observed or stated behaviour and freeing the measure from its context is a difficult task. The validity of risk attitude elucidated in hypothetical settings about actual behaviour is questioned and does not show complexity on the ground (Van Winsen 2014). Both experimental and survey methods should be used jointly in risk attitude elucidations.

In general, unlike many studies in the traditional literature, for example, Crentsil (2018) and Hansson and Lagerkvist (2012), our farmers are less risk averse (45%). This might be attributed to the presence of more farmers who are risk neutral. In addition, the shortcomings of the psychometric or survey approach, which is highly affected by subjectivity bias, may not reflect the true risk attitudes of farmers. Moreover, the uncertainty events selected, including hazards and shocks, may not be the most worrisome, so this may not reflect the actual disquiet and behaviour of the farmers towards risks and uncertainties.

Furthermore, since the areas under consideration are affected by frequent drought and are exposed to various shocks and disasters, the local people may be familiar with the frequent occurrence of hazards and uncertainties and have tried to adapt to them. This means that we did not identify new risky or uncertain events so that we did not present farmers with new issues. Finally, social and cultural differences may also lead to such results. For example, Van Winsen (2014) reported Flemish farmers to be more on the risk-neutral spectrum. Therefore, such slight differences in the attitudes of smallholder farmers towards risk might result from methodological reasons and traditions.

Figure 4. 1. Self-reported risk attitudes (SRRA) of smallholder farmers based on three simple risk attitude elicitation methods (percent)

4. 4. 2. How socio-psychological factors influence smallholder farmers' risk attitudes?

This section pinpoints determining factors for the risk attitudes of smallholder farmers. As stated above, the dependent variable is risk attitude, which has three ordinal levels, such as more risk aversion, risk neutral and less risk aversion. Whereas attitudes towards sustainable agriculture, agricultural extension services, information sources, household size, membership in formal organisations, participation in informal community groups and education are some target explanatory variables. There are also other control variables, such as demographic variables and biophysical factors. Non-normality, multicollinearity and heteroscedasticity are already checked. The estimation method used is the ordered logistic regression model.

In this model, there is an important assumption, known as the parallel lines assumption, where the null hypothesis states that the location parameters or slope coefficients are the same across response categories. The Brant test is used to examine the equality of the different categories and decides whether (or not) the assumption holds. If the assumption fails (especially for the main or target variables), ordered logit coefficients are not equal across the levels of the outcome. This suggests that the variables vary across the risk attitude levels.

As indicated in Annexe 4.2, the Wald chi-square test shows that the assumption is weakly violated, for example, by special skills and agro-ecology. If the assumption does not hold, there is no parallelity between categories. This suggests that the results of the ordered logit model can be wrongly interpreted and the conclusions misleading. Accordingly, it would be better to find an alternative model instead. However, first, most target variables do not violate the assumption. Second, the Brant test shows that the parallel regression assumption has not been violated statistically using all the variables jointly (*chi-square statistic=18.83, df=21 and* $P(\chi^2)=0.596$). Third, the oparallel method that checks the model for the overall parallel regression assumption, instead of each variable, shows that the model does not violate the assumption (*Wolfe Gould:* $P(\chi^2)= 0.607$ *and Score test:* $P(\chi^2)= 0.375$). Hence, the use of the ordered logit model seems reasonable and possible.

In spite of these facts, which are unlikely to reject the use of the ordered model, as stated in section 4. 2.4, we decided to complement the ordered logit model with a generalized ordered logit model (to relax the assumption) and a heteroscedastic ordered model (to account for residual variability) to build confidence and produce parsimonious results. Therefore, the robustness of these models can accommodate heterogeneity effects on the risk attitude equation.

In the heterogeneous choice model, variables such as extension service, gender, media influence, technical training, education, relational capital, group membership and attitude are used as scale parameters to understand and examine whether there is unmeasured bias (heteroscedastic errors) that affects the risk attitudes within these variables. However, we could not find heteroscedasticity problems (residual variability) associated with them. These variables are found to be supportive of risk attitudes.

The results of the marginal effects of the three models are presented in Table 4.2. The overall Wald test for the three models, which tests whether the combined effect (each variable in the model is different from zero), is statistically significant. This indicates that each model has some relevant explanatory power. There is no significant difference between the observed and expected data. Each model produces a good level of fit for smallholder farmers' risk attitudes. Therefore, we should use a better model for these three models because the parallel line assumption was not violated and the problem of residual variability was not exhibited. Using the likelihood-ratio chi-square test, a weak significant difference is found between the results of the ordered logit model and the generalised ordered logit model ($P(\chi 2) = 0.086$), while an insignificant difference is found between the ordered logit model and the heterogeneous choice model ($P(\chi 2) = 0.173$).

Considering the information statistic criteria, such as the Bayesian information criterion (BIC) and the Akaike information criterion (AIC), both slightly lean towards, or favour, the ordered logit model compared to the generalised ordered logit model, not forgetting, however, that this trivial difference may also be because of the difference in the degree of freedoms. The BIC and AIC also slightly favour the ordered logit model over the heterogeneous choice model. Since the ordered logit provides a better fit to the data than the others, we, therefore, use its results for further analysis.

Importantly, even if the three estimation methods are appropriate and have produced closely related results for most target variables, which are consistent in direction and magnitude, a slight difference has been observed for some variables in terms of the value of coefficients, the sign of parameters, and statistical significance. For example, personal efficacy is found to be statistically significant using the generalized ordered logit model but insignificant with other models. Similarly, the gender of the farmer is a significant factor using the ordered logit model, but it is insignificant with the others. It is also found that landholding size is significant using the generalised ordered logit model but not with the others. Applying the generalized ordered logit model, religion has a significant effect on risk attitudes while it is found to be insignificant using the ordered logit and heterogeneous choice models. Based on this result, religion, especially orthodox religion, seems not to encourage farm households to take risks and adopt technological innovations. The result, however, could be simple statistical associations, since the majority of the households are orthodox followers.

Table 4.2 indicates that variables, such as education, attitudes, group membership, relational capital, technical training and household size are found to significantly determine the risk attitudes of smallholder farmers, while agricultural extension services, media influence and access to credit are found to be insignificant factors. For example, capacity building is one variable in the risk attitude model. As explained in the focus groups, training and agricultural field demonstrations can improve understanding and awareness, broaden knowledge and skills, create opportunities to identify a weakness that needs to be improved, build confidence and independence habits, and develop inspiration to perform activities that contribute to livelihoods.

In this paper, technical training refers to capacity building such as short-term training, on-farm trials and exposure visits, and workshop experience sharing, and overall influence on decisions and behaviour (see Annexe 2.2). Effectively, a significant effect of technical training on risk attitudes is reported. Farmers who have been more exposed to sustainable agriculture through training and farm trials are about 4% less likely to report more risk aversion and they are about 4% more likely to report less risk aversion (risk seekers). As indicated in the focus groups, training could help farmers not only to build positive confidence but also to evaluate and take risks. Concerned organisations should create an enabling environment for farmers to participate in different capacity building training sessions and agricultural field days.

Education is both an input and an output because it can improve awareness and understanding and can also be a source of income. Bishu (2014) stated that education reduces uncertainties and improves farmers' decision making. It helps farmers to minimise risks and shocks. Table 4.2 shows that education has a significant positive effect on the risk attitudes of farmers. Literate farmers are about 6% less likely to report risk aversion and about 5% more likely to report risk seeking compared to illiterate farmers. Bishu (2014) found similar findings, where individuals with a lower level of education are found to be more risk averse, while Haile (2007) found an insignificant effect for education on risk attitudes. Therefore, literate farmers seem less worried about potential shocks and hazards and are more likely to be less risk averse.

Another important factor is social capital (see chapter 3), which includes relational capital and group membership. The influence of friends, families, neighbours, society and traditional or informal institutions plays an important role in rural economies, especially in less developed countries, where many institutions are either absent or not strong. The same also holds true for formal rural organisations, such as farmers' associations, resource users' groups and cooperative societies, which are dominant and common in the area under consideration.

In the sustainable livelihood approach, social capital is also one of the five livelihood capitals. It is defined as networks, relationships, affiliations, associations and connections between people, institutions and individuals (Chambers and Conway 1991). This indicates that relational capital and group membership are significant factors that should not be overlooked or undermined in livelihood analysis and studies on adoption strategy.

In the area, membership in formal organisations and having strong relationships and ties with local community groups are considered as good insurance schemes, because local people not only have the same interests and values, but also the same problems. Relevant information about potential hazards and general issues are exchanged among the local communities. They can share losses from unforeseen events, and can also help each other in terms of the labour and physical resources used to execute farms. They can discuss and increase their understanding of sustainable agriculture. They can also organize short-term training and exposure visits to members to enhance their awareness. These enable rural people to have strong attachments with local community groups and local institutions and encourage joint action and decisions.

The point is now how social capital influences risk attitudes. Based on their responses, farmers can have either poor or strong (plus in-between) social networks and relationships. As indicated in chapter three, relational capital is constructed from five statements with a five-point response scale (very low, low, uncertain, high and very high). In most cases, farmers who have lower values in the relational capital are often those who responded 'very low' and 'low'. They believe that community groups, such as friends and neighbours, have low influence on their decisions and behaviours. They have weak interpersonal contacts and relationships.

Table 4.2 shows that farmers who have strong relationships and ties with community groups (responding 'high' and 'very high') are about 9% less likely to report risk aversion, while they are about 7% more likely to exhibit risk-seeking behaviour. This suggests that aversion declines when smallholder farmers have good interpersonal contacts and relationships with community groups and traditional institutions, because they can feel confident when they have strong networks and they can also obtain support from these groups in handling risks and shocks.

Similarly, group membership is constructed from three observed statements with a five-point response scale (no, slightly, somewhat, moderately and very high influence). Those farmers who are members and participate in the full activities of the formal organizations can easily understand the importance and influential power of these organization (high values), whereas those farmers who are either not members or passive in participation, even if they are members, may not notice or be aware of how these formal institutions affect their decisions and behaviours (low values). Table 4.2 indicates that membership in formal organizations reduces risk aversion while encouraging smallholder farmers to take and bear risks.

Indeed, if farmers considered formal organizations to be important and significant in bringing changes of mindset and affecting their decisions and behaviour, they are about 9% less likely to report more risk aversion and are about 11% more likely to exhibit less risk aversion (risk seekers). Group membership affects risk aversion negatively and risk-seeking positively. Consequently, it seems important to strengthen formal organisations, smooth interpersonal communication between farmers, and empower traditional institutions, such as *Equb* and *Idir*, to enable smallholder farmers to be optimistic about potential risks and shocks.

Attitude is one of the target variables indicating the farmers' feelings about adopting sustainable agriculture after evaluating the benefits and limitations. In the three different models, attitude is found to importantly influence farmers' risk attitudes. In the coefficient for the ordered logit model, it has a significant positive effect on risk attitudes. Those farmers who have positive attitudes (high-value response, for example, 'agree' and 'strongly agree') are about 1% less likely to report risk aversion compared to farmers with a low-value response. Similarly, farmers with positive attitudes are about 1% more likely to report less risk aversion (risk seekers) than their counterpart farmers. Therefore, risk aversion is reduced when the value of attitudes towards sustainable agriculture is increased and building positive attitudes seems pertinent.

Perceived resources, referring to the availability and distribution of economic resources and rural services, are found to be weakly significant for risk attitudes. Access to credit and special skills are taken as indicators of financial capacity. However, both are completely insignificant. These variables, such as access to credit, special skills and perceived resources insignificantly explain how financial resources and rural facilities influence risk attitudes. As stated in the focus groups, these results are quite different from reality in the area. Because when farmers are relatively rich, they are respected and are also less risk averse.

According to Table 4.2, household size positively affects risk attitudes. A unit increase in household size reduces the probability of farmers reporting risk aversion by 5%. This suggests that children can share some responsibilities and help their families in farming and non-farming activities. On this basis, more risk averse farmers have been encouraged to have more children as a risk management strategy (Todaro and Smith 2011; Norton, Alwang, and Masters 2010). However, risk seekers do not use more children as a risk management strategy, because their probability of being less risk averse is reduced by 6% with an additional child. A related result was found, where a household with more children was found to be more risk averse (Yesuf and

Bluffstone 2009). Thus, the utility of a child varies depending on farmers' attitudes towards risk, because an additional child is an asset for more risk avoiders but a liability for risk seekers.

Table 4.2 shows that gender influences farming decisions, because it reflects the division of labour. The finding indicates that the probability of having greater risk aversion is about 4% higher for female-headed households than male-headed households, while other variables remain constant. In contrast, the probability of being less risk averse is about 4% higher for male-headed households than for female-headed households. Similar observations were made in India and Namibia. Females were relatively risk averse compared to males (Banerjee 2014; Teweldemedhin and Kafidi 2009) while Nelson (2012) reported mixed findings.

The difference in risk attitudes across gender might be linked to existing cultural and traditional issues. First, women are often engaged inside the home, while men are involved in outside activities, which are often regarded as riskier. This might enable male-headed households to experience dealing with risks. Second, the rate of literacy in Ethiopia is higher for men (57%) than women (41%), which might help male farmers to entertain positive opportunities. Third, women are more vulnerable and exposed to culture and various traditions. These might contribute to the case that male-headed households are more likely to accept risks.

Livestock and farmland are interrelated. They are the basis for agricultural productivity and livelihoods (Todaro and Smith 2011; Norton, Alwang, and Masters 2010). Both have economic and social implications, for example, farmers with more livestock and larger landholdings are considered wealthy and are more respected than their counterparts. The finding depicts that with a unit increase in livestock assets (TLU), the probability of farmers reporting risk aversion is reduced by 2% and risk-taking behaviour declined by about 3%. This might be due to the fact that since animals are sensitive to drought and climate change, farmers may not prefer to have more animals. Farmers who have few animals have often preferred the safest choice. This is consistent with previous studies. Farmers who had a large number of cattle had less risk-averse behaviour (Yesuf and Bluffstone 2009; Flaten et al. 2005), and a negative correlation was found between household wealth in terms of livestock size and risk aversion (Haile 2007).

Since agriculture in the area is highly exposed to potential risks and shocks, such as natural risks, biological factors and market risks, high reliance on the sector and having infertile farmland can often make farmers fear shocks, avoid risks and develop risk aversion. Table 4.2 shows that farmers whose livelihoods rely primarily on agriculture (occupation) are about 7% more likely to evade risks compared to those who are non-agriculture dependent. If farmers have fertile farmland, they are 12% less likely to report greater risk aversion and they are also 16% more likely to be less risk averse (or risk seekers). This suggests that the probability of taking risks is higher when farmers have better quality farmland conditions.

However, personal efficacy, perceived resources, media influence and extension services were found insignificant. Mass media such as television and radio, and extension services are important sources of information (awareness and knowledge) for rural people, but they are insignificant in reducing risk aversion. This might be linked to problems with the availability of media appliances, accessibility of extension services, and the competence of extension agents. Annexe 2.1 indicates that about 60% of the farmers do not have confidence in the competence and skills of extension agents. Farmers in the area might also have similar skills, knowledge and competence.

In general, the results of the three models indicate that the target variables, such as attitudes, group membership, capacity building training, relational capital, education, household size, agricultural extension services, and media influence jointly influence the risk attitudes of farm households, even if not all of these variables are statistically significant. Most variables play pivotal roles in reducing aversion, building awareness and motivating smallholder farm households to adopt sustainable agriculture. Therefore, attention should be given to effectively exploiting the positive effects of these social and psychological issues.

Table 4. 2. Coefficients of marginal effects across farmers' risk attitudes: ordered logit model, generalised ordered logit and heterogeneous choice models

	Ordered logit		Generalized ordered		Heterogeneous choice	
Explanatory variables	More risk averse	Less risk averse	More risk averse	Less risk averse	More risk averse	Less risk averse
Education	-0.056**	0.046**	-0.043**	0.073**	-0.056***	0.046*
Attitudes	-0.117***	0.142***	0.066**	0.037*	-0.022**	0.142***
Extension service	0.054	-0.067	0.035	-0.077	0.054	-0.067
Group membership	-0.093***	0.113***	-0.064**	0.132***	-0.093***	0.113***
Media influence	0.017	-0.021	0.016	-0.014	0.017	-0.021
Relational capital	-0.091**	0.072**	-0.089**	0.096*	-0.091*	0.072**
Personal efficacy	0.060	-0.073	-0.086*	-0.052	0.060	-0.073
Perceived resource	0.037	-0.044*	0.029	-0.051*	-0.044*	0.037*
Technical training	-0.042***	0.035**	-0.088**	-0.088**	-0.142***	0.035***
Household size	-0.051***	-0.062***	0.048***	0.073***	-0.051**	0.062**
Religion	-0.040	0.047	0.110**	-0.077**	-0.040	0.047
Special skills	-0.026	0.031	0.047	0.100	-0.026	0.031
Credit access	-0.004	0.043	-0.212	0.069	0.010	-0.012
Gender	-0.037**	0.044***	-0.043	0.049	-0.037	0.044
Log(age)	-0.006	0.007	0.030	0.030	-0.056*	0.036**
Occupation	0.070*	0.083*	-0.055	0.113	-0.070	0.083
Livestock	-0.016**	-0.029*	0.019	-0.012	0.016	-0.019
Farmland	-0.061	0.075	-0.029*	0.149***	-0.061	0.075
Flat slopes	0.038	-0.045	0.000	-0.077	0.038	-0.045
Agroecology	-0.004	0.004	0.084	0.075	-0.004	0.004
Fertile soils	-0.117**	0.157**	-0.172***	0.139*	-0.117**	0.157**
Overall model Chi-square test						
LR Wald test	34.14		61.55		44.10	
$P(\chi^2)$	0.025		0.036		0.029	
Pseudo R^2	0.50		0.69		0.47	

*Note: *, ** and *** refers to the level of significance at 10, 5 and 1 percent.*

4. 5. Conclusion and implications

This chapter aims for a better understanding of how socio-psychological factors affect farmers' attitudes towards risk in a complex environment. Cross-sectional data is analysed using the ordered logit model with the heterogeneous choice model to address heteroscedasticity problems. The potential risks in the area under consideration relate to natural hazards, financial shocks, market volatility, human security and technology risks. Farmers have diverse reactions to potential risks, because nearly 45% are less risk averse (or risk seekers) while the remaining are either more risk averse or risk indifferent farmers.

The results confirm that risk aversion is negatively affected by education, relational capital, attitudes, rural organisations and capacity building training. These factors have also encouraged farmers to take risks. Farmers who have strong relationships and networks with local community groups and formal organizations (social capital), those who have received capacity building training, those who have favourable attitudes, and those who are literate are more likely to have less risk averse behaviour (=be risk seekers) than their counterparts. Consequently, social capital and behavioural factors are found to be powerful predictors of smallholder farmers' risk attitudes.

This paper offers an insight into how to reduce risk aversion. Governments and development actors should design specific strategies to improve awareness and create positive attitudes. For example, smallholder farmers should receive capacity building training and also participate actively in agricultural field days and farm demonstrations. There is also a need either to raise the resilience of agriculture to risks and shocks or diversify rural livelihoods to the non-agriculture sector. These would help rural people to easily adapt to various shocks and hazards.

The focus should also be given to expand pro-female education and to provide capacity building for female-headed households to enhance their awareness, to reduce their risk aversion and to enable them to become active participants in the socio-economic-political systems. Moreover, there is a need to build positive attitudes of farmers to reduce their risks and uncertainty. Besides, formal organisations and informal institutions should be supported and strengthened.

The results of the study have both practical and theoretical contributions. It can improve the awareness and understanding of researchers, academics, policymakers, development actors and farmers in determining factors for farmers' attitudes towards risk, especially in agriculture and rural development. The findings also help us to gain a better understanding of how smallholder farmers react or behave in relation to risks, and how they deal with or respond to risks.

In addition, if the types of frequently occurring risks are known, and if the attitudes of farmers towards these risks are understood, it is easy for concerned bodies to, at least, prepare coping strategies. Furthermore, if farmers are updated with the necessary information in advance, they can identify proactive and reactive risk management strategies, for example, the use of improved technology, the use of early maturing and drought-resistant varieties, sending children to relatives, and investing in non-farm activities.

Chapter Five
Impacts of socio-psychological issues on actual adoption of sustainable agricultural practices

Abstract

This chapter investigates how socio-psychological factors affect smallholder farmers' decisions to adopt agricultural practices, such as agroforestry systems, organic compost and crop rotation with legumes. Cross-sectional data is collected using a pre-tested and structured questionnaire, and a multivariate probit model is used to investigate factors that influence the adoption of these practices. The ordered probit model is also applied to identify and analyse the determinants of the number of agricultural practices adopted. The findings show that attitudes, information, education, group membership, relational capital, risk attitudes, labour supply and livestock ownership significantly affect the probability of adopting these practices. The estimates of the ordered probit model also indicate that extension services, risk attitudes, group membership, relational capital, education and labour supply are major determinants of the number of agricultural practices used. However, financial resources and rural institutions are found to have an insignificant effect on adoption. Furthermore, in the areas under consideration, lack of information, shortage of family labour, small size of landholdings and personal characteristics are identified as reasons for non-adoption of sustainable agriculture. This implies that when it is necessary to promote sustainable agriculture and stimulate smallholder farmers to adopt such practices, in isolation or combination, specific strategies should be designed to raise awareness, build positive attitudes, reduce aversion, strengthen formal organizations and empower endogenous groups (or informal institutions).

Keyword: Attitudes, social capital, information, risk attitudes, agricultural practices, multivariate analysis.

Adapted from

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5. 1. Introduction

Because of land degradation, low use of improved agricultural inputs, limited marketing systems, climate change and frequent drought, subsistence farming system (also known as traditional agriculture), which is characterised by very low productivity and weak overall performance, has remained the dominant farming system, particularly, in most sub-Saharan African countries (Bonabana-Wabbi, Mogoka, Semalulu, Kirinya, & Mugonola, 2016; Norton, Alwang, & Masters, 2010; Todaro & Smith, 2011).

In Ethiopia, for example, about 80% of the population depends on agriculture to sustain their livelihoods. The sector constitutes about 85% of the foreign exchange earnings. Furthermore, agriculture has around 43% share of the gross domestic product (National Plan Commission, 2017). For this reason, agricultural growth not only determines the fate of non-agricultural sectors but also accelerating overall economic development.

Despite its dominance, the productivity of this sector in these countries remains very low and has grown by about 2.2% annually since 1991, whereas the corresponding figure is 3.9% for developed countries and 4.2% for other emerging countries (UNCTAD, 2015). The low productivity has retarded the growth of other sectors and the overall economy. This demonstrates the widening agricultural productivity gap which will continue unless agriculture in less developed countries grows faster than in other countries.

As documented in the literature, one way to improve the productivity of the sector is to invest in technologies and agricultural practices (Hillbur, 2014) that can further improve food security and livelihoods (Muzari, Gatsi, & Muvhunzi, 2012) while maintaining environmental sustainability (Lichtfouse, 2012; Veisi & Toulabi, 2012). Agricultural productivity can also be increased through the use of improved varieties and improved farming practices, which could ensure food security and reduce rural poverty (Khonje, Manda, Alene, & Kassie, 2015; Wollni, Lee, & Thies, 2010).

However, the adoption and diffusion of improved technologies and sustainable agricultural practices in these countries still remain below the expected levels (Gumataw, Bijman, Pascucci, & Omta, 2013; IFAD WFP and FAO, 2015; Teklewold, Kassie, & Shiferaw, 2013; UNCTAD, 2015; Van Thanh & Yapwattanaphun, 2015; Wollni et al., 2010). Several studies have been conducted to identify the reasons for this. For example, physical soil and water conservation, agroforestry systems, seeds of improved varieties and commercially available organic fertilizer are often linked to demographic variables, plot-location characteristics, financial resources, information access, government effectiveness and the presence of shocks, for example, climate change, flooding and climate change (Gumataw et al., 2013; IFAD, WFP and FAO, 2015; Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2013; Teklewold et al., 2013).

Undoubtedly, the findings from these studies are highly variable across locations. Subsequently, a location-based specific study is often necessary to understand the real factors that prevent farmers from adopting productivity-enhancing technologies and practices. Along with this, since farmers' decisions to adopt technological innovations depend on several factors (Swanepoel, van der Laan, Weepener, du Preez, & Annandale, 2016), empirical evidence is still needed to understand what motivates farmers to adopt technologies and improved practices (Yazdanpanah, Hayati, Hochrainer-Stigler, & Zamani, 2014).

In the traditional adoption literature, the main focus is on how socioeconomic variables and biophysical factors affect adoption. However, socio-psychological issues affecting adoption have received attention in more recent literature. Some available studies include Swanepoel et al. (2016), Menozzi, Fioravenzi, and Donati (2015), Erwin Wauters and Mathijs (2014), Foley (2013), Yazdanpanah et al. (2014), Martínez-García, Dorward, and Rehman (2013), Wauters (2010), Wauters and Mathijs (2013), and Yamano, Rajendran and Malabayabas (2013).

Since these empirical studies are potentially limited, the effect of socio-psychological factors on (actual) adoption decisions seems insufficiently captured or addressed. More studies are still needed to adequately understand their impacts on adoption. In addition, the potential role of attitudes, social capital, personal competencies, capacity building and information in the adoption decisions are less well researched in the empirical literature. Therefore, it seems pertinent to undertake a study to provide additional empirical literature on the subject matter.

Parallel to this, the northern part of Ethiopia is highly deforested and degraded due to traditional and unsustainable farming practices associated with other natural and human factors, which leads to low yields and increases farmers' vulnerability. As explained in chapter one, in areas that are susceptible to degradation and have resource-poor farmers, one possible way to improve productivity is to use sustainable agriculture, which can be adopted by locally available inputs. Despite this, there are few such empirical studies; and, in particular, the effect of socio-psychological factors on the adoption of sustainable agriculture remains unexplored in Ethiopia.

Therefore, this paper has three purposes: assessing the adoption status of smallholder farmers for sustainable agriculture, which helps us to understand how many farmers are currently adopting, how many farmers are dis-adopting and how many farmers are planning to adopt sustainable agriculture in the future. This chapter also assesses the reasons for non-adoption of sustainable agricultural practices. Finally, the paper also investigates how socio-psychological factors, for example, social capital, attitudes, personal efficacy, risk attitudes and information stimulate farmers to adopt sustainable agricultural practices.

This paper has five sections. The necessity and focus of the study are justified above. Theoretical and methodological frameworks for the study (model estimation and explanation) are briefly described in section two. Section three describes the sustainable agricultural practices selected and studied in this chapter. Section four displays and discusses the main findings. The final section concludes and makes suggestions for the future.

5. 2. Model estimation and explanation

As explained in the literature or chapter 1, farmers' decisions to adopt technological innovations to improve agricultural productivity and maximise yields are based on their expected utility (U_i) (Teklewold et al., 2013; Wollni et al., 2010). They would decide to adopt if the expected utility of adopting (U_i^m) exceeds the expected utility of not adopting or retaining the traditional management practice (U_i^0) (see section 1.5.2).

While the expected utility cannot be observable, the adoption decision can be observable. In this case, we can derive this unobserved utility from the observed variable, and smallholder farmers' choice for sustainable agricultural practices is given as follows:

$$D_{im} = \begin{cases} 1 & if\ D^{*}_{im} = \mathrm{E}(U_i^m - U_i^0) = \alpha X'_{im} + \varepsilon_{im} \geq 0 \\ 0 & Otherwise \end{cases} \quad (5.1)$$

Where D_{im} is the observable variable and D^{*}_{im} is a latent variable representing the decisions of farmers (i) to adopt agricultural practices (m). This depends on a vector of explanatory variables, such as attitude towards the practices, social capital, farmers' risk attitudes and demographic factors (X'_{im}) and unobserved characteristics (ε_{im}) and the error terms are expected to capture errors in optimisation and perception.

In the presence of more agricultural practices, farmers can adopt them in combination or separately. If adoption of the practices is interrelated, a separate estimation may lead to under (over) estimation and a joint analysis is therefore preferable. This retains potential correlation between unobserved disturbances and also allows for possible contemporaneous correlation in the adoption decision (Greene, 2003).

Following this fact, adoption decisions for interdependent or interrelated agricultural practices have a multivariate structure and a multivariate probit model is hence more appropriate to handle the issue (Greene, 2003). Thus, the multivariate probit function can be specified as:

$$D^{*}_{im} = \alpha_i X_{im} + \varepsilon_{im}; \quad D_{im} = 1(D^{*}_{im} > 0) \qquad \varepsilon \sim MVN(0, \Omega) \quad (5.2)$$

Where the error terms jointly follow a multivariate normal distribution (MVN) with zero means and variance normalised to unity, Ω refers to symmetric variance-covariance matrix, ρ is the conditional tetrachoric correlation between two different sustainable agricultural practices.

$$\Omega = \begin{bmatrix} 1 & \rho_{12} \cdots & \rho_{1m} \\ \rho_{12} & 1 \ \cdots & \rho_{2m} \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots.. \\ \rho_{1m} & \rho_{2m} \ \cdots & 1 \end{bmatrix} \quad (5.3)$$

While this allows us to estimate the probability of adopting agricultural practices, it does not define the number of agricultural practices adopted. In the literature, it is usually assumed that farm households adopting two strategies or practices have higher utility levels than farm households adopting only one strategy (Ali & Erenstein, 2017). Accordingly, this can be expressed below:

$$U[F(M_{1i}, M_{2i})] > U[F(M_{0i}, M_{1i})] \quad (5.4)$$

To capture this, two models are suggested in the literature, namely, the ordered probit model (Teklewold et al., 2013; Wollni et al., 2010) and the censored least absolute deviation (CLAD) (Ali & Erenstein, 2017; Huang, Ma, & Xie, 2007). Both could help to explore factors that influence the number of agricultural practices adopted. In both models, the dependent variable[1] (Y_i) is the number of agricultural practices adopted ranging from zero to three. However, the

[1]. *Number of agricultural practices adopted, assuming three sustainable farming practices, farmers adopt zero (Y_i=0), one (Y_i=1), two (Y_i=2) and three (Y_i=3) sustainable practices, regardless of their sequence and combination.*

CLAD model assumes this to be a continuous variable while it is assumed to be an ordered variable by the ordered probit model. Hence, the ordered probit model is used to produce more reliable results, since we assumed it to be an ordered variable.

With regard to the ordered model, at first sight, the number of practices adopted seem to be count data, which would justify the use of a Poisson regression model instead of an ordered probit model. However, the events do not have perceived equivalence probabilities for occurrence or adoption. In addition, the dependent variable is assumed by Poisson model as a continuous variable, whereas it is assumed by this study as an ordered variable.

Furthermore, the probability of adopting the first agricultural practice is also found to differ from the probability of adopting the second practice (Wollni et al., 2010). The ordered model is appropriate and what is important is whether the farmer adopts zero, one, two or more practices despite the sequence and combination. This function is given by:

$$P(Y_i = j \mid X_i) = P(X_i\beta + e_i \le \lambda_j \mid X_i) = \Phi(\lambda_j - X_i\beta) - \Phi(\lambda_{j-1} - X_i\beta); j = 0,1,2,3 \quad (5.5)$$

Where $\Phi(.)$ is the standard normal cumulative distribution function, β is parameter vector and $\lambda_0 < \lambda_1 < \lambda_2 < \lambda_3$ are unknown threshold parameters to be estimated by maximum likelihood.

5. 3. Sustainable agricultural practices studied

In chapter two, sustainable agricultural practices are categorized into two groups: those practices commonly applied and those practices recently established (introduced) in the area. From the commonly adopted agricultural practices, agroforestry systems[2], crop rotation with legumes[3], and application of compost[4] are selected to assess the influence of socio-psychological factors on smallholder farmers' choice of these practices. In the areas under consideration, farmers are expected to use these agricultural practices to improve soil fertility, increase water retention, enhance productivity and maximize yields.

As indicated in previous studies, agroforestry systems, which combine both agriculture and forestry practices, create more productive and ecologically healthy land-use systems. In addition to food and livestock forage, agroforestry systems could reduce greenhouse gas emissions by capturing carbon, improve resilience to climate variability and extreme drought conditions, and could also enhance soil fertility, leading to higher yields and income (Hillbur 2014; Mbow 2014; Zerihun et al. 2014; Sirrine 2008).

Several studies have also been conducted on crop rotation with legumes and found that crop rotation helps to replenish nutrients, because legumes fix nitrogen in the soils. Using cover crops also prevents soil erosion and mitigates diseases/pests that often occur when a single crop is continuously cropped, improves soil structure and fertility by increasing biomass, improves yields and increases income (Gan et al., 2015; Martin-Rueda et al., 2007). In this area, farmers

[2]. *Agroforestry systems (1 if the farmer has planted multipurpose trees, such as commercial fruit, grass strips, shrubs and forage trees with crops and/or livestock in the same management unit, otherwise 0).*
[3]. *Crop rotation with legumes (1 if the farmer has used legume crops (beans, chickpeas, lentils, and peas) following cereal crops (wheat, barley and maize) in the same area in sequential seasons, otherwise 0)*
[4]. *Compost (1 if the farmers have applied organic matter, such as weeds, farm waste, dry leaves, ash and food waste as organic fertilizers and otherwise 0).*

have often used legume crops, such as peas, beans, chickpeas and lentils following cereal crops, such as wheat, barley and maize. Therefore, these legumes are involved in the rotations with these cereals.

With regards to compost, farmers in the area have often used organic materials, such as weeds, farm waste, ash, food waste, leaves and straw/hay leftovers as inputs for compost. The literature indicates that the application of compost improves soil fertility, controls soil erosion and increases crop yields, which tends to raise the income of compost adopters (Ibrahim, Hassan, Iqbal, & Valeem, 2008; Ouédraogo, Mando, & Zombré, 2001). In the study area, I believe that there are no shortages of the availability of the organic materials used for compost. Therefore, shortage of organic materials used for compost could not be a reason for unwillingness of farmers to introduce or adopt compost as organic fertilizer to increase productivity.

As can be seen in Table 5.1, agroforestry systems, crop rotation with legumes and compost are response or choice variables. For each agricultural practice, farm households are asked a dichotomous question (yes/no) as to whether they have applied these specific practices on their field plots. In this paper, 'adopter' refers to a smallholder farmer who has adopted a selected agricultural practice; otherwise, they are referred to as a 'non-adopter'. These selected agricultural practices can be adopted separately or in combination and, therefore, there are eight possible adoption choices.

During the survey, about 46% of the farmers had adopted agroforestry systems; the corresponding figure for compost application was 55% and crop rotation with legumes was 59%. This suggests that there are also a significant number of farmers in the area who have not yet adopted these practices. Of these, about 9% adopted agroforestry systems only but not crop rotation and compost. The corresponding figure for solely compost is about 11% and 15% is for only crop rotation.

Considering the conditional probability that shows the interdependence decisions, the proportion of farmers who have adopted agroforestry systems, given that they have already applied crop rotation are 59%; and the corresponding figure for compost is about 47%. About 14% of farm households have adopted all these agricultural practices in combination, while about 10% have not adopted any of the practices.

It is also possible to use these agricultural practices in combination. About 11% have used agroforestry systems combined with crop rotation. Compost and crop rotation with legumes are used jointly by about 18% of farmers. Furthermore, about 12% of farmers have adopted agroforestry systems together with compost. Therefore, these agricultural practices are interdependent and individual or separate decisions to adopt them seem less realistic.

Table 5. 1. Conditional and unconditional[5] probability of adopting agricultural practices

Conditions	Agricultural practices	Percentage of farmers who adopted		
		Agroforestry systems	Crop rotation	Compost
Independence probabilities	Unconditional probability of practice	46	59	55
	Only specific practice	9	15	11
Joint probabilities	Crop rotation	11	0	18
	Compost	12	18	0
Conditional probability	Agroforestry systems	100	61	60
	Crop rotation	59	100	57
	Compost	47	56	100

5. 4. Results and discussion

5. 4. 1. Socio-psychological behaviours across selected agricultural practices

In this section, we aim to see whether there is a significant difference in social and psychological variables between those farmers who adopted the agricultural practices and those farmers who did not. The statistical significance tests on equality of means for continuous variables, for example, labour supply, landholding size, attitudes, personal efficacy and perceived resource (sample t-test), and equality of proportion for binary variables, for instance, education, risk aversion and risk-seeking (chi-square test) are presented in Table 5.2.

As can be seen in Table 5.2, there is a strong relationship between education and adoption of the practices ($P(\chi^2)<0.05$). Literate farmers are more likely to adopt agroforestry systems and crop rotation with legumes, whereas they are less likely to adopt compost application compared to illiterate farmers. This seems to suggest that educated farmers are more aware of the benefits of agroforestry systems and crop rotation. Additionally, educated farmers may be less likely to apply compost because it is more labour intensive and more time consuming than other agricultural practices.

A strong relationship between social capital and adoption of some practices is also observed ($P(\chi^2)<0.10$). There is a statistically significant difference in social capital between adopters and non-adopters. The proportion of farmers who have a strong social capital (high ties and bonds within formal organizations and informal community groups) is significantly higher for adopters than for non-adopters. Farmers who have a high social bond can discuss technologies and farming practices with each other. Since they trust each other, the actions of one person can

[5]. *Marginal probability (unconditional probability) as a probability of adopting agricultural practice regardless of any pre-requirement while conditional probability is the probability of adopting a specific practice given that other practices have already been adopted; and joint probability is the probability of adopting two or more agricultural jointly and simultaneously.*

affect the behaviour of others. The probability of adopting these practices increases if the farmer has a strong interpersonal network and communication within various community groups.

The same table also shows the presence of a statistically significant difference in attitude towards sustainable agriculture between those farmers who adopted agroforestry systems and compost application, and those farmers who did not adopt them. The mean score is relatively higher for adopters than for non-adopters. This suggests that many farmers who adopted these practices have positive attitudes, while those who did not adopt are unsure or have low attitudes. Accordingly, relationships are observed between farmers' attitudes towards sustainable agriculture and actual adoption of these agricultural practices. No significant relationship is revealed, however, between attitudes and the adoption of crop rotation. Therefore, having positive or high attitudes can speed up the adoption of agroforestry systems and compost.

Risk aversion and risk seeking (less risk averse) are other variables in the model. The percentage of those who are less risk averse (or risk seekers) is higher for farmers who adopted agroforestry systems than those who did not, as well as for those who adopted compost application compared to non-adopters. Similarly, the proportion of risk avoiders is lower for compost fertilizer adopters than non-adopters. This figure, however, is higher for crop rotation adopters than for non-adopters. This suggests that more risk averse farmers are less likely to adopt compost, whereas risk seekers are almost certain to adopt it. This might be due to the fact that the organic materials used to prepare compost is required by more risk averse farmers for their livestock.

For example, about 29% of the risk-averse farmers adopted compost while about 71% did not. For risk seekers, about 90% are compost adopters but only 10% are compost non-adopters. In addition, about 60% of less risk averse (or risk seekers) adopted agroforestry systems and about 57% of risk-averse farmers adopted crop rotation with legumes. In the area, risk attitude seems to have a significant impact on the adoption of sustainable agriculture. However, we cannot draw conclusions based solely on this simple mean comparison approach.

A strong relationship is also observed between technical training and the adoption of compost, media influence with compost, and labour supply with the adoption of agroforestry systems and compost application. Farmers who have attended short-term training and have participated in agricultural field days are more likely to adopt compost. Agroforestry systems and compost are more likely to be adopted if the farmer has a greater labour supply.

Information is instrumental in the adoption of technological innovations, and mass media, such as television or radio, increases the likelihood of adopting agroforestry systems. In general, these variables affect the adoption of agricultural practices even if it is less likely and too early to draw conclusions using this mean comparison approach.

Table 5.2. Socio-psychological variables across adopters and non-adopters of agricultural practices (mean for continuous variables or share for categorical variables)

Variables	Agroforestry systems			Compost			Crop rotation		
	Yes	No	P-value	Yes	No	P-value	Yes	No	P value
Two-sample t-test									
Attitudes	3.32	3.00	0.024**	3.31	3.11	0.015**	3.22	3.19	0.699
Media influence	3.35	3.27	0.334	3.32	3.30	0.961	3.31	3.30	0.896
Group membership	3.89	3.47	0.046**	3.81	3.37	0.006***	3.79	3.70	0.313
Relational capital	3.87	3.45	0.039**	3.62	3.40	0.084*	3.77	3.51	0.041**
Extension service	3.27	3.18	0.437	3.41	3.15	0.075*	3.32	3.21	0.951
Technical training	3.37	3.33	0.690	3.69	3.30	0.039**	3.36	3.34	0.855
Farming experience	24.0	23.0	0.486	23.0	25.0	0.100	24.0	23.0	0.219
Labour supply	4.70	4.29	0.054*	4.64	4.24	0.041**	4.51	4.43	0.727
Landholding size	0.56	0.55	0.682	0.57	0.55	0.382	0.57	0.55	0.402
Personal efficacy	3.13	3.09	0.674	3.22	3.23	0.837	3.21	3.24	0.364
Perceived resource	3.23	3.21	0.471	3.13	3.07	0.245	3.10	3.12	0.607
Chi-square independence test									
Religion	0.86	0.87	0.432	0.88	0.84	0.305	0.84	0.89	0.270
Education	0.60	0.40	0.030**	0.41	0.59	0.020**	0.57	0.43	0.041**
Risk aversion	0.52	0.48	0.167	0.29	0.71	0.000***	0.57	0.43	0.047**
Risk seeking	0.59	0.41	0.026**	0.89	0.11	0.000***	0.53	0.47	0.427

Notes: 'Yes' for agricultural practice adopted and 'No' for agricultural practice not adopted
, ** and * significant at 10%, 5% and 1% probability of error, respectively*

5. 4. 2. Smallholder farmers' adoption decisions for sustainable agriculture

This section assesses the adoption rate of farmers in relation to these agricultural practices (see section 5.3.1). Their adoption decisions are grouped into four decision types (a) farmers who are currently adopting the agricultural practices (b) farmers who have never used the practices but plan to experiment with them next year (c) farmers who have previously used but abandoned the practices and have no plans to adopt them again (d) farmers who have never used the practices and have no plans to adopt them in the future. Accordingly, farmers were asked whether they are currently adopting the agricultural practices and (if not) whether they are planning to adopt them in the future.

Table 5.3 shows that, given the unweighted mean, on average, nearly half of the farmers in the area (53%) are currently adopting the selected agricultural practices to improve agricultural productivity and maximise yields. While about 30% represent farmers who have never used the practices before, but would like to adopt them in the future, about 6% adopted them previously but discontinued and have no plans to adopt them again. As stated in the focus groups, this might be due to labour bottlenecks, limited cultivated farms, limited financial resources and issues of ageing.

More explicitly, about 46% of the farm households have applied agroforestry systems on their field plots. This indicates that more than half of the farm households in the area have not adopted the practice. About 34% have already planned to use agroforestry systems next year (currently not adopting) while about 14% do not have any plans to adopt them. About 6% of smallholder farmers who had not adopted the practice during the survey were using it before but terminated the practice for some reason and have no plans to adopt it again.

Farmers can also use organic matter as organic fertilizer (compost) to improve productivity, thereby ensuring food security (Ibrahim et al., 2008; Ouédraogo et al., 2001). Table 5.3 indicates that about 55% of smallholder farmers have applied compost to their field plots. Some farmers are not currently applying compost to enhance productivity. About 28% have never used compost, although they have plans to use it next year; about 11% have never used it before and do not have any plans to use it even in the future, and about 6% have used it previously but have currently stopped and have no plans to use it again. This figure is by far higher than was found in Vietnam, where only about 2% of farmers applied compost to enhance farm yields (Van Thanh & Yapwattanaphun, 2015).

Use of crop rotation with legumes is expected to improve soil fertility and productivity, thereby increasing farmers' income (Gan et al., 2015; Martin-Rueda et al., 2007). As indicated in Table 5.3, about 59% of the farmers have recently adopted cereal-legume rotational practices (wheat and barley with peas and beans). 41% of farmers in the area are presently not adopting crop rotations. About 5% of the farmers used it formerly but have currently discontinued, and have no plans to continue in the future, while about 26% of the farmers have never used it but have plans to apply it next year, and about 10% have no plan to use crop rotations.

A point to focus on here is that almost half of the local people in the area are not adopting the agricultural practices. There are also some farmers who have used them previously but stopped applying them. As explained during the focus groups, the reasons are linked to lack of information, shortage of family labour, lack of institutional support and personal characteristics (*see section 5.4.3*). Therefore, it is necessary to understand the limiting factors or constraints that impede farmers from adopting these practices, as well as to identify the reasons for the farmers' decision to abandon the practices.

Table 5. 3. Percentage of farmers who use and plan to use agricultural practices (percent)

Sustainable agricultural practices	Farmers currently adopting the practice	Farmers who plan to adopt the practice	Farmers who have never used and do not plan to adopt the practice	Farmers who previously used the practice but discontinued and do not plan to adopt it again
Agro-forestry systems	46	34	14	6
Compost	55	28	11	6
Crop rotation	59	26	10	5
Mean score	53	29	12	6

5. 4. 3. Reasons for non-(dis)adoption of sustainable agricultural practices

This section assesses constraints that limit farmers from adoption using a survey and focus group discussions because there are some difficulties in sustaining these operations, although many farmers are proactive in adopting agricultural practices. There are also barriers that prevent them from adopting the practices. Farmers were asked an open-ended question about the obstacles that impede adoption, and that make farmers abandon the practices.

Different factors were identified. The responses are not specific to non-adoption or dis-adoption, and not to specific agricultural practices. They are general reasons for sustainable agriculture as a whole. Based on their similarity, they are summarized into six constraints: lack of information, insufficient landholdings, lack of financial resources, limited institutional support, labour shortages and personal characteristics. Some could be reasons for non-adoption and others also for dis-adoption. Some could be reasons for specific practices while others could be for general sustainable agriculture. Figure 5.1 presents the results of the responses.

Similar constraints were also reported in Ethiopia, Nigeria and Tanzania, such as limited land, lack of knowledge, lack of capital, lack of information, and lack of support (Shiferaw, 2014); lack of knowledge, lack of land ownership, labour shortages, lack of information and lack of credit (Obayelu, Adepoju, & Idowu, 2014); and lack of knowledge about the benefits, limited land size and high dependency on short-term benefits (Hillbur, 2014). In Iran, the high cost of agricultural practices, the weak economic status of farmers, low profitability, low technical knowledge, failure to provide credit, lack of support services, and complexity of practices were found to be the main barriers to the adoption of agricultural practices (Kheiri, 2015).

a) Inadequate information and technical knowledge

Farmers should understand how sustainable agriculture would benefit them in the long term (Rodriguez, Molnar, Fazio, Sydnor, & Lowe, 2009). They should also have the knowledge and skills to effectively implement, especially, some agricultural practices (Zeweld, Huylenbroeck, Tesfay, & Speelman, 2017). Besides, they should also have relevant information about them (Rogers, 1983). In this respect, about 82% of farmers in the areas have claimed lack of information and knowledge as the main barrier to adoption of sustainable agriculture.

This is also confirmed in the focus groups. Unless farmers are aware of the advantages and attributes of improved agricultural practices, they are less likely to adopt them. They need to have the necessary skills on how to use and apply them, for example, organic compost. They should be informed about the attributes and benefits of newly introduced agricultural practices, for example, minimum tillage, on their farmland and the environment.

Related reports were found in the literature that poor access to information has often been blamed for the limited spread of improved technologies (Drechsel et al., 2006). In the US, lack of knowledge was found to be an obstacle for producers to adopt grassed waterways (Reimer, Weinkauf, & Prokopy, 2012) and lack of knowledge and information as a barrier to convert from conventional farming to sustainable farming and to implement either minimum tillage or no-tillage in Europe and Asia (ESCAP 2007). Lack of information and technical assistance impeded many Iranian farmers from adopting sustainable farming practices (Kheiri, 2015).

b) Weak (limited) institutional support

As stated in the literature, insufficient government support decelerated the adoption and expansion of technological innovations (Rodriguez et al., 2009) and lack of technical assistance was frequently regarded as a barrier to adopting conservation practices (Fazio et al. 2007). Farmers have often favoured the status quo due to fear of failure and it is necessary to contravene the conventional wisdom built up over thousands of years about the traditional practices and show them that the new practice works effectively (ESCAP 2007). Farmers have often perceived that extension workers and government personnel lack technical knowledge to help them to adopt sustainable agricultural practices (Kheiri, 2015).

In the area under consideration, lack of technical assistance and incentives is mentioned as a problem by about 78% of the farmers. This is ranked the third most serious barrier in the focus groups. People can fear new (improved) practices as they do not fully understand their attributes. They may fail or have an irreversible impact. The solution is to organise training and provide technical and financial support. Farmers have to see some successful practices in demonstration sites to incentivize them to adopt the practices on their farm and to convince themselves that they work. Model farmers should be encouraged and increased in number, even with the use of financial support, so they can influence and exert pressure on other farmers to adopt sustainable agriculture.

For introduced agricultural practices, such as improved seeds, new livestock breeds, biological disease control and row planting, farmers may perceive them to be new and incompatible with their existing traditions and cultural norms and would remain uncertain, at least, at the beginning. In this case, they need information through technical training or exposure visits to raise their awareness of the attributes that would then inspire them to adopt. Unless farmers are technically or financially supported, they are likely to wait until they have observed the success or failure of others. For example, for new livestock breeds, the government could give these to some farmers for free so that their friends and neighbours could visit and observe the benefits.

There are farmers' training centres in each village. Extension workers are assigned to technically assist farmers in the application of technological innovations and improved farming practices. They are responsible for enhancing awareness and reducing uncertainties through short-term training, and agricultural field days. In spite of this, lack of technical assistance and inadequate information are still considered to be the main barrier to adoption. This shows that extension services in the country seem weak. Also, extension agents may lack either motivation or competence to capacitate farmers and encourage them to adopt sustainable agriculture.

c) Shortage of family labour supply

Figure 5.1 shows that about 66% of the farmers have expressed shortages of family labour as a barrier to implementing sustainable agriculture. In the focus groups, this is ranked the first serious impediment to adoption. Farmers who have engaged in the adoption of sustainable agriculture are demanding to use less chemical fertilizers, pesticides and herbicides, which are harmful to ecosystems, and this increases their dependence on human labour. This also requires a huge commitment and more time to operate on the farms, for example, removing weeds.

In the literature, shortage of labour was reported as a main constraining factor for using crop residue management systems, minimum tillage and planting of multipurpose trees (Kheiri, 2015). It also dissuaded farmers from adopting soil and water conservation in Sub-Saharan Africa (Drechsel et al., 2006). Furthermore, labour bottlenecks prevented farmers from adopting sustainable agricultural practices in eastern and southern Africa (Fisher et al., 2015).

As explained in the focus groups, children are enrolled at schools due to education-for-all and are less likely to fully engage in agricultural activities. In the area under consideration, some adults prefer to move to Arab countries or urban areas to find better jobs. They believe that they would get a higher income than they would gain from farms. For this reason, they are less interested in agricultural work and the opportunity cost of working on farms seems higher for them. Therefore, farming for these people seems unproductive or unprofitable.

This suggests that old farmers remain on the farms and they are less likely to adopt agricultural practices that need more labour and time. Since the limited availability of family labour is a serious constraint in the area, the opportunity cost of youths and adults should not be neglected in the promotion of sustainable agriculture. Therefore, focus should be given to sustainable agricultural practices that demand less labour during implementation.

d) Small size of landholdings

Size and ownership rights to land were reported in the literature as a barrier to adoption in both developed and developing countries. For example, farmers with insecure property rights had no clear vision of the future and therefore degraded the environment unintentionally (Arellanes & Lee, 2003; Kheiri, 2015); and some producers wanted to adopt grass waterways but the landlords did not want this. Some wanted to adopt, but had very limited farmland size. Others owned large areas of farmland, but they did not want to adopt the practices (Reimer et al., 2012).

In the study area, the average landholding size is about 0.5ha. This small size is mentioned by about 54% as a deterrent to adopting sustainable agriculture, such as the construction of water harvesting schemes. This is also expressed by the focus groups as one of the most severe barriers to adoption. In reality, however, it has been observed that some farmers who have large areas of farmland have allocated sufficient land, especially marginal areas, to adoption. Some farmers with small areas of land have also used improved agricultural practices to increase yields and productivity.

e) Shortage of financial resources

Money is an important factor in the adoption and widespread use of technologies (Reimer et al., 2012). Shortage of financial resources is regarded by about 48% as a barrier to adoption. This is supported by the focus group participants who mentioned that it is one of the difficulties, particularly for the application of water harvesting schemes and improved varieties. Previous studies have found mixed results. Two-thirds of producers in the Indiana watersheds did not adopt grassed waterways because it was expensive and time-consuming to install and maintain them (Reimer et al., 2012). Adoption progressed slowly due to lack of funds to stimulate participation (Rodriguez et al., 2009). Many Iranian farmers have transited from conventional to sustainable farming after the government provided economic incentives (Kheiri, 2015).

Conversely, it was reported that farmers did not need advanced equipment, agrochemical inputs and fuels to implement sustainable agriculture (Fazio et al. 2007; Lee 2005). It was also reported that economic resources and rural facilities insignificantly influence farmers' intentions to adopt sustainable agriculture, particularly minimum tillage and row cropping systems (Zeweld et al., 2017). Many types of agricultural practices are implemented with locally available inputs and on-farm inputs with very limited external inputs, such as chemical fertilizers. However, money is still needed to implement some practices that need resources, also to incentivize farmers to participate and to enhance awareness of the practices. Therefore, there is a positive correlation between financial incentives and the adoption of sustainable agriculture.

f) Farmer-specific characteristics

Age of the farmers, farming experience, attitude towards sustainable agriculture, and familiarity with sustainable agriculture are viewed by about 40% of the farmers as obstacles for adoption. Some were also identified as barriers in the focus group discussions. Some old farmers who were ready to retire and had a short time span to see the benefits perceived the use of sustainable agriculture to be unfeasible and they preferred traditional practices. Some farmers needed an immediate benefit, and therefore they were not keen to adopt agroforestry systems, and soil and water conservation measures.

Under normal circumstances, some farmers were more reluctant to change their traditional practices than others, and they were not willing to adopt even with financial support. Furthermore, some farmers who were not confident would need to be late adopters. Since they often questioned the feasibility, they decided to wait and see other successful farmers. Finally, some farmers were uncertain whether the introduced (exogenous) practices were compatible with their current production systems and whether they were profitable.

Kheiri (2015), Hall et al. (2010) and Fazio et al. (2007) found that the livelihoods of some farmers were highly reliant on natural resources and they were less likely to support managed community forests. Because of aversion, some were found not adopting sustainable agriculture because they considered it too risky for them. Age and farmers' attitudes, were also found to impede farmers from adopting sustainable agricultural practices (Barreiro-Hurlé, Espinosa-Goded, & Dupraz, 2008; Hall et al., 2010; Kheiri, 2015; Reimer et al., 2012; Rodriguez et al., 2009). Furthermore, unwillingness was found to be a reason for non-adoption and dis-adoption of drought-tolerant maize varieties, water harvesting schemes and other practices in eastern and southern Africa and Colorado (Drechsel et al., 2006; Fisher et al., 2015; Presley, 2014)

In general, farmers are able to identify numerous obstacles to the adoption of sustainable agriculture and these help us to focus on two specific strategies to stimulate adoption; namely, information and institutional support. At least at the inception stage of adoption, which is often the uncertain stage, it is necessary to raise farmers' awareness and provide them with technical and financial support. Therefore, agricultural extension agents are needed to improve their competence towards sustainable agriculture to motivate farmers to adopt. Farmers should also be informed about the potential benefits, limitations and attributes to prioritise sustainable agriculture as a means of improving productivity and livelihoods.

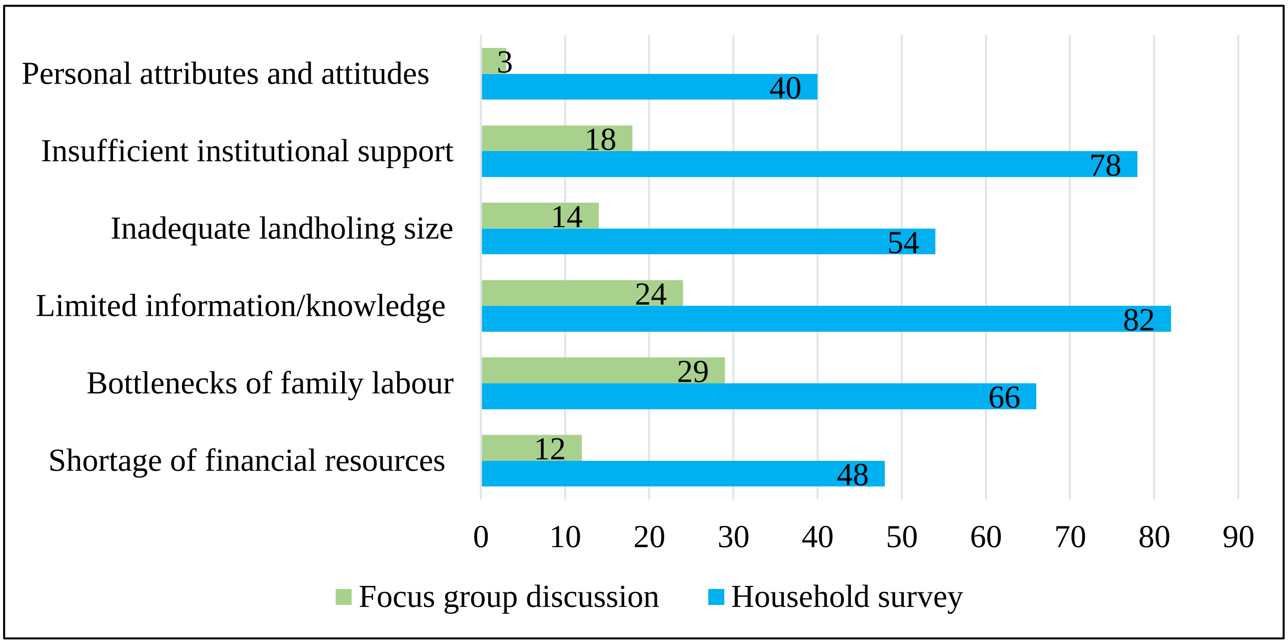

Figure 5. 1. Reasons for dis/non-adoption of sustainable agriculture identified by farmers (%)

5. 4. 4. Determining factors for adoption of sustainable agricultural practices

This section explores factors that influence farmers' decisions to adopt agroforestry systems, compost and crop rotation. Variables are found to be normally distributed. Multicollinearity is also not a problem. As indicated in chapter 4, some socio-psychological factors are highly correlated with risk aversion and risk seeking dummy variables. We have used risk attitude[6] instead of aversion and risk seeking in the multivariate model. However, risk attitude is also highly correlated with personal efficacy. Accordingly, personal efficacy is then dropped from the model. Robust standard errors estimation is used to correct for potential heteroscedasticity.

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[6]. *As indicated in chapter four, 22 risk-related statements, which measured overall risk behaviour of farm households, are loaded into five risk factors or domains. Accordingly, risk attitude in this chapter, represents the average sum of the values of the 22 statements in the dataset. Thus, value of risk attitude ranges from 1(the most risk averse) to 5 (the most risk seeking behaviour). The higher the value of the risk attitudes, the higher would be the willingness of farmers to choose risky activities (risk seekers=less risk averse) while the lower value represents the more risk averse farmers.*

Table 5.4 presents the results of the multivariate probit, which is estimated using the maximum likelihood method.

The Wald chi-square test indicates that the estimated model is significant overall. The slope coefficients are jointly different from zero, suggesting that the model has a strong explanatory power. The rho likelihood ratio test also shows that the correlation of the error terms across the three different equations is statistically significant. This implies that the choices for these practices are interdependent; a positive coefficient for complementary effect and a negative coefficient for substitution effect, for example, compost and crop rotation (ρ=-0.26) are substitutable, while agroforestry systems and compost (ρ=0.31) are complementary. Agroforestry systems and crop rotation are unrelated, since they have no significant correlation.

As indicated in Table 5.4, education, labour supply, social capital, risk attitudes, farming experience, extension services and attitudes are factors that significantly affect farmers' choice to adopt agroforestry systems, crop rotation with legumes, and compost application. However, landholding size, religion, and special skills are found to be insignificant. With regard to these variables, some previous empirical studies have reported mixed findings (Arellanes & Lee, 2003; Ngombe, Kalinda, Tembo, & Kuntashula, 2014; Van Thanh & Yapwattanaphun, 2015).

In the literature, previous innovation was found to be a potential predictor in the adoption of ecologically sustainable practices (Menozzi et al., 2015), conservation tillage practice and herbicide-resistant cotton varieties (Ban Banerjee et al., 2009). In this regard, farming experience is used to approximate previous innovation of farmers and is proposed to have a positive effect on current adoption. The results of the study show that farming experience has a significant positive effect on the adoption of agroforestry systems and a negative effect on compost application.

This suggests that farmers with more farming experience are unlikely to adopt compost because application of compost is negatively correlated with experience. This might be linked to age and negative experience. Firstly, preparation of compost is not easy. It is labour intensive and time-consuming to collect the organic materials used for compost from different sources and to prepare the compost. Since there is a strong correlation between age and farming experience (chapter 4), these factors might explain a dislike by more experienced farmers for compost. Secondly, the negative past experiences of farmers in the area might be a particular reason. For example, silkworm trees were given to farmers and they planted on their field plots, but no-one (neither the government, researchers nor NGOs) provided them with the insects. Accordingly, they abandoned the silkworm trees from their field plots after four years.

Concerning risk attitudes, the more willing the farmers are to take risks, the higher their risk attitudes, the less inclined they are to implement any risk-reducing strategy. An individual who is more (less) willing to take risk will have a lower (higher) subjective/perception of risks (Van Winsen, 2014). For this fact, we include farmers' risk attitude in the model, which is a proxy variable for uncertainty or aversion. Table 5.4 indicates that risk attitude is negatively related to the probability of adopting compost, whereas it is positively related to the probabilities of adopting agroforestry systems and crop rotation.

Some factors can indicate positive effects of risk attitudes on the adoption of agroforestry systems and crop rotation but negative impacts on the application of compost. Assuming that risk seekers (less risk averse) have more livestock than risk averse farmers, risk seekers may not prefer compost because they need the organic materials for their livestock, for example, weeds, farm waste, leaves. However, this may not work for risk averse farmers. Risk seekers may also prefer other practices (animal manure, agroforestry systems, crop rotation) to compost due to the labour and time demands of compost preparation (collecting, mixing, etc.).

With regards to agroforestry systems, farmers have to purchase the seedlings (permanent fruit, Moringa trees, mulberry or silkworm trees, livestock forage) and these trees also require some time before harvesting. Accordingly, the cost and time implications may lead risk averse farmers not to use agroforestry systems or use them less. However, this may not work for risk seekers. In addition, shrubs, eucalyptus, acacia trees, olive trees and other trees often compete for land with crops. Due to their small landholdings, risk averse farmers may be less likely to use agroforestry systems, but risk seekers may not care about the size of the land as long as these practices have opportunities for them.

Several authors report that risk-averse farmers are more reluctant to adopt agricultural practices and have a lower probability of adoption decisions compared to risk seekers. Examples of a lower adoption by risk averse farmers include Yu et al. 2014 for improved technologies; Ghadim et al. (2005) for pro-environmental land management practices and Liu 2013 for sustainable agricultural practices until adequate information is available. However, Van Winsen (2014) found the opposite. It is stated that risk attitude, which measures to what extent a person is willing to take or to avoid risk, was found to have a negative influence on the intended and actual adoption of risk management strategies. Higher risk attitudes mean a greater willingness to take risks and a lower likelihood of implementing risk strategies.

It has been shown that information is an important input in making farming decisions; a decision to use sustainable farming practices was positively shaped by the availability of technical information (Fazio, Baide, & Molnar, 2014) and a lack of information hindered adoption of sustainable practices (Tutkun, Lehmann, & Schmidt, 2006). Uncertainty (or aversion) is reduced when information is diffused, which motivates the uncertain group to adopt improved technologies (Liu, 2013). Therefore, access to alternative information sources (mass media and extension services) is included in the model to investigate the potential effects of information on implementing agricultural practices. The probability of farmers adopting them increases if they have access to alternative information. With adequate information on the attributes of agricultural practices, farmers reduce their uncertainties and that enables them to be more willing to adopt them.

Specifically, extension services have a significant and positive effect on the adoption of agroforestry systems and crop rotation with legumes. At village level, there are some agricultural extension agents who are assigned by the government to advise farmers about improved technologies and agricultural practices. They can help them to become aware of their attributes, advantages and disadvantages. Several authors: Van Thanh & Yapwattanaphun (2015) in Vietnam, Kassie et al. (2013) in Tanzania, Barham et al. (2014) in the US, Manda et al. (2016) in Zambia and Okuthe (2014) in Kenya reported that extension agents positively influenced the adoption of improved farming practices. Farmers are more likely to adopt improved farming practices if they have frequent contacts with public extension agents since they have shown and encouraged them (how) to apply the farming practices.

As stated in chapter two, some farmers in the area have access to television or radio, which helps them to obtain agricultural information, because agricultural issues are sometimes broadcast nationally through these devices. The findings show that the media has a significant positive influence on the implementation of compost but an insignificant effect on the adoption of agroforestry systems and crop rotation with legumes. It seems that the use of compost, including the process of preparing it, is broadcast by the government media agency.

In line with this result, it was reported in the literature that the presence of radio or television positively influenced the adoption of insect-resistant corn, drought-tolerant soybean varieties, and conservation practices (Barham et al., 2014; Gumataw et al., 2013; Okuthe, 2014). Conversely, farmers' access to a mobile phone (Gumataw et al., 2013) and radio (Ngombe et al., 2014) were found to insignificantly affect the adoption of improved farming practices.

The availability of labour supply is an important determinant of adoption decisions (Menozzi et al., 2015; Wollni et al., 2010). In smallholder systems, household size can be a proxy variable for family labour endowment. The larger the family, the more labour is available, not only for agricultural production but also for non-agricultural activities. Therefore, a large family does not suffer from a shortage of labour supply. Here labour supply is found to have a significant positive effect on the adoption of compost, but an insignificant effect on agroforestry systems. This suggests that agroforestry systems require less labour while compost demands more labour, and thus the probability for using compost is higher for large families. Therefore, a large labour supply allows farmers to execute sustainable agriculture.

We also see the potential effect of education on the adoption of agricultural practices, because education improves awareness of farm households about technologies and improved practices, and also enables them to achieve greater efficiency in farming production (Manda et al., 2016). Table 5.4 shows that literate farmers are more likely to apply agroforestry systems, crop rotation with legumes, and compost to enhance productivity and yields, compared to illiterate farmers. When observing Table 5.2, literate farmers show a greater preference for agroforestry systems and crop rotation but less preference for compost. Therefore, education is important to enhance awareness and promote the adoption of sustainable agricultural practices.

In this regard, previous studies have reported mixed findings; farmers' education was found to have an insignificant impact on adopting conservation tillage and herbicide-resistant cotton varieties (Ban Banerjee et al., 2009) but a significant positive impact on the adoption of insect-resistant corn and soybean varieties (Barham et al., 2014) and the adoption of a greater number of sustainable practices (Van Thanh & Yapwattanaphun, 2015; Wollni et al., 2010). Education can, therefore, be positively correlated with the use of sustainable agricultural practices.

In almost every rural village in Ethiopia, farmers' training centres have been established and equipped (partially) with the necessary human resources and physical facilities with the aim of transferring knowledge about new (improved) farming practices and technologies. These centres have served as demonstration sites. Capacity building training or demonstrations have often been organised in these centres, especially by practitioners, to transfer technological innovations and improved farming methods. The centres are also used to store improved inputs, such as chemical fertilizers, improved seeds, pesticides and herbicides so that farmers can obtain these inputs from the centres.

Table 5.4 illustrates that technical training has a significant positive effect on the adoption of compost, but it does not affect agroforestry systems and crop rotation. This suggests that compost requires practical training and field trials to see how it is prepared and implemented while this is not the case for the other practices. Previous studies have confirmed that participation in farm-level demonstrations or capacity building training contributes positively to farmers' decisions to adopt sustainable practices, such as farmyard manure, seeds of improved varieties, crop rotation and green compost (Bonabana-Wabbi et al., 2016; Kassie et al., 2013; Okuthe, 2014).

In this study, social capital includes both relational capital and group membership. Formal organizations (e.g., farmers' associations, resource users' groups and cooperative societies), and interpersonal interaction and informal communication among local community groups help farm households in the area to exchange information, to harmonise their beliefs and attitudes, and to overcome resource constraints. Table 5.4 confirms the positive effect of social capital on the adoption of agroforestry systems, grain-legume rotational practices and compost. This constitutes evidence that formal organizations, neighbours, friends and other community groups stimulate smallholder farmers to adopt sustainable agricultural practices.

Previous studies have documented the positive effect of social capital on adoption in the way that the number of sunflower adopters increased when there were strong social ties among friends and families (Bandiera & Rasul, 2006); peers and family members shaped the demand for protecting and preserving land and water resources (Fazio, Baide, and Molnar 2014). The positive impacts of agricultural leaders on the adoption of sustainable environmental practices have also been documented (Price & Leviston, 2014). A positive impact of social pressure was observed for the adoption of organic agriculture (Hattam, 2006) and membership of farmers' organizations was found to positively affect the adoption of agricultural technologies (Bonabana-Wabbi et al., 2016). Additionally, farm households who are adopting some sustainable agricultural practices could influence other farmers around them to adopt different agricultural practices (OECD 2001).

It is recognized from chapter three that farmers' attitudes[7] are constructed from observed statements relating to perceived easiness, perceived usefulness and perceived compatibility of agricultural practices (Taylor & Todd, 1995; Zeweld et al., 2017). The findings indicate that attitude has a significant and positive effect on adopting crop rotation with legumes and compost application. Farmers who have highly positive attitudes towards both practices are more likely to adopt them. This suggests that they have perceived those practices as useful for them, easy to understand, learn and adopt, and they are compatible with their existing farming values and traditions. But farmers' attitudes towards agroforestry systems are not linked to their

[7]. *Attitude consists of three components, such as perceived usefulness, perceived easiness and perceived compatibility which respectively represent whether the practices improve farm yield and farmers' income, whether they are easy to understand, learn and operate, and whether they closely complement existing farming traditions and current needs.*

adoption. Therefore, positive attitudes have significant impacts on inspiring farmers to implement agricultural practices.

Similar findings were reported previously, such as the significant positive impacts of attitudes on adopting ecological focus areas and private sustainability schemes (Menozzi et al., 2015), using agri-environmental schemes, such as environmental fallow and use of alternative crops in special protected areas (Barreiro-Hurlé et al., 2008), implementing pro-environmental agricultural practices (Price & Leviston, 2014), converting to organic agriculture (Hattam, 2006) and adopting agricultural practices (Hall, Dennis, Lopez, & Marshall, 2009; Van Thanh & Yapwattanaphun, 2015). Perceived advantages and perceived compatibility were found to be significant predictors for adopting conservation tillage, grassed waterways, filter strips and cover crops in the US (Reimer et al., 2012).

Wollni et al. (2010) stated that the application of conservation practices and integrated soil management techniques requires farmers to learn new skills and knowledge to determine the functioning of the soil and the impact on agricultural yields. Following this, personal efficacy (farmers' knowledge, skill and competence) is included to understand its impacts on adoption decisions. As indicated in chapter three, five different statements related to internal qualities of farm households are loaded to personal efficacy. But farmers' abilities and competence are removed from the model due to the multicollinearity effect with risk attitudes.

Previously, the perceived ability, which represents farmers' competence and experience, was found to positively influence farmers' intentions and adoption of organic avocado production. Growers who had a negative perception of their abilities were less likely to become involved in organic production (Hattam, 2006). A self-concept that includes personal norms and personal competence, was also found to positively predict sustainable practices (Price & Leviston, 2014).

As explained by Taylor & Todd (1995), rural facilities and capital resources retard or expedite decisions to adopt technological innovations. Accordingly, perceived resources are included to determine how this influences the adoption of sustainable agriculture. Based on factor analysis, three observed statements relating to the impacts of resources and facilities (*see Annexe 2.2*) are loaded to perceived resources, which has a significant positive effect on compost. Farm households can apply compost if economic resources are not perceived to be obstacles. Additionally, special skills and access to credits, which show financial capacities, have insignificant effects on all these agricultural practices. This may indicate that these practices may not require purchased inputs or may not need institutional support for their implementation.

The result, however, is inconsistent with the existing evidence, where perceived control, which shows the influences of economic resources and physical facilities, was found to be a significant predictor for the adoption of environmental practices (Menozzi et al., 2015) and the adoption of land management practices (Price & Leviston, 2014). An individual decision to implement sustainable practices was also positively shaped by infrastructure and necessary resources (Fazio, Baide, and Molnar 2014). In addition, the availability of resources, such as money and access to credits had a positive influence on the use of seeds of improved varieties, chemical fertilisers and sustainable agricultural practices (Ngombe et al., 2014; Okuthe, 2014).

In some previous studies, gender had an undefined effect on adoption (Teklewold et al., 2013; Yu et al., 2014). In this study, the gender of the farmers has a significant positive effect on the adoption of agroforestry systems and compost, but it has an insignificant effect on the adoption of crop rotation. Female-headed households might be less likely to adopt compost owing to time constraints since they are responsible for all household activities. Preparing compost is also not an easy task because it is labour intensive. Accordingly, males may be relatively physically stronger than females to perform these labour-intensive activities. Therefore, the probability of implementing compost as organic fertilizers is higher for male-headed than for female-headed households.

In the area, the livelihood of most farmers relies on mixed farming: both livestock and crops. Farmers with more livestock and large landholdings are more likely to have a higher output and income and to be wealthier. Livestock are sources of food, biogas, manure and income. Manure can be a complementary or substitutable for other practices. As indicated by the results, the physical quantity of livestock (TLU) reduces the application of compost, but it does not affect agroforestry systems and crop rotation. This suggests that the number of livestock has a significant negative impact on the probability of farmers adopting compost.

This might be linked to two explanations. Firstly, farmers could prefer and choose other agricultural practices, for example, such as animal manure. Secondly, there may be a competing effect between the organic materials used to produce compost and animal feeds. In Ethiopia, the organic materials used for compost, such as weeds, farm waste, leaves and food waste are often given to animals. Consequently, farmers who have animals prefer not to use compost.

However, the results for agroforestry systems differ from observations in the area. Farmers have often collected fodder and forage from multipurpose trees. The leaves of various trees, such as acacia trees and other local trees are used as animal feed. They have collected grasses and forage from the managed and exclosure areas via cut-carry feeding systems. Despite this, livestock insignificantly affects agroforestry systems. In previous studies, mixed findings were reported. Livestock did not affect the adoption of crop rotation, inorganic fertilisers, conservation tillage and improved seeds (Teklewold et al., 2013), while a higher likelihood of adopting agroforestry was reported with a larger number of livestock (Zerihun, Muchie, & Worku, 2014).

Annexe 5.1 presents the determining factors for the aggregate number of sustainable agricultural practices adopted. The results of the ordered probit model reveal that education, labour supply, social capital, attitudes, risk attitudes, extension services, technical training and perceived resources have significant effects on the number of sustainable agricultural practices adopted. However, demographic variables (farming experience, gender and religion), landholding size, credit access, special skills, agroecology and possession of a radio or television are not associated with the number of sustainable agricultural practices used.

Obviously, membership in formal rural organizations and relationships with local community groups (social capital) have a positive spillover for smallholder farmers to adopt more and various sustainable agricultural practices. Because of the uncertainty issues, it is obvious that more risk averse farmers are less likely, while risk seekers (or less risk averse) are more likely, to adopt more agricultural practices. Literate farmers are more likely to adopt a number of agricultural practices than are illiterate farmers. This might be linked to awareness of the attributes and benefits.

As indicated in the ordered model (Annexe 5.1), livestock tends to impede farmers from adopting more agricultural practices. Livestock ownership does not encourage smallholder farmers to adopt a number of sustainable agricultural practices. This suggests that there is a negative relationship between livestock and some practices of sustainable agriculture. This might be due to some explanations. Firstly, it seems that animal husbandry and other farming practices can compete for time and labour.

For example, production of leftovers (or crop residues) has been often used for livestock feed. The organic materials used for compost have been also used as livestock feed. In addition, most sustainable practices, for example, completely managed, rotational grazing system, and planting multipurpose trees, do not encourage free grazing of meadows and communal areas and therefore compels to reduce the size of livestock. This could not be favoured by most farmers because they prefer free grazing even if they understand that it is not sustainable.

The unexpected result here is the negative effect of extension services (to adopt one sustainable farming practice) and the insignificant effect of technical training for one or two sustainable farming practices. Practically, extension agents in the area have taught or advised farm households to adopt agricultural practices. Receiving participatory (or experimental) capacity building training has been shown to stimulate farm households to apply more agricultural practices to enhance productivity and yields.

As outlined in Annexe 5.1, the marginal effect of the ordered probit model indicates that farmers who have strong ties, relationships and networks within local community groups, such as neighbours, families, friends and relatives are 5-6% more likely to apply one or more agricultural practices than other farmers. Farmers who are members of formal organizations (and understand their strong influence), such as farmers' associations and cooperative societies, have a 6% higher probability of adopting two or more agricultural practices.

Adoption of two or more agricultural practices increases by about 10% with an increase in the value of attitudes towards five points (strongly agree) while adopting either nothing or only one practice declines by 7-11% if the attitude is positive or increases to five points. This suggests positive attitudes imply adoption of more agricultural practices. For every additional livestock unit, the probability of adopting more practices is reduced. The availability of economic resources and physical facilities does not help farmers to adopt more sustainable agriculture.

With the exception of some variables, the ordered probit and multivariate probit models reported very similar results for the probability of adopting agricultural practices. Also, the target variables (sociopsychological factors), such as attitude, perceived resources, personal efficacy, relational capital, group membership, risk attitudes, information, education and labour supply are found to have joint significant effects on the probability and intensity (number) of adopting agricultural practices, even if not all these variables are statistically significant from an individual perspective. Thus, social and psychological issues are vital to stimulating smallholder farmers to adopt sustainable agriculture that has economic and ecological benefits.

Table 5. 4. Coefficients of the explanatory variables: results of the multivariate probit model

Variables	Agroforestry		Compost		Crop rotation	
	Coefficient	*Robust std. err.*	Coefficient	*Robust std. err.*	Coefficient	*Robust std. err.*
Education	0.286	0.142**	0.276	0.143*	0.077	0.044*
Relational capital	0.111	0.046**	0.102	0.087	0.192	0.087**
Group membership	-0.097	0.087	0.138	0.073*	0.053	0.018***
Technical training	-0.051	0.082	0.041	0.019**	0.078	0.079
Media influence	-0.060	0.088	0.080	0.033**	0.126	0.088
Attitudes	-0.088	0.066	0.033	0.011**	0.054	0.015***
Extension service	-0.199	0.102*	0.055	0.097	0.071	0.022***
Perceived resource	-0.017	0.072	-0.062	0.021**	0.003	0.096
Risk attitudes	0.307	0.114**	-0.035	0.012**	0.081	0.017***
Labour supply	0.040	0.039	0.035	0.015**	0.068	0.039*
Gender (male)	0.126	0.039***	0.102	0.051**	-0.095	0.148
Religion	0.133	0.215	-0.131	0.205	0.169	0.208
Special skills	0.125	0.226	0.293	0.220	-0.082	0.220
Occupation	-0.273	0.150*	-0.106	0.150	-0.277	0.153*
Experience (log)	0.141	0.045**	-0.016	0.009*	0.127	0.129
Livestock	-0.046	0.045	-0.065	0.025**	0.047	0.046
Landholding size	0.461	0.449	-0.377	0.435	0.485	0.449
Flat slopes	-0.279	0.193	-0.206	0.161	-0.209	0.162
Fertile soils	-0.040	0.175	-0.278	0.187	-0.455	0.379
Agroecology	0.386	0.185**	-0.052	0.184	-0.058	0.183
Credit access	0.007	0.208	-0.259	0.200	-0.090	0.203
Constant	-1.781	1.094*	0.946	1.027	0.733	1.049

Overall estimated model test: *Wald chi-square test:* $\chi^2(63)=95.2;\ P(\chi^2)=0.007;\ n=350$

rho Likelihood ratio test: $\rho_{agroforestry}=\rho_{rotation}=\rho_{compost}=0;\ \chi^2(3)=17.3\ \ P(\chi^2)=0.014$

Estimated covariance of the correlation matrix : $rho_{rotation\text{-}compost}=-0.26\ (0.043)$**;

$rho_{agroforestry\text{-}compost}=0.31(0.003)$***; $rho_{agroforestry\text{-}rotation}=0.07(0.105)$

5. 5. Conclusion and implications

In the area, although many smallholder farmers have introduced and implemented sustainable agricultural practices to enhance productivity and maximise yields, there are still a significant number of farmers who have not yet adopted sustainable agriculture. This paper explores major factors that motivate the adoption of sustainable agriculture using cross-sectional data collected from 350 respondents and using an estimation approach with the multivariate probit model together with the ordered probit model.

The key finding of the study shows that the probability of farmers adopting sustainable agricultural practices is significantly affected by relational capital, group membership, attitudes, risk attitudes, education and information. Similarly, education, labour supply, group membership, relational capital, technical training, attitudes, extension services and risk attitudes influenced the number of agricultural practices adopted.

The implication is that some socio-psychological variables, such as social capital, attitudes, risk attitudes, agricultural extension services, formal organizations, relationship with local community groups and education, which have previously been overlooked in the conventional literature but have recently received attention in the contemporary literature, can motivate smallholder farm households and thereby positively foster the adoption of more sustainable agricultural practices.

It is also found that risk aversion and livestock ownership are negatively correlated with the adoption of more sustainable agricultural practices. This justifies that farmers who are risk averse or who have more livestock are less likely to adopt a number of agricultural practices. Accordingly, specific risk-averting strategies are needed to reduce uncertainty and build local resilient systems, and to motivate farmers to focus on quality livestock, for example, providing insurance schemes, arranging credits, giving livestock management training, providing timely information and organizing various capacity building initiatives to enhance awareness.

Therefore, to stimulate adoption and promotion of sustainable agricultural practices, awareness of stakeholders (for example, extension agents, development actors and policymakers) should be enhanced and aversion should also be reduced. Interpersonal and informal interaction and formal organizations should be strengthened and supported. These points would help farmers to build confidence and have positive attitudes towards sustainable agricultural practices.

Chapter Six
Sustainable agricultural practices and their consequences for agricultural production, food security and livelihoods

Abstract

There is limited empirical evidence on how a combination of agricultural practices influences crop production and household welfare even if the combined impact could be high or low due to a complementarity or substitution effect between various agricultural practices. To highlight this, this paper investigates the joint impact of agricultural practices, such as soil and water conservation, retention of crop residues, and application of animal manure on agricultural yields and livelihoods of smallholder farmers. Original cross-sectional data is collected from farm households in six rural villages in Ethiopia using a pre-tested and standardized questionnaire. The data is estimated by using an endogenous switching regression approach to account for potential selection bias from observed and unobserved factors. The results show that education, labour supply, agricultural extension services, attitudes, social capital, risk attitudes, farming experience and soil conditions are factors that significantly affect farmers' decisions to adopt these agricultural practices either in isolation or combination. After controlling and correcting biases from both observable and unobservable confounding factors, it is found that adoption of these agricultural practices significantly increased crop yields, per capita harvests, per capita incomes and per capita assets. Relatively high effects on yields, income and assets have occurred when farmers have used these practices in combination (jointly) rather than in isolation. Furthermore, adoption of these practices also leads to an increase in the number of food secure farmers, for example, by 11% when compared single-practice adopters with non-adopters, regardless of which agricultural practice. This suggests that adoption results in livelihood improvements. Therefore, agricultural production and household welfare can be increased significantly by promoting integrated sustainable agricultural practices in the dryland and water stressed areas.

Keywords: *sustainable practices, yields, income, asset, expenditure, household food insecurity access scale, endogenous switching regression*

6. 1. Introduction

In Sub-Saharan African countries, around 30% of the population remain food insecure and poor and more than 60% live in rural areas (IFAD, WFP and FAO 2015). Food insecurity and poverty are largely the result of low productivity agriculture, which is linked to the low use of improved inputs in rain-fed systems and heavy reliance on subsistence farming (Norton et al. 2010). Agricultural growth could provide a partial solution to this problem because it contributes to food security directly through auto-consumption, and indirectly through income generation (Haddad 2013). These effects of agricultural growth on household food security, livelihoods and poverty are widely acknowledged, for example, by FAO, IFAD and WFP (2015), Muzari, Gatsi, and Muvhunzi (2012) and Norton, Alwang, and Masters (2010).

The question for the less developed countries is how to stimulate growth in agriculture. Agricultural growth is often expected from the expansion of cultivated farmland (extensive margins) or by increasing productivity (intensive margins) (Niragira 2016) as well as enhancing the productivity of land resources, such as soil, water, forest and livestock (Hillbur 2014). An increase in agricultural productivity is believed to result from the application of technological innovations, for example the Green Revolution (Abdulai and Huffman 2014), the introduction of sustainable agriculture (Kaczan, Arslan, and Lipper 2013; Teklewold, Kassie, Shiferaw, et al. 2013), and favourable policy environments (Niragira 2016; Todaro and Smith 2011).

As explained in chapter one, sustainable agriculture is defined as farming systems that use locally available resources and farmers' knowledge and skills (with low use of chemical inputs) to enhance productivity, to build the resilience of local systems, maintain the quality of the environment and to improve household food security. These include, for example, cropping systems, expansion of irrigation, agroforestry systems, integrated pest management, rotational grazing, green compost, laser land levelling, biological controls, improved livestock breeds, soil and water conservation measures, drought-tolerant varieties, crop diversification and manure application (Abubakar and Attanda 2013; FAO 2013; Kaczan et al. 2013; Khatri-chhetri et al. 2016; Van Thanh and Yapwattanaphun 2015).

Intercropping is an example of a sustainable agricultural practice. It is intensively used in Botswana, Kenya, Nigeria, Ghana, Egypt and South Africa. Studies have shown that farmers who applied grain-bean intercropping produced yields more than 70% above those of farmers who applied a pure wheat or bean strand. They also earned at least 25% higher profits. Besides, intercropping was found to suppress weeds, reduce pest or disease infestation, and reduce the risks associated with droughts. Farmers who apply intercropping were more food secure (Tsubo et al. 2005, Adu-Gyamfi et al. 2007, Segun-Olasanmi and Bamire 2010, Amujoyegbe 2012, Chazovachii 2012, Fanadzo 2012, Kuwornu and Owusu 2012, Muzari et al. 2012).

Similar empirical studies exist on crop rotation, for example, in the US, Iran, Kenya, the Philippines, Nepal, Taiwan, Brazil, Nigeria and Pakistan. The results indicate that cereal-legume rotational practices were found to increase crop yields by at least 36%. For example, maize following legumes had 1.3 fold yields compared with maize after maize. It was also found to increase livestock forage, such as wheat straw and corn stover, enhance the fertility and organic matter content of the soils, and improve farmers' incomes. Farmers who applied crop rotation on their field plots were found to have higher welfare than those farmers who were non-adopters (Witt et al. 2000, Sanginga et al. 2002, Wilson and Al-Kaisi 2008, Muthoni and Kabira 2010, Rajan et al. 2011, Mohammad et al. 2012, Lincoln et al. 2012, Ahmad 2013).

In Ghana, the government, along with international organizations, have initiated the Lowland Rice Development Project, which focuses on developing and disseminating soil and water conservation technologies, especially the construction of earthen bunds and ridge channels to create a profitable and sustainable intensive rice production system in the country. Abdulai & Huffman (2014) investigated whether this had significant impacts on yields and net returns. It was found that soil and water conservation technologies increased rice yields by about 24% and net returns by 16%. Thus, the expansion of soil and water conservation technologies increases agricultural productivity, which tends to maximize rice yields and farm income significantly.

Another example of agricultural practices is conservation agriculture, particularly, minimum tillage. This is widely applied, for example, in Honduras, Brazil, Canada and Norway to enhance agricultural productivity, restore soil fertility and circumvent weeds (Arellanes and Lee 2003; Derpsch, Sidiras, and Roth 1984; Ekeberg and Riley 1997; Lindwall and Anderson 1981; Sijtsma et al. 1998). In Norway, for instance, average yields of several crops were, at least, 23%, 52% and 59% higher with deep tine cultivation, shallow tine cultivation and minimum tillage, respectively, than with plough tillage (Ekeberg and Riley 1997). In Honduras, farm plots with minimum tillage were found to produce 31% higher yields compared to field plots without minimum tillage. Due to higher yields, farmers who applied conservation agriculture were found to earn higher farm incomes than counterparts (Arellanes and Lee 2003).

Considering the potential of technological innovations, the government in Ethiopia, along with development actors in the country, have focused on the application of improved technologies and the adoption of sustainable agricultural practices to improve agricultural productivity, maximize yields and facilitate economic development. However, the overall adoption and diffusion of sustainable agriculture and technologies remain below expectations, partly due to household-village-resource characteristics, institutional variables, socio-psychological factors, and infrastructure services (Abebe and Bekele 2014; Jaleta et al. 2016; National Plan Commission 2015, 2017; Teklewold, Kassie, Shiferaw, et al. 2013; Zeweld et al. 2017).

While there have been several empirical studies on the adoption and diffusion of improved technologies, such as high-yield varieties, chemical fertilizers, pesticides and herbicides, the overall literature concerning the driving forces to adopt sustainable agricultural practices is limited. Empirical studies on the impacts of sustainable agricultural practices remain relatively scarce globally (Abdulai and Huffman 2014; Amare et al. 2012; Faltermeier and Abdulai 2009; Jaleta et al. 2016; Kassie et al. 2013; Kassie, Shiferaw, and Muricho 2011; Manda et al. 2016; Teklewold, Kassie, Shiferaw, et al. 2013). These previous studies have shown positive impacts of sustainable agricultural practices on crop yields, especially rice and maize.

Considering these, and bearing in mind that empirical results vary across locations and over time, this study is motivated to undertake research as a case study to highlight the visible and significant impacts of a number of sustainable agricultural practices. Therefore, this chapter assesses the food security situation in the area using the household food insecurity access scale approach. This paper also investigates and estimates how these sustainable agricultural practices impact on crop yields, food security and household welfare.

The rest of this paper is organized as follows. Section two presents the conceptual and econometric frameworks. Section three explains the sustainable agricultural practices selected and studied in this chapter. Descriptive results are briefly discussed here. Section four presents and discusses the main findings. The final section concludes and draws policy implications.

6. 2. Theoretical framework and model estimation

Adoption of agricultural practices may not be random. Farmers themselves may have preferences to adopt the practices for a specific objective, for example, to maximize yields, to protect against erosion and to supply forage for livestock or they might be stimulated by the government or NGOs. This means that adoption decisions can be affected by multiple observable factors and unobservable characteristics of the farmers, such as motivation and managerial skills, which may be correlated with outcome variables. Following this, a two-stage endogenous switching regression (ESR) is used to investigate the impact of adopting agricultural practices on outcomes, for example, agricultural production and livelihoods.

Farmers' choices for individual and combined agricultural practices, taking into account the interrelationships between these practices, are estimated using the first-stage of the ESR or known as a multinomial logit model. The relationship between the outcomes and alternative adoption choices is established using the second-stage of the ESR (=error correction ordinary least square or OLS with selectivity correction terms). The true impact of adoption on outcomes is also estimated using inverse-probability weighted regression adjustment, which indicates the average treatment effects (*selmlog stata command*).

The ESR model is also known as a polychotomous choice selectivity model. It controls for both observable and unobservable biases (Wu, Babcock, and Lakshminarayan 1996) and allows us to obtain both consistent and efficient estimates. Furthermore, it is a good correction for the outcome equations, even when the Independence of Irrelevant Alternatives Assumption (IIA) is not achieved (Bourguignon et al. 2007). Because the model evaluates both individual and combinations of agricultural practices, it captures the interactions or interrelationships between alternative agricultural practices; and, finally, it accounts for self-selection (Wu et al. 1996).

6. 2. 1. Multinomial adoption model

As indicated in the literature, farmers normally take into account potential benefits when making decisions about new (improved) technological innovations (Abdulai and Huffman 2014) and their adoption decisions are often modelled using a random utility framework (Faltermeier and Abdulai 2009; Kabunga, Dubois, and Qaim 2014; Kassie et al. 2011; Teklewold, Kassie, Shiferaw, et al. 2013). Viz., farmers compare the expected benefits from adoption $(U_{ik}(Z_{ik}))$ and non-adoption $(U_{i0}(Z_{ik}))$ and decide to adopt if net benefits exceed zero.

$$U_{ik}(Z_{ik}) = \sum \beta Z_{ik} + v_{ik} \tag{6.1}$$

Where U_{ik} are the expected net benefits (or utility) of farmer $'i'$ choosing an alternative combination of agricultural practices (management decision plan) $'k'$ that depends on a vector of resources and constraints (Z_{ik}) and error terms (v_{ik}). These error terms are identically and independently distributed to capture hidden heterogeneities.

Here, the problem is that the expected net benefits are unobservable, while the choice of adopting or not adopting alternative agricultural practices (s) is observable. Consequently, this latent (or unobserved) variable (D_{ik}^{*}) is derived from the observed variable and can be expressed by a latent variable model as follows:

$$D_{ik} = \begin{cases} 1 iff \quad U_{i1}^{*} > \underset{k \neq 1}{Max} U(Z_{ik}) \\ 2 iff \quad U_{i2}^{*} > \underset{k \neq 2}{Max} U(Z_{i2}) \\ \ldots \quad \ldots \quad \ldots. \quad \ldots. \\ s \quad iff \quad U_{is}^{*} > \underset{k \neq s}{Max} U(Z_{is}) \end{cases} \quad \text{Where for } k \neq s \quad i = 1,2,\ldots n \text{ and } k = 1,2,\ldots s \qquad (6.2)$$

It has been understood that since the farmer can adopt several agricultural practices separately or in combination, they have different possible management decision choices based on a constant-power rule (2^{n}, where n=number of agricultural practices adopted).

The probability that farmer $'i'$ with explanatory variables (Z) will choose decision choice $'k'$ can be given by a multinomial logit model (eq. 6.3). This indicates the factors that affect the adoption of the alternative packages of agricultural practices.

$$P_{ik} = \Pr(s = k / X) = \frac{\exp(\beta Z_{ik})}{\sum_{k=1}^{s} \exp(\beta Z_{ik})} \qquad (6.3)$$

6. 2. 2. Endogenous switching regression

This section describes interactions between the adoption decision choices and the outcome variables. For three agricultural practices, for example, farmers are expected to have eight possible management decision choices (k=1, 2, 3… 8). Suppose k=1 is non-adoption and serves as a base category or reference group while at least one practice is adopted in the remaining choices (k=2, 3, …,8). The conditional expectation of the outcomes for each possible decision plan $'k'$ is given as:

$$\begin{cases} regime\_1: M_{1i} = \alpha_1 Y_{1i} + u_{1i} \quad if \quad k = 1 \\ . \\ regime\_s: M_{si} = \alpha_s Y_{si} + u_{si} \quad if \quad k = s \end{cases} \quad k = 1, 2, \ldots, s \qquad (6.4)$$

Where M_{ik} denotes the outcome variables for a farmer $'i'$ in adoption decision plan $'k'$ while u_{ik} are error terms or uncertainty faced by farmers. The error terms satisfy $E(u_{ik} / Y, Z) = 0$ and $\text{var}(u_{ik} / Y, Z) = \delta^2$. Thus, M_{ik} is observed if the plan $'k'$ is used.

If the two error terms (u_{ik}, v_{ik}) from the two different equations (eq.6.1 and eq.6.4) are dependent, OLS estimates (eq. 6.4) will be biased and inefficient due to the self-selection problem. In other words, OLS can either underestimate or overestimate the outcome effects.

In such a problem, the solution is to follow the multinomial selection-bias correction framework suggested by Bourguignon et al. (2007), which states that consistent and efficient estimates (α_k) can be obtained by inclusion of the selection correction terms of adoption choices (eq.6.3) into Eq.6.4 considering the following linearity assumption.

$$\mathrm{E}(u_{ik} / v_{i1},..,v_{ik}) = \delta \sum_{k \neq s}^{S} r_k (v_{ik} - \mathrm{E}(v_{ik})) \quad where, \sum_{k=1}^{S} r_k = 0 \qquad (6.5)$$

The correlation between $u's$ and $v's$ is summed to be zero. Using this assumption, the equation of the multinomial endogenous switching regression in eq.6.4 can be rewritten as in eq.6.6 below, which is known as the selection bias-corrected outcome equation or second-stage of ESR (Bourguignon et al. 2007).

$$\begin{cases} regime\_1 : M_{1i} = \alpha_1 Y_{1i} + \delta_1 \hat{\lambda}_1 + \omega_{1i} & if \quad k = 1 \\ . \\ regime\_k : M_{si} = \alpha_s Y_{si} + \delta_s \hat{\lambda}_{si} + \omega_{si} & if \quad k = s \end{cases} \qquad (6.6)$$

Where ω_{ik} is independently and identically distributed error terms with an expected value of zero and constant variance, δ_k is the covariance between $u's$ and $v's$; ρ is the correlation coefficient of $u's$ and $v's$ while λ_k is the Inverse Mills Ratio or selection correction term or factor loading computed from the estimated probabilities in eq.6.3 as follows:

$$\lambda_k = \sum_{k \neq s}^{S} \rho_s \left[\frac{\hat{P}_{ik} \ln(\hat{P}_{ik})}{1 - \hat{P}_{ik}} + \ln(\hat{P}_{ik}) \right] \qquad (6.7)$$

Based on Dubin & Mcfadden (1984) in the multinomial choice setting (s), there are two possibilities (a) $'s-1'$ selection correction terms for correcting the multinomial cases and to be included in the outcome equations if there are 's' choices (b) $'s'$ selection correction terms in the more flexible assumptions, one for each alternative decision choice. Here, $'s'$ selection correction terms are included in our outcome equations. The robust standard errors in eq.6.6 are used to account for heteroscedasticity arising from the estimation procedures (λ_k and others).

Often, the two-stage estimation method is criticized for being sensitive to misspecification, for example, lack of identification when the same variables are affecting both adoption decisions and outcome equations (Wu et al. 1996). To solve this problem and enable identification, we follow the exclusion restriction assumption - some selection instruments, such as attitudes and farmer-school are included in the second equation, although obtaining valid instruments that directly affect the adoption decisions, but not the outcomes, is theoretically and empirically challenging. The strength of the instrument is directly observed in the treatment but does not directly influence the outcome functions except through the treatment.

As indicated in the literature (Di Falco and Veronesi 2011, Kassie et al. 2013 and Jaleta et al. 2016), a falsification test that evaluates the validity of the exclusion restriction is used to check whether the instrumental variables are valid instruments. To be valid they should affect the adoption decisions (selection equations) but not the interest variables (outcome equations). If the instrument variables have no significant estimated effect on the outcome equations, the exclusion restriction is not rejected. The exclusion restriction is rejected if the instrument variables have a statistically significant effect on the outcome equations (see section 6.4.3).

Besides, the presence of correlation between field plot-invariant unobserved heterogeneity and observed factors is assumed. In order to obtain consistent estimates and minimize the problem of unobserved heterogeneity, as suggested by Mundlak (1978), mean field plot-varying covariates such as field plot soil fertility, slope and depth, which show missing information, such as farmland quality, are included as explanatory variables in the regression model (Di Falco and Veronesi 2013; Kassie et al. 2011; Wooldridge 2010). However, we did not include field plot distance from homes because they are highly fragmented and small.

The effect of adding these explanatory variables is assessed. Almost all equations reject the null hypothesis that all coefficients for the mean of field plot-varying covariates are jointly statistically equal to zero. Some of the mean plot characteristics, such as fertility level of the field plots, the slope of the field plots, depth of the soils and size of the field plots, are statistically significant, which allows us to estimate the Mundlak effects. The presence of correlation between unobserved household fixed effects and observed covariates is confirmed. Therefore, the inclusion of these variables is important to control for unobserved heterogeneity, for example, quality of farmland conditions.

6. 2. 3. Counterfactual and average treatment effect

The adoption of agricultural practices has direct or indirect effects on crop yields and income (Faltermeier and Abdulai 2009; Kabunga et al. 2014). To evaluate the outcome effect, the relationship between the outcome variables, adoption of the practices and other exogenous variables is already established in eq.6.6 for each management decision plan. The outcome variables (M_{ik}) depend on a set of explanatory variables (X_i), sample selection bias adjusted or corrected adoption decision (λ_k) and normal random disturbance terms (ω_{ik}) to capture the measurement errors and unobservable factors.

A pivotal point here is to understand the treatment effect, including the average treatment effect (ATE), which is the average treatment effect for the whole sample; average treatment effect on the treated (ATT_T), which is the participation effect; and the average treatment effect on the untreated (ATT_U), which is the non-participation effect (El-Shater et al. 2016).

There are several approaches to compute these. The most commonly used approach in the literature is propensity score matching, even if it does not involve parametric or distributional assumptions (Caliendo and Kopenig 2008). It does not account for unobservable variables which affect adoption because it requires a conditional independence assumption (Heckman and Vytlacil 2007; United Nations Development Programme 2009).

Recently, the endogenous switching regression approach, which accounts for observable and unobservable heterogeneities affecting both adoption and outcome equations (endogeneity problem) by simultaneously estimating both functions for each group, has been employed to understand and determine the treatment effects, for instance, the treatment effect of continuous or binary outcomes: Inverse-probability-weighted regression adjustment.

The literature has described how the multinomial endogenous switching treatment regression model addresses selection bias from unobserved heterogeneities, controlling for selection bias due to observed heterogeneities (Abdulai and Huffman 2014; El-Shater et al. 2016; Di Falco and Veronesi 2014; Di Falco, Veronesi, and Yesuf 2011; Manda et al. 2016; Shiferaw et al. 2014; Teklewold, Kassie, Shiferaw, et al. 2013). Following the procedure used to compute and estimate the counterfactual and average adoption effects in these previous studies, we compute the following conditional expectations for each outcome variable, taking into account eq.6.6.

Adopters with adoption decision plans (actual):

$$E(M_{ki} / k = s, X_{ki}, \hat{\lambda}_{ki}) = \alpha_k X_{ki} + \delta_{k\omega} \hat{\lambda}_{ki} \qquad (6.6.1)$$

Non-adopters without adoption decision plans (actual):

$$E(M_{1i} / k = 1, X_{1i}, \hat{\lambda}_{1i}) = \alpha_1 X_{1i} + \delta_{1\omega} \hat{\lambda}_{1i} \qquad (6.6.2)$$

Adopters who had decided not to adopt the decision plans (counterfactual):

$$E(M_{1i} / k = s, X_{ki}, \hat{\lambda}_{ki}) = \alpha_1 X_{ki} + \delta_{1\omega} \hat{\lambda}_{ki} \qquad (6.6.3)$$

Non-adopters who had decided to adopt the decision plans (counterfactual):

$$E(M_{ki} / k = 1, X_{1i}, \hat{\lambda}_{1i}) = \alpha_k X_{1i} + \delta_{k\omega} \hat{\lambda}_{1i} \qquad (6.6.4)$$

The outcome function (expected yields, assets and income) observed in the sample for adopters and non-adopters is respectively given by equations 6.6.1 and 6.6.2 while equations 6.6.3 and 6.6.4 are their respective counterfactual outcome functions.

These address two questions (a) how would the outcomes have changed had the farmers who have already adopted these practices not adopted them? (b) How would these outcomes have changed if the farmers who did not adopt these practices had chosen to adopt them? These conditional expectations helped us to compute the average adoption effects for adopters or treated (ATT_T) that is defined as the difference between equations 6.6.1 and 6.6.3 (*see eq.6.8*).

$$ATT_T = E(M_{ki} / k = s, X_{ki}, \hat{\lambda}_{ki}) - E(M_{1i} / k = s, X_{ki}, \hat{\lambda}_{ki})$$

$$= (\alpha_k X_{ki} + \delta_k \hat{\lambda}_{ki}) - (\alpha_1 X_{ki} + \delta_1 \hat{\lambda}_{ki}) = X_{ki}(\alpha_k - \alpha_1) + \hat{\lambda}_{ki}(\delta_k - \delta_1) \qquad (6.8)$$

The average adoption effect for non-adopters (ATT_U) can be calculated using a similar procedure (difference of 6.6.2 and 6.6.4 as eq. 6.9). This indicates the counterfactual impact of adoption of agricultural practices on non-adopting farmers if they had adopted the practices (*but we did not estimate this part since it is not relevant to this chapter*).

$$ATT_u = E(M_{1i} / k = 1, X_1, \hat{\lambda}_{1i}) - E(M_{ki} / k = 1, X_{1i}, \hat{\lambda}_{1i})$$

$$= (\alpha_1 X_{k1i} + \delta_1 \hat{\lambda}_{1i}) - (\alpha_k X_{1i} + \delta_k \hat{\lambda}_{1i}) = X_i(\alpha_k - \alpha_1) + \hat{\lambda}_i(\delta_k - \delta_1) \qquad (6.9)$$

Where ATT_T and ATT_U are unbiased estimates of the average treatment effects (since controlling for selection bias) for the treated and untreated farmers. The terms $(\alpha_k - \alpha_1)$ represent the expected change in adopters' mean outcome variable if adopters had the same characteristics as non-adopters, while $(\delta_k - \delta_1)$ denotes the selection term that captures all potential effects of differences in unobserved variables.

6. 3. Research method and data

6. 3. 1. Sustainable agricultural practices studied

In the area, local people have implemented several agricultural practices to enhance soil fertility, water retention capacity and agricultural productivity. Of the various and many farming practices that are commonly adopted in the area, soil and water conservation[1], use of animal manure[2] and retention of crop residues[3] are selected to explore their impacts on farm yields and household welfare (see chapter 2 Table 2.2). These practices are the choice variables. Because of severe soil erosion and land degradation, soil conservation is widely applied in the area. In many parts of Ethiopia, crop residues have been harvested, stored and used for animal feed for centuries. Alternatively, livestock were allowed to graze the residues and green crops on the fields. More recently, some farmers have started to retain the residues in the fields to improve the soil quality (Kassam et al. 2009).

Many studies have found that the application of animal manure increases carbon and nitrogen content in the soils, enhances the chemical and physical properties of the soils, reduces soil erosion and increases water retention. Animal faeces in the form of dung have also been used as fuel for cooking and baking in many rural areas. Manure can also relieve farmers from dependence on chemical fertilizers. The use of animal manure has positive impacts on agricultural production, and leads, in turn, to an increase in income (Fagwalawa and Yahaya 2016; Saleem et al. 2016; Verde, Danga, and Mugwe 2013).

In the literature, soil and water conservation is found to reduce erosion and land degradation and to improve soil fertility by maintaining organic matter content and reducing nutrient losses. It is also found to cut the emission of greenhouse gases. In many areas, water discharge and water holding capacity have substantially improved, which alleviates water shortages and leads to higher yields and incomes (Abebe and Bekele 2014; Ashoori et al. 2016; Fisher et al. 2015; Nyangena and Köhlin 2008; Ochuodho et al. 2014; Prusty, Mishra, and Tripathy 2016).

Some studies were conducted to explore the environmental and economic values of crop residues. Leaving crop residues on the soil surface can reduce water evaporation, prevent soil erosion from water and wind, improve soil structure, and enhance surface water infiltration and retention. These lead to improving farm yields, directly and indirectly, and raise farm incomes and welfare (Agneessens, De Waele, and De Neve 2014; Anderson and Siddique 2015; Blanco-Canqui and Lal 2009; El-Shater et al. 2016; Hobbs et al. 2008; Meena et al. 2015).

These practices are examples of sustainable agricultural practices, which can improve productivity and reduce degradation. They are not mutually exclusive, because farmers can adopt them either separately or in combination. During the survey, farmers were asked whether (or not) they have adopted these agricultural practices and about 51% have retained crop residues on their field plots. About 54% of farmers have used animal manure as organic

[1]. *Soil and water conservation measure (1 if the farmer has used stone walls, soil bunds and bench terracing on private field plot levels and 0 otherwise)*

[2]. *Animal manure (1 if the farmer has applied animal faeces such as dung, chicken poop or other waste as organic fertilisers on private field plot levels and 0 otherwise).*

[3]. *Crop residues (1 if the farmer has retained grain production leftovers such as stalks, straw, stems, leaves, cobs, seed pods and stubble on private field plots and 0 otherwise).*

fertilizer. Finally, 67% of the farmers have applied soil bunds, stone walls and hillside terracing as soil and water conservation measures. About 10% of the farmers have adopted none of these practices; while 20% have used these agricultural practices in combination (see Table 6.1).

While observing adoption separately or in combination, about 17% of the farmers combined soil and water conservation either with the application of animal manure or the retention of crop residues. About 12% of the farmers have solely adopted soil and water conservation but not the other practices. A few farmers either just use crop residues or they combine this with animal manure. This limited number of observations invoked us to merge crop residues only with crop residues and animal manure (to jointly form crop residues and animal manure) in our model to avoid non-convergence problems, as explained by Manda et al. (2016). In this way, seven possible agricultural practice packages are used for the further analysis.

Table 6. 1. Agricultural practices used by farmers separately or simultaneously (percent)

Sustainable agricultural practice packages	Decision choices	Soil and water conservation (C)	Animal manure (M)	Crop residues (R)	Freq.	%
None of the practices	$C_NM_NR_N$	No	No	No	35	10
Soil and water conservation only	$C_YM_NR_N$	Yes	No	No	42	12
Crop residues only	$C_NM_NR_Y$	No	No	Yes	23	7
Animal manure only	$C_NM_YR_N$	No	Yes	No	36	9
Soil and water conservation and crop residues	$C_YM_NR_Y$	Yes	No	Yes	58	17
Soil and water conservation and animal manure	$C_YM_YR_N$	Yes	Yes	No	60	17
Crop residues and animal manure	$C_NM_YR_Y$	No	Yes	Yes	27	8
All these practices simultaneously	$C_YM_YR_Y$	Yes	Yes	Yes	69	20

Note: Subscript ‘Y’ shows agricultural practice adopted while ‘N’ shows agricultural practice not adopted

6. 3. 2. Variable specification and characteristics

Table 6.2 shows outcome variables for this chapter (cereal yields, per capita harvests, per capita income, per capita expenditure and per capita assets). They have been seen commonly in the literature as proxy variables for agricultural production, food security and household welfare (Amare et al. 2012; Kassie, Jaleta, and Mattei 2014). During the survey period, the mean wheat and barley yields per hectare in the area (cereal yields) is about 22 quintals while the corresponding figure for total grain (both cereal and legume crops) production (harvest), adjusted for household size (per capita harvest), is about 6 quintals. The mean annual income and assets[4] adjusted for household size are about €490 and €644, respectively. The average expenditure on food and non-food items corrected for household size is about €129.

[4]. *Assets are computed through the ownership of durable items, such as household items (for example, blankets, beds, tables, chairs, radio/television, kerosene/gas stove, clock, lantern, drinking water device, mobile phones), agricultural items (example, sickle, axe, water pump facilities, storage facilities, plough), and other traditional and modern tools. However, this does not include the value of the house, landholdings and livestock.*

Annexe 6.1 presents summary statistics for explanatory variables across these packages of agricultural practices. We observe that special skills are less important for adopting more practices because of the competing time effect. Farmers who have special skills want to spend more time on non-farm activities and earn additional income from those activities rather than spending more time on implementing agricultural practices. Labour supply is also an important input to adopting more agricultural practices, especially soil and water conservation and the application of animal manure, which demands more labour than other practices. The percentage of literate farmers adopting solely animal manure, or this combined with other practices, is lower, although the adoption of more practices increased with the education level of the head.

In a mixed farming system, livestock are equally important to crop production and therefore livestock ownership affects farming decisions. The descriptive results show that the physical quantity of livestock in terms of TLU also increases with adopting more agricultural practices, particularly when farmers adopt organic animal manure in combination with others. If the farmland is either fertile or has flat slopes, farmers are less likely to adopt more practices, especially soil and water conservation combined with others. The idea of sustainable practices is to reduce erosion and improve fertility so that farmland with flat slopes is less susceptible to erosion and degradation. Farmers in the temperate zone do not adopt crop residues in isolation but they apply it in combination with others, for example, in conserved or manured farmlands.

Concerning the risk attitudes of farm households, less risk-averse farmers (=risk seekers) are more likely to adopt more agricultural practices than those who are more risk-averse because the percentage of risk-taking increases slightly with the adoption of a combination of agricultural practices, whereas it declines for risk aversion. Access to information is expected to accelerate adoption of more agricultural practices. The probability of adopting more combinations of sustainable practices is higher if the farmers have frequent contacts with agricultural extension agents, if they have a television or radio for information, and if they have good relationships, communication and networks with local community groups (friends, neighbours, families and relatives) and local informal groups (*equib and idir*). However, it is too early to conclude this finding on the basis of this descriptive analysis.

Table 6. *2*. Definition and explanation of outcome variables and their means

Variable	Description and measurement of the variables	Mean
Cereal yields	Only wheat and barley cereal produced (hectare) by the household head in 2015 adjusted for landholding size (kg/ha)	2177
Per capita harvests	Total grain production (cereal and legume crops) harvested (kg/hectare) by the household head during 2015 adjusted for household size	603
Per capita income	Total farm and non-farm income of the household head earned in 2015 adjusted to household size (Euro)[5]	490
Per capita assets	The total value of durable and productive goods of the household head (excluding the value of house, landholding size and livestock) adjusted to members of the household (Euro)	644
Per capita expenditure	Total expenditure on food and overall non-food items by the household head in 2015 adjusted for household size (Euro)	129

[5] . *During the time of the survey, the average exchange rate was approximately 1Birr=0.04102 Euro*

6. 4. Results and discussion

6. 4. 1. Food security situation of smallholder farmers in the area

This section assesses the food security status of farmers in the area using a household food insecurity access scale (HFIAS). This is easy and less costly to implement than other food security measuring approaches, for example, the supply and demand approach, anthropometric method, household coping strategies, dietary diversity index (calorie adequacy) and Foster-Greer-Thorbecke (FGT) formula (Knueppel, Demment, and Kaiser 2010). These alternative methods are either technically difficult or require a lot of data, which are costly to collect (Coates, Swindale, and Bilinsky 2007). Apparently, the household food insecurity access scale utilizes data from the experience of farmers on the physical availability and accessibility of food over the last four weeks or one-month period (Knueppel et al. 2010).

HFIAS is based on nine standardized but heterogeneous questions to estimate the prevalence of food insecurity (*see Table 6.3*). These nine generic questions detect the level of concern and lack of access to food variety, quantity and quality, and follow two sequential procedures: a dichotomous question (yes or no) as to whether food insecurity has occurred over the last four weeks. After reflecting this, it follows how frequently this food insecurity has occurred with three pre-determined responses, namely, 'rarely', 'sometimes' and 'often'. Overall, HFIAS is based on a four-point response scale, such as never occurs (no response), rarely occurs (1-3 times), sometimes occurs (4-10 times) and often occurs (more than 10 times). The higher the score the greater is the perceived food insecurity over the last 30-day period.

Table 6.3 presents the percentage of the responses. Concerning food insecurity access-related conditions, which show the percentage of households who responded to a specific occurrence question, for example, for the question '*whether there was a day with no food to eat (Q_7)*', around 3% of the farmers ran out of food often while 4% of them had sometimes experienced food shortages over the last 30 days. Similarly, about 12% of the farmers rarely ran out of food and therefore their family members rarely suffered from a lack of foodstuffs. However, about 80% of the farmers never experienced a shortage of food over the last four consecutive weeks.

Results of HFIAS also explain household food insecurity-related domains by reorganizing these nine questions into three domains (Coates et al. 2007), namely, food anxiety (Q1), which shows uncertainty about household food supply over the last four weeks; insufficient food quality (Q2-Q4), which reveals preference, quality and varieties of food; and inadequate food quantity (Q5-Q9) which elucidates the food intake practices and physical consequences. Thus, these three domains reflect whether farmers have sufficient food in terms of quality, variety and quantity.

Following this and the definition of food security[6], the proportion of 'rarely-often' responses in the anxiety food domain, who have concerns about fulfilling their food needs was about 34%. Considering the unweighted mean, about 28% of the farmers had no access to quality and diversified foods while the proportion of households who did not have access to sufficient food supply was about 27%. Nearly 70% of farmers in the area do not worry about food and therefore

[6]. *The United Nations Food and Agriculture Organization defined food security in 2001 as 'a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' and therefore implying households who answered 'never' are considered as food secure whereas those who responded 'rare-often' are food insecure*

have concurrent access to quality, varied, sufficient and preferred foods, while 30% do not have access to such foods. A similar finding was reported in Kenya by Kabunga et al. (2014). Thus, two-thirds of smallholder farmers in the area are food secure while the others are not.

In a similar way, when evaluating the mean of the unweighted HFIAS value, the column 'never' indicates 72%, which means that over 70% of the farmers have never encountered food insecurity during the last 30 days. Under the 'rare' column, the value of HFIAS is about 15%, where about 15% of the farmers have rarely faced food insecurity problems. Furthermore, about 8% and 5% of the farmers in the area under consideration have respectively suffered either sometimes or often from food insecurity over the preceding month.

Since each response choice is assigned a number from 0 (never) to 3 (often), the HFIAS score is calculated for each respondent by summing these numeric codes for each frequency-of-occurrence question. It theoretically ranges from zero (never face a shortage of food) to 27 (often face a shortage of food). Practically, however, it ranges from zero to 20. The higher the score, the more food insecurity the household experienced and vice versa. Observing the first and the last HFIAS score, about 27% of the farmers have a 0 HFIAS score while the figure for farmers who have a '*20 HFIAS*' score is about 1%. Others are unevenly distributed between these two extreme HFIAS scores, although negatively skewed towards zero scores.

More frequently, HFIAS is used to indicate a categorical food insecurity status (prevalence), which helps to make geographic and social-group targeting decisions (Coates et al. 2007) and is useful for program monitoring and evaluation (Castell et al. 2015). To understand this prevalence, four dimensions of household food (in)security[7] are used, which have been developed by the United States Department of Agriculture Economic Research Service (2006).

Based on this and Coates et al.'s (2007) explanation for this, the farmers are grouped into four different food security levels, i.e. highly food secure (HFSAI=0), slightly food secure (1≤HFSAI≤3), occasional food insecure (4≤HFSAI≤10) and chronic food insecure (HFSAI≥11). About 27% of the farmers are highly food secure and they have experienced none of the food insecurity conditions over the last 30 days.

In this paper, farmers are moderately food insecure if they have sacrificed quality more frequently, for example, sometimes or often eating a monotonous diet or undesirable foods, and rarely or sometimes reducing the size or number of meals. However, they have never experienced any of the three most severe conditions, such as running out of food, going to bed hungry and going a whole day and night without eating. Based on the results, about 25% of the farmers in the area are categorized under this food insecurity level and therefore are occasionally food insecure.

The corresponding figure for farmers who are slightly food secure is about 40%. They have sometimes worried about having enough food. They have rarely been unable to eat preferred

[7]. *The United States Department of Agriculture (USDA) Economic Research Service identified four dimensions of food security (a) high food security if there is no report indicating food access problems in the household (b) marginal/slightly/fairly food security if there are one to three reports indicating the presence of anxiety over shortage of food in the household (c) low food security or moderately/transitory food insecurity (food insecurity without hunger) if there are up to ten reports indicating a reduction in food quantity, quality or desirability (d) very low food security or severe/chronic food insecurity (food insecurity with hunger) if there are reports of multiple indications of disrupted eating patterns and reduced food intakes.*

food and eat a more monotonous diet than desired. Furthermore, about 8% of the farmers are severely food insecure. They have often reduced the size or number of meals. They have rarely experienced any of the three most severe food insecurity conditions.

In the literature, HFIAS is criticized for its non-inclusive measurement of food insecurity. It does not address the utilisation and stability dimensions of food security (Coates et al. 2007). The experience of farmers over 30 days cannot be used to assess long-term stability and seasonality aspects. Kabunga et al. (2014) argued that it does not show how foods are prepared and consumed. It does not address whether the food fits the farmers' traditions and culture. It does not show intra-household distribution and feeding practices with foods, and whether the farmers have sanitary facilities.

However, these limitations do not reduce its merits. While evaluating its feasibility and usefulness, it generated results closely correlated with other food security measuring methods (Castell et al. 2015). If the assessment is also undertaken during the off-season for the harvests (during the sowing period when farmers are often faced with food shortages), the results can show the temporal dimension of food security and food supply, access and stability dimensions. Therefore, the results of this chapter are valuable and effective because the survey was carried out during the off-harvest period with careful questioning and experienced enumerators.

Table 6.3. The proportion of farm households who responded to nine household food insecurity access scale questions (percent)

Que.	How often has this food insecurity element happened in the last four weeks or last 30 days?	Never	Rarely	Sometimes	Often
Q1	Did you worry that your household would not have enough food?	66	18	9	7
Q2	Were you or any household member not able to eat the kind of foods you preferred because of lack of resources?	74	15	8	3
Q3	Did you or any household member have to eat a limited variety of foods day after day due to a lack of resources?	61	20	13	6
Q4	Did you or any household member have to eat some foods that you did not want to eat because of a lack of resources to obtain other types of food?	83	9	6	2
Q5	Did you or any household member eat a smaller meal than you felt you needed because there was not enough food?	61	20	11	8
Q6	Did you or any household member eat fewer meals in a day because there was not enough food?	68	19	8	5
Q7	Was there ever no food to eat of any kind in your household because of a lack of resources to obtain food?	81	12	4	3
Q8	Did you or any household member go to sleep at night hungry because there was not enough food?	80	10	7	3
Q9	Did you or any member go a whole day and night without eating anything because there was not enough food?	80	12	4	4
Mean HFIAS (Unweighted)		72	15	8	5

6. 4. 2. Mean difference in yields and household welfare between adopters and non-adopters

This section assesses whether there is a significant difference in these stated outcomes between farmers who adopted any of the agricultural practices (adopters) and those who did not adopt them during the survey (non-adopters). After checking whether the variables are normally distributed (skewness) and whether they have an equal variance (Levene test), one-way ANOVA analysis is used to assess whether a significant difference exists between the variables across different adoption choices for agricultural practices. Table 6.4 presents the summary statistics and statistical significance tests on equality of means for these outcome variables.

In the study area, wheat and barley, which are the dominant crops, have often been cultivated for hundreds of years. Recently, farmers have used improved varieties of these crops to maximize yields. During the survey, mean wheat and barley yields per hectare were about 22 quintals for adopters and about 16 quintals for non-adopters. Adoption of any combination of the agricultural practices would increase wheat and barley yields by about 44% in comparison with our reference group (non-adoption). The Fisher's Least Significant Difference (LSD) test shows a significant difference in cereal yields between adopters and non-adopters. A higher proportion of wheat and barley yields have been observed for agricultural practice adopters compared to farmers who do not adopt any practice.

In addition to barley and wheat, several crops such as beans, peas, maize, teff, sorghum, lentils and finger millets are also grown and harvested in the area. As far as total harvest per capita is concerned, which relates to total harvest per household size, around 6 quintals were observed for those farmers who adopted the agricultural practices compared to 5 quintals for those who did not adopt them. As shown by the ANOVA (LSD) test, we find a significant difference in per capita harvests between soil and water conservation adopters (combined with the use of animal manure and retaining crop residues) and non-adopters. Adopters have higher per capita harvests compared to other farmers with the absence of these farming practices.

In this paper, income that affects farmers' decisions to adopt technology (Daloğlu et al. 2014) is computed as a sum of farm incomes (crops, horticultural products and livestock production), off-farm incomes (waged labour and selling of charcoal, cactus, commercial trees and firewood), non-farm incomes (migration earnings, safety nets, food aids, and own business earnings). As per Table 6.4, the average per capita income for adopters is about €542 while for non-adopters it is €330. This simple comparison suggests that adoption of the practices would increase per capita income by 50 to 70%. It can be concluded that per capita income differs significantly between those who have adopted these practices and those who have not.

With regard to per capita expenditure, this includes expenditure on food consumption, human investment (health and education expenditure), agricultural expenditure and other non-food expenses. It is found that there are statistically insignificant differences between farmers who adopted and who did not adopt the agricultural practices. However, a weak significant effect is found for the application of animal manure only or for this practice combined with other practices. This might be linked to livestock ownership. Farmers who have more animals have to spend more on fodder and forage, as well as medical expenses, such as straw, hay, residues, drugs, veterinary services and vaccination.

As explained above, assets include permanent durable goods but it does not include the value of livestock, housing and cultivated land. It indicates temporal economies of farmers and allows greater access to foods. Under credit constraints, assets can provide farmers with cash to invest in productivity-enhancing inputs. This affects the performance of agriculture and tends to increase output and incomes. It can prevent a degradation of the natural resource base. As can be seen, per capita assets for adopters are, on average, about €660 and the figure for non-adopters is €510. Thus, per capita assets of adopters is about 29% higher than that of non-adopters. The LSD test explains that a significant difference in per capita asset holdings is found between farmers who adopted and those who do not adopt those agricultural practices.

Concerning the levels of food insecurity, across different combinations of agricultural practices (*see section 6.4.1*), we merged highly food secure and fairly food secure and named as food secure and therefore three levels, such as food secure, and transitory and chronically food insecure. Of the farmers who do not adopt any of those agricultural practices, about 60% are food secure while 14% are chronically food insecure. Of the farmers who adopted all those agricultural practices together, about 70% are food secure while about 30% are food insecure. In a similar way, about 64% of the farmers who adopt solely soil and water conservation are food secure while about 2% are severely food insecure.

Table 6.4 also indicates that on average, about 67% of agricultural practice adopters are food secure while the corresponding figure for that of non-adopters is about 60%. This simple mean comparison shows that adoption increases the level of food security by about 8%. The chi-square test (*Chi-square statistic=17.56*) reports a significant difference in household food security levels across farmers with different levels of adoption. This significant relationship is especially higher when farmers have used either crop residues combined with animal manure or all those agricultural practices simultaneously.

Roughly speaking, this may justify that the proportion of food secure people is higher for adopters than non-adopters. Farmers are more likely to be food secure when they have adopted sustainable agricultural practices, justifying the level of food insecurity declined with the adoption. In the area under consideration, food insecurity is still a major challenge and is also a development agenda. So, this result has an implication. Food insecurity can be reduced if specific strategies are formulated to inspire farmers to adopt sustainable agricultural practices.

This mean comparison, which assumes unconditional (exogenous) adoption decisions, reveals a substantial difference between adopters and non-adopters of those agricultural practices. The results are significantly positive for most adoption choices. Adopters have higher yields than non-adopters. The results of per capita income, per capita harvests, and per capita assets are higher for adopters than non-adopters for most practices. Insignificant results are found in per capita income for those solely applying animal manure and non-adopters. Adoption of soil and water conservation and this joint with crop residues has insignificant effects on per capita assets.

However, this unconditional approach is not sufficient to capture the net impact of adoption on outcomes. The results may not be fully due to those practices. It can be attributed to household-village level differences (Jaleta et al. 2016). It does not accurately capture impacts of adoptions since it fails to account for unobserved characteristics (Abdulai and Huffman 2014; Kabunga et al. 2014; Maertens and Swinnen 2009; Manda et al. 2016; Teklewold, Kassie, Shiferaw, et al. 2013). These results may be misleading to infer conclusions. The unobserved heterogeneities would be verified after controlling for confounding factors. Therefore, ESR is used to account for selectivity bias and understand the net or true effect of these practices on outcomes.

Table 6. 4. Mean difference (exogenous average treatment effect) in household welfare across farmers with different choices of agricultural practices

Outcome variables	Cereal yields	Per-capita harvest	Per-capita income	Per-capita asset	Per-capita expenditure	Food secure	Occasionally food insecure	Chronically food insecure
None of these practices	1560	541	327	510	118	59	27	14
Soil and water conservation only	2368†	676♥	490*	600	133	64	34	2
Animal manure only	2248*	576	504	655♥	134*	66	29	5
Soil and water conservation and crop residue	2090♥	538	623†	535	124	67	26	7
Soil and water conservation and animal manure	2262♥	628*	574†	727†	135*	70	27	3
Crop residues and animal manure	2096*	590	533♥	715†	128	66	26	8
All these practices simultaneously	2392†	622*	525♥	705♥	138*	73	23	4

*Notes: The level of statistically significant test († for P<0.01; ♥ for P<0.05 and * for P<0.10).*

6. 4. 3. Farmers' decisions for the adoption of sustainable agricultural practices

This section briefly explains factors that influence smallholder farmers' decisions to adopt soil and water conservation measures, retention of crop residues and application of animal manure. The explanatory variables are checked for multicollinearity and non-normality problems. The robust standard error estimations are also applied to correct any heteroscedasticity. Some continuous variables, such as age, cereal yields, per capita harvests, per capita income and per capita assets are logged to make them more homogenous. This full information maximum likelihood approach overcomes the heteroscedastic resulting from stepwise regression through a simultaneous or joint estimation of the selection and outcome questions.

Table 6.5 presents the results of the polytomous or multinomial logistic regression (first-stage of ESR) for each adoption choice, which is estimated using the stata selmlog routine (Fournier and Gurgand 2007). The base category, or reference group, is non-adoption ($C_NM_NR_N$) and refers to farmers who did not implement any of the practices. This is used to compare and evaluate the results relative to this (relative effect). The test of goodness-of-fit (Wald chi-square test) shows that the selected covariates provide good estimates of the conditional density of adoption and a joint significance of the explanatory variables at 1%.

While observing the identifying instruments, such as attitudes and farmer-school, the chi-square test ($\chi^2(2)$), which shows the validity test for the overidentifying restriction, confirms that these variables are jointly significant in adoption decisions (Table 6.5). Insignificant impacts are, however, found on outcome variables (F-statistic (2, 347): per capita harvest =0.83, per capita income=1.83 and per capita assets=1.12) even if a weak joint effect on crop yields is observed (F(2, 347)=2.18) at a 10% significant level. Since these instruments are significant drivers of the adoption decisions, jointly, they are considered as valid selection instruments. Therefore, these instruments are successful at enabling identification.

The results of the selection equation are roughly consistent with previous studies, where demographic variables, field plot-varying characteristics and rural institutions are found to be significant factors (Abdulai and Huffman 2014; Jaleta et al. 2016; Manda et al. 2016; Teklewold, Kassie, Shiferaw, et al. 2013). Variables such as education, risk attitudes, extension services, attitudes, group membership, relational capital, soil quality, gender, farming experience, labour supply and market proximity are found to be significant factors for at least one alternative farming practice. Consequently, these factors are important to stimulate farmers to use one or more agricultural practices to improve farm productivity and maximize yields.

The set of social-psychological variables, such as group membership, relational capital, technical training, education, labour supply, aversion behaviour, agricultural extension services and attitudes are jointly significant in determining the choice of farmers to adopt these practices (separately/in combination) although not all these variables are statistically significant. Educated farmers and those with a large family size are more likely to adopt them, especially for labour-intensive productivity-enhancing practices. Abdulai & Huffman (2014) and Manda et al. (2016) found that households facing a shortage of family labour chose not to adopt labour-demanded agricultural practices.

Having more experience in agriculture positively affects farmers' decisions to adopt soil and water conservation in combination with the retention of crop residues or application of animal manure. This suggests that the use of soil and water conservation measures on private field plots can give high yields when it is concurrently applied with either animal manure or crop residues. More experience is an indication of having or accumulating more skills and greater competence, which helps to evaluate things critically from a wider perspective.

In Ethiopia, extension agents, who are assigned to every village, often provide farmers with technical advice and information about agricultural conditions. The results in Table 6.5 indicate that extension services are found to positively impact the adoption of most agricultural practice packages, for example, solely soil and water conservation, and this combined with animal manure or crop residues, but not for the simultaneous use of all the agricultural practices. In previous studies, it was found that contacts with extension agents had a positive effect on adopting soil and water conservation technology (Abdulai and Huffman 2014).

Farmers who have frequent contacts with extension agents are more likely to adopt alternative agricultural practices separately/in combination because extension agents are expected to provide information to reduce uncertainty and enhance awareness. However, extension agents may sometimes not provide timely information if they lack the necessary competencies. Hence, confidence in extension agents is included in the model to capture how farmers perceive the skills and knowledge of extension agents. About 60% of the farmers question the skills and knowledge of extension agents. The results show that farmers who have confidence in the skills and knowledge of extension agents are more likely to adopt the agricultural practices in combination instead of adopting them in isolation.

Interestingly, although market imperfection and information asymmetry are observable challenges in less developed countries, membership in formal organizations and having strong networks and relationships with the local community groups can provide necessary information, improve bargaining power and reduce transaction costs (transportation and information costs). Such social capital has positive impacts on the adoption of most agricultural practices. With imperfect markets and inadequate information, relational networks and formal organizations have positive spillover effects and can effectively facilitate the exchange of information among farmers, which enables them to adopt agricultural practices to improve agricultural yields.

To capture uncertainty or the aversion of farmers, risk attitude is included in the model, which evaluates the impact of risks on farmers' adoption decisions. A low value for risk attitude indicates an aversion (more risk averse) while a high value shows risk-seeking (less risk averse). We find a strong correlation between adoption of most agricultural practices and risk attitudes (more risk averse or less risk averse). Although we expected more risk-averse farmers to be more likely to adopt risk-reducing agricultural practices, risk aversion has significant negative impacts on adoption of more agricultural practices because risk attitude increases with the adoption of more agricultural practices. It can be concluded that less risk-averse farmers are more likely to adopt most agricultural practices than more risk-averse farmers.

Importantly, these practices can be used in combination if farmers have more farming experience; they have no shortage of family labour; they can read and write; they are less risk avoidant; they are confident in the competence of extension agents; they have strong social capital; they have positive attitudes and if they have received training on sustainable agriculture. However, the quality of soil conditions does not inspire farmers to use sustainable agricultural practices in combination. In addition, farmers who dwell closer to main markets prefer to engage in non-farming activities, such as petty trades, casual work and other transactions rather than working on farming activities.

Table 6. 5. Coefficients for adoption of alternative agricultural practices: I-stage of endogenous switching regression (multinomial logit model)

Variables	$C_YM_NR_N$	$C_NM_YR_N$	$C_YM_YR_N$	$C_YM_NR_Y$	$C_NM_YR_Y$	$C_YM_YR_Y$
Labour supply	0.38(0.19)♥	-0.15(0.27)	0.15(0.05)♥	-0.17(0.15)	-0.22(0.19)	0.03(0.01)♥
Education	0.19(0.21)	-0.54(0.04)♥	0.14(0.53)	0.18(0.04)♥	0.07(0.02)†	0.10(0.05)♥
Attitudes	-0.38(0.93)	-0.15(0.53)	0.05(0.02)†	0.17(0.06)†	0.09(0.17)	0.08(0.03)†
Special skills	-0.07(0.73)	0.84(0.71)	0.02(0.01)♥	0.05(0.06)	0.06(0.01)†	0.82(0.59)
Extension service	0.54(0.16)†	-0.16(0.27)	0.08(0.04)♥	0.17(0.03)†	0.03(0.13)	0.26(0.55)
Risk attitudes	0.32(0.63)	0.16(0.03)♥	0.04(0.02)♥	0.05(0.02)♥	0.06(0.02)†	0.07(0.02)†
Media influence	-0.89(0.93)	0.08(0.73)	0.83(0.88)	0.25(0.29)	-0.09(0.10)	0.06(0.09)
Social influence	0.35(0.16)♥	-0.56(0.39)	0.12(0.04)♥	0.02(0.54)	0.31(0.10)♥	0.08(0.05)*
Group membership	0.47(0.08)†	0.49(0.22)♥	0.05(0.01)†	-0.33(0.49)	0.24(0.06)†	0.06(0.02)†
Farmer school	0.08(0.05)♥	0.04(0.01)♥	0.03(0.43)	0.08(0.05)*	0.22(0.49)	-0.02(0.46)
Gender (male)	0.89(0.25)†	-0.28(0.08)†	-0.49(0.84)	0.43(0.84)	-0.06(0.03)♥	0.35(0.29)
Experience (log)	0.02(0.25)	0.08(0.06)	0.13(0.02)†	0.13(0.02)†	0.02(0.03)	0.12(0.02)♥
Occupation	0.11(0.45)	0.72(0.50)	0.71(0.89)	-0.04(0.09)	-0.78(0.52)	0.03(0.23)
Farmland	0.15(0.90)	0.04(0.56)	-0.25(0.45)	-0.07(0.05)	-0.15(0.89)	0.05(0.16)
Livestock	-0.38(0.29)	0.58(0.18)†	0.10(0.41)	-0.27(0.07)*	0.33(0.16)♥	0.33(0.15)
Extension confidence	-0.15(0.21)	0.32(0.45)	0.08(0.05)*	0.09(0.01)†	0.08(0.03)♥	0.09(0.03)†
Market proximity	-0.03(0.92)	-0.92(0.13)♥	0.04 (0.47)	-0.59(0.47)	-0.21(0.10)♥	-0.22(0.03)♥
Flat slopes	-0.94(0.25)†	-0.72(0.46)	-0.09(0.05)*	-0.11(0.29)	-0.26(0.88)	-0.28(0.08)
Road accessibility	0.30(0.26)	0.32(0.42)	0.24(0.51)	-0.16(0.50)	-0.83(0.63)	0.35(0.57)
Gentle slopes	0.08(0.90)	0.09(0.30)	0.59(0.50)	-0.44(0.64)	0.16(0.17)	0.01(0.56)
Fertile soil	0.18(0.65)	-0.19(0.01)†	-0.12(0.04)♥	0.05(0.06)	-0.04(0.01)†	0.41(0.58)
Medium soil	0.23(0.24)	-0.43(0.28)	0.03(0.06)	0.09(0.05)*	0.08(0.09)	0.25(0.74)
Soil depth	-0.33(0.29)	0.07(0.02)†	-0.07(0.11)	-0.23(0.17)	-0.03(0.01)♥	0.05(0.12)
Credit access	-0.71(0.79)	0.50(0.62)	0.02(0.08)	0.36(0.46)	0.15(0.19)	0.12(0.19)
Technical training	0.36(0.27)	0.11(0.66)	0.19(0.65)	0.08(0.03)†	0.48(0.09)†	0.08(0.01)†
Agroecology	-0.07(0.18)	-0.15(0.35)	-0.02(0.11)	0.53(0.63)	0.70(0.93)	0.12(0.69)
Stress (pest/disease)	-0.19(0.56)	0.73(0.52)	-0.42(0.40)	0.38(0.48)	-0.09(0.04)♥	0.54(0.59)
Constant	-5.68(11.02)	-16.35(13.3)	-5.14(6.50)	2.69(6.82)	-0.24(0.13)*	-0.76(0.62)
Joint significance of selection instruments	25.6†	17.0♥	127.1†	97.4†	34.8♥	305.4†

Overall model diagnosis: *Wald $\chi^2(140)$ =310; $P > \chi^2$ =0.000; observations=350; Pseudo R-square=0.78; Log pseudo likelihood=-573; statistically significant level († for P<0.01; ♥ for P<0.05 and * for P<0.10)*

Notes: Figures in parenthesises are robust standard errors. The reference group for this result is non-adoption ($C_NM_NR_N$). The steep slope and poor soil quality are considered as reference categories for slopes and soil fertility.

6. 4. 4. Impact of agricultural practices on agricultural yields and household welfare

This section investigates the impacts of application of sustainable agricultural practices on outcome variables using II-stage endogenous switching regression analysis. This estimates under the assumption of endogenous (conditional) adoption decisions. Both observed factors and unobserved heterogeneity, which could affect the adoption decisions and outcome variables, are controlled. The standard errors are bootstrapped to account for heteroscedasticity arising from the two-stage estimation procedures. Table 6.6 presents the estimates of the impacts of those agricultural practices on the abovementioned outcome variables.

In section 6.4.3, we indicated the factors that explain the adoption of these agricultural practices. In Annexes 6.2-7, the results of the second stage of ESR are presented. This considered how a set of explanatory variables and the selection correction terms derived from the multinomial logit are affecting outcomes across alternative combinations of agricultural practices. The variance inflation factor for most variables is less than 2, although it is found to be around 8 for relational capital and soil fertility. It is found that age, education, household size, extension services, plot characteristics, social capital, capacity building, training, markets and roads are explanatory variables that significantly affect the outcome variables (yields, income, assets and food security) but the impacts of these variables differ across the different agricultural practices.

The coefficients for the selection correction terms for most combinations of these practices are significant (positive or negative). This manifests the presence of positive or negative selection bias in the outcome variables (Abdulai and Huffman 2014; Manda et al. 2016) and evidence of self-selection in the adoption of sustainable farming practices (Jaleta et al. 2016; Teklewold, Kassie, Shiferaw, et al. 2013). Sample selection bias could occur if the outcome equations were to be estimated without considering the adoption decision (Abdulai and Huffman 2014). Adoption of these practices does not have the same effect on non-adopters, had they chosen to adopt, compared to the impact it has on adopters; while the insignificant rho indicates that the outcomes for the adopters are not different from those for individuals randomly drawn from the whole sample (El-Shater et al. 2016).

The positive selection bias suggests that unobserved factors, which increase the probability of adopting the practices, are associated with a higher level of the outcome variables than expected under random assignment to the adoption choices. Farmers with above average outcomes, or more productive farmers, are more likely to adopt these practices. Conversely, the negative selection bias associated with an increase in the probability of adopting the practices would have a lower level effect on the outcomes. Farmers with below average outcomes are more likely to adopt them (Abdulai and Huffman 2014; El-Shater et al. 2016; Manda et al. 2016). What is important is that significant selection correction terms can overestimate or underestimate the results of the outcome variables unless they are corrected.

The conditional adoption decision accounts for selection bias arising from a systematic difference between adopters and non-adopters and estimates the true average adoption effects of treated farmers (ATT_T) by comparing the outcome variables for farmers who adopted the practices (adopter) with what they would have been had they not adopted them (counterfactual).

The results in Table 6.6 show that all the combinations of agricultural practices have significant positive effects on crop yields. Farmers could have significantly higher barley and wheat yields when they solely apply animal manure on their field plots or when they have applied the three agricultural practices in combination. The use of soil and water conservation measures combined with the application of animal manure or retention of crop residues has lower crop yield effects compared to other combinations.

However, a combined use of animal manure and retention of crop residues is the worst, as it generates negative yields. This means that farmers who adopted both practices simultaneously would have lower yields compared to what they would have obtained if they had not adopted them. This seems to imply that these agricultural practices should not be used together. There appears to be no logical agronomic or biological explanation for this result.

One potential reason might be that crop residue, such as straw, stover and other production leftovers are often used in the study area as animal feed. This might result in some kind of resource competition. In addition, both practices are quite labour intensive. Gaining insight into the mechanism at work would require detailed information about the current application of the practices by farmers. In contrast to the result for cereal yields and per capita harvest, Table 6.5 also shows that the combined use of the same two practices generated higher per capita income and per capita assets compared to not adopting them. Given the result for yields, this seems to suggest that it is not the crop production which is responsible for this increase in income, for example, the fact that farmers who use manure have livestock. Finally, we need to acknowledge that some of these results might be due to the small sample sizes for some combinations.

Here, total harvest is a sum of cereal and legumes produced because farmers have often harvested crops, such as beans, peas, maize, lentils and chickpeas although they have mostly produced barley and wheat. Per capita harvest, which relates total harvest to household size, is used to understand the welfare difference between farmers. Farmers who adopted the agricultural practices have relatively higher per capita harvests than counterfactuals – what they would have received if they had not adopted them. However, farmers would have obtained higher per capita harvests if they had not used animal manure and retained crop residues simultaneously. The results indicate positive contributions and farmers can increase their overall harvests through the adoption of various agricultural practices.

Regarding the per capita income, the results show that adopters have earned a higher income than the counterfactual for most of the agricultural practices. For example, the per capita income of farmers who adopted the three agricultural practices in combination earned about €500 more compared to what they would have done if they had not adopted the practices together. In relative terms, the retention of crop residues together with the application of animal manure has generated the lowest net per capita income compared to other options. This might be linked to the opportunity cost of manure and crop residues. The economic value of the crop residues for livestock and animal manure for firewood production seems to be high. The highest per capita income is found when the three agricultural practices are used together.

In a similar way, per capita expenditure, which approximates to household food security, has a significant effect in almost half of the adoption choices. This shows that farmers who adopted sustainable agricultural practices can budget for a higher income, which allows them to spend more on food and non-food items compared to what would have happened if they had not adopted the practices. However, an insignificant difference is found in the application of animal manure only. A weak effect is also found if animal manure is used in combination with other agricultural practices, for example, soil and water conservation, and crop residues.

As stated above, household assets include farm equipment, beehive boxes, bank savings, jewellery, radios, televisions, watches and other permanent and durable goods. In most alternative combinations of these agricultural practices, adopters have higher per capita assets than counterfactuals. However, an insignificant difference is found for the adoption of soil and water conservation in combination with the retention of crop residues. Use of animal manure as organic fertilizer to enhance productivity and maximize yields seems to have the highest effect on asset holdings. Therefore, farmers who adopt these agricultural practices have higher per capita assets compared to what they would have had they not adopted them.

Concerning the household food insecurity access scale (HFIAS) score (with food options: highly food secure, fairly food secure, occasionally food insecure and chronically food insecure), we have tried using a two-limit Tobit model and the censored least absolute deviations estimator (CLAD) with selection bias terms. Using CLAD estimation, the non-coverage problem has occurred for all adoption choices for the agricultural practices, because the trimmed sample size is smaller than the number of degrees of freedom. While using the two-limit Tobit model, a convergence problem has occurred for the use of animal manure only ($C_N M_Y R_N$); the selection terms are also found to be statistically insignificant for the adoption of all the agricultural practices simultaneously, whereas they are found significant for the remaining options (*see Annexe 6.7*). It was not possible to estimate the average treatment effect for the treated (the impact of the practices on food security) due to the convergence problem.

Evidently, the simple mean comparison (*section 6.4.2*) generates relatively higher cereal yields, per capita harvests, per capita income and per capita assets for adopters than for non-adopters. Adopters of these agricultural practices are also better off than non-adopters. But the net impact of adoption is overestimated because unobserved factors are overlooked. After adjusting the potential heterogeneities from unobserved factors, farmers who actually adopted these agricultural practices would have had lower net outcomes than they would have been had they not adopted the agricultural practices.

The overall results of ESR seem pragmatic. The outcomes are higher when farmers used different agricultural practices than they would have been had they not adopted them. A combined use of these agricultural practices could produce higher outcomes despite substitution effects lowering the outcomes. It also reveals that agricultural practices improve agricultural production and household welfare significantly, even if the magnitudes vary across the outcomes and agricultural practices used. Therefore, it is necessary to enhance awareness and understanding of smallholder farmers to stimulate them to adopt sustainable agricultural practices to improve agricultural production and overall household welfare.

Table 6. 6. Endogenous average impact of agricultural practices (treatment) on the treated farmers (ATT_T) for outcome variables (endogenous switching regression model)

Agricultural practice choice	Cereal yield per hectare	Per-capita harvests	Per-capita income	Per-capita asset	Per capita expenditure
Soil and water conservation only	376(89)†	283(71)♥	305(50)†	273 (74)♥	103(64)
Animal manure only	658(61)†	542(94)†	357(48)†	809(272)†	17(11)
Soil and water conservation and crop residues	365(86)♥	220(65)*	292 (58)†	195(125)	19(6)†
Soil and water conservation and animal manure	480(120)†	297(100)♥	284(55)†	250(55)♥	10(6)*
Animal manure and crop residues	-121(259)	-68 (61)	261(54)†	259(80)♥	69(42)*
All these practices simultaneously	558(59)†	259(72)♥	496(68)†	432(93)†	15(5)†

*Notes: The baseline is farmers who did not adopt any of the sustainable agricultural practices. The figure in parentheses is bootstrapped standard errors. We used 100 simulation draws. Statistically significant level test († for P<0.01; ♥ for P<0.05 and * for P<0.10)*

6. 5. Conclusion and implications

In less developed countries, an increase in agricultural production is an important forward step to improve the living conditions of rural people. This could be achieved, for example, by adopting sustainable agricultural practices. Because literature on the impacts of adoption on agricultural production and rural livelihoods is scarce, this paper looks at the effects of three agricultural practices. We use per capita harvests, per capita incomes and per capita assets to indicate household welfare while agricultural production is approximated by wheat and barley yields. Cross-sectional field data are analysed using ESR model. This provides the true effects of adoption on outcomes by correcting for biases from observable and unobservable factors.

The robust results of the I-stage of ESR indicate that the use of soil and water conservation is applied mostly by male-headed households and by large families because it is labour intensive in nature. Use of animal manure is implemented by female-headed households, while retention of crop residues is implemented more often by farmers who have more farming experience. Formal organizations and local community groups are important to motivate farmers to adopt agricultural practices. In all, education, risk attitudes, extension services, rural organizations, social influence, capacity building and household size are factors that significantly influence the probability of farmers adopting sustainable agricultural practices under consideration.

In the areas under consideration, it is confirmed that many farmers have implemented soil and water conservation measures, and used organic fertilizers in their private plots to reduce soil erosion, improve soil fertility, enhance water retention capacity, and to raise agricultural yields. But we also personally observed a negative relationship between livestock management and adoption of agricultural practices. The structure of soil bunds, stone walls and bench terracing is usually destroyed and ruined because of the open grazing practices in some areas. Also, crop residues, such as straw, stover and other leftovers are often used for animal feed. Farmers who have more livestock seem less likely to retain crop residues on the private field plots as an adaptation strategy to enhance soil fertility and improve crop yields. Furthermore, some farmers preferred to use animal manure for firewood production instead of using it as organic fertilizer.

While evaluating how sustainable agriculture influences agricultural production and household welfare, farmers who have encountered production uncertainty due to unpredictable rainfall and other constraints can improve crop harvests and incomes significantly through the adoption of agricultural practices, such as soil and water conservation, and organic fertilizers (animal manure and crop residues). These would also tend to reduce food insecurity and improve livelihoods indirectly. In less developed countries, promotion of sustainable agriculture has the potential to improve agricultural productivity and bring meaningful livelihood changes.

The result of ESR shows that if unobserved heterogeneities are overlooked, the net impacts of the adoption would be overestimated. Furthermore, the use of mean comparisons to evaluate impacts may mislead the conclusion and implications. This suggests that unobserved factors should not be forgotten while evaluating the impacts of development projects. Therefore, since the adoption of sustainable agricultural practices has positive impacts on agricultural production and household welfare, smallholder farm households should be inspired to adopt various agricultural practices as a means of improving agricultural productivity and rural livelihoods.

Chapter Seven
Sustainable agricultural practices as response to climate change

Abstract

Since climate change and its impacts vary spatially and between people, this paper explores whether smallholder farmers have noticed a change in climate over the last two decades. The paper also investigates whether they have made some adjustments in their farming decisions in response to the change. The driving forces for farmers' decisions to adopt strategies to reduce adverse impacts, as well as whether (or not) those strategies are related to sustainable agriculture, are explored. The results show that the amount and variability of rainfall, temperature, humidity, and extreme weather events are identified as local indicators of climate change. Most farmers have perceived a change in climate, especially an increase in temperature, the occurrence of unusual weather events, shifting patterns and distribution of rainfall, and a decline in moisture. These have led to a significant disturbance in crop yields, livestock, water, wildlife, biodiversity and livelihoods. As a result, many farmers have implemented adaptation measures in response to climate change. For example, they use different crop/livestock varieties and cultivate drought/disease resistant varieties; they use alternative water harvesting schemes to expand irrigation; they plant multipurpose trees, use varieties with better WUE, apply organic fertilizers and shift to non-farm activities. Furthermore, their decisions to adopt these strategies are affected by their education level, livestock ownership, household size, attitudes, social capital, access to information, availability of financial resources, and extension services. Often, farmers have used their indigenous knowledge to predict climatic conditions because they do not receive institutional support. Accordingly, the main barriers to climate change adaptation strategies are lack of information, shortages of money, shortage of farmland and lack of institutional support. Therefore, there should be specific strategies to strengthen agricultural extension services, and empower formal organizations and traditional institutions that enhance awareness, provide timely information on agricultural and climatic conditions and help farmers to choose effective adaptation strategies to mitigate or reduce climate change risks and build resilient systems.

Keywords: *Climate change, perception, impacts, adaptation strategies, smallholder farmers, multinomial analysis*

7. 1. Introduction

Most farmers in less developed economies are heavily dependent on rain-fed subsistence farming for their livelihoods (Nhemachena, Hassan, and Chakwizira 2014) and on the natural resource base (Debela et al. 2015). Their productivity is highly reliant on favourable seasonal weather conditions and unpredictable natural factors (Solomon, Snyman, and Smit 2007). This also tends to proportionally increase their vulnerability to climate change (Antwi-Agyei et al. 2012; Debela et al. 2015).

Global warming has significant adverse consequences for agricultural production and increases the risk of poverty. A decline of 15-30% in agricultural productivity is estimated for the most exposed developing countries, especially in Sub-Saharan Africa and South Asia. The poorest farmers with few safeguards against climate calamities often live in areas prone to natural disasters (Hoffmann 2011).

Regions that are socioeconomically underdeveloped are expected to be more severely affected by the effects of climate change than others, especially when their economies are closely tied to the natural resource base and climate-sensitive sectors, such as agriculture, water and forestry (Singh, Bantilan, and Byjesh 2014). The impacts of climate change are thus greater in agricultural based economies (Debela et al. 2015; Hanjra and Qureshi 2010). Moreover, those countries often have limited capital resources (Antwi-Agyei et al. 2012) with very low adaptation capacities (Menike and Arachchi 2016; Nhemachena et al. 2014).

In Ethiopia, for example, agriculture is a leading sector. It has pivotal importance in the economic, social and political issues of the country. The sector, however, still has a predominately rain-fed base. Farmers have often used family labour, simple technologies and traditional farming practices (Debela et al. 2015). This climate-sensitive subsistence farming has led to the deterioration of ecological resources because of erosion, overexploitation, overgrazing, continuous cultivation, degradation and deforestation. Rapid growth, especially in the rural population, is another issue for the sector. Farmers have also been susceptible and vulnerable to the potential adverse impacts of climate change and drought. These factors have made agriculture weak, and have reduced its adaptive capacity, and increasing the vulnerability of rural communities.

In many African countries, yields from rain-fed agriculture could be reduced due to climate change by up to 50% by 2020 (IPCC 2014). Food crises in Sub-Saharan Africa are reminders of the continuing vulnerability of the region to changing climatic conditions (Obayelu et al. 2014). Climate change affects agriculture by altering the spatial and temporal distribution of rainfall and the availability of water (Mbow et al. 2014). Several studies have shown that climate change has significantly affected agriculture and the environment. This has led to crop failure, livestock deaths, and the prevalence of pests and diseases (crops, animals and humans) and starvation (Addisu et al. 2016; Antwi-Agyei et al. 2012; Fisher et al. 2015; IPCC 2007; Singh et al. 2014).

On the other hand, there is also a debate on the role of agriculture in causing climate change, for example, by the emission of greenhouse gases from different farming practices, deforestation, environmental degradation and other human activities (Beddington et al. 2011;

Debela et al. 2015; Tazeze, Haji, and Ketema 2012). It is estimated that the agricultural sector accounts for about 13-15% of global greenhouse gas emissions (GHG) and this increases to 30-32% if land use changes, such as land degradation, wildfires and deforestation are included. Also, these emissions are predicted to increase further as the result of population growth, dietary changes favouring ruminant meats and dairy products, and the further spread of industrial farming. Under a business-as-usual scenario, agriculture GHG emissions are predicted to rise by almost 40% by 2030 (Hoffmann 2011; IPCC 2014; IPCC 2007).

Evidence of the effects of climate change is already clearly visible. For example, the average global temperature from 2001 to 2010 was 0.46℃ above the 1961-1990 average (*World Meteorological Organization 2010*). Under a medium scenario from the IPCC, the mean annual temperature over extensive areas of Africa is predicted to be 2℃ higher by the middle of the 21st century than during the late 20th century (Fisher et al. 2015; IPCC 2014).

Apparently, the climate has changed in the past and it is changing currently. Accordingly, there is a high probability that climate change will continue into the future (Beddington et al. 2011; Deressa, Hassan, and Ringler 2011). This implies that climate change will continue to adversely affect agricultural production and livelihoods. For example, in SSA, increasing temperature and changes in precipitation will adversely affect biodiversity, increase water stress, increase the burden of health issues and exacerbate the vulnerability of agricultural systems (IPCC 2014). The incidence of droughts in Sub-Saharan Africa is predicted to consistently increase (Fisher et al. 2015). In particular, the adverse impacts will be worse if communities have low (or no) adaptive capacities.

The question that is repeatedly mentioned in the literature and requires attention is what are the possible and pressing options in response to climate change and how can the adaptive capacity of farmers be improved. In other words, what possible mitigation and adaptation strategies[1] are available (Roco et al. 2015) with the aim of achieving long-term resilience in which society and managed ecosystems are largely able to absorb the impacts of climate change and drought (Obayelu et al. 2014) and which are efficient and able to neutralize the adverse effects of climate change and avoid welfare losses (Komba and Muchapondwa 2012).

Many farmers in less developed countries have used different strategies to lessen their exposure and vulnerability to climate change, although they have low capacities (Fisher et al. 2015; Norton et al. 2010). Examples include changes to crop mixes, use of soil and water conservation measures, changes to planting dates, use of improved crop varieties, planting multipurpose trees, use of irrigation and water harvesting schemes, increasing agroforestry systems, growing

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[1]. *Adaptation strategy is an understanding of how individuals, groups and natural systems can prepare for, and respond to, changes in their environment. It is about adjustment in natural and human systems to reduce vulnerability to shock, such as the use of scarce water resources more efficiently, building flood defences and developing drought-tolerant crops. A mitigation strategy is a way of limiting the severity, seriousness, painfulness or the magnitude of long-term climate change through a reduction in human emissions of greenhouse gases and increasing the capacity of carbon sinks, such as through reforestation and conservation practices. While mitigation tackles the causes of climate change, adaptation tackles the effects of the phenomenon. The more mitigation there is, the less will be the impacts to which we will have to adjust, and the less the risks for which we will have to try and prepare. Conversely, the greater the degree of preparatory adaptation, the less may be the impacts associated with any given degree of climate change. The potential to adjust in order to minimize the negative impact and maximize any benefit from changes in climate is known as adaptive capacity. A successful adaptation can reduce vulnerability by building on and strengthening existing coping strategies (IPCC 2014, Mitchell and Tanner 2006). Therefore, adaptation and mitigation are complementary strategies to reduce risks and shocks.*

drought resistant and early maturing crop varieties (Addisu et al. 2016; Debela et al. 2015; Menike and Arachchi 2016).

In fact, the success of such types of climate change adaptation or mitigation strategies, however, depends on the availability of the necessary resources, such as natural, capital and financial resources, knowledge, technical capability and institutional resources (IPCC 2007) and other socio-economic and environmental trends, which also shape the ability of farmers to perceive and adapt (Deressa et al. 2011).

Coming to the area under consideration, drought has occurred more frequently. The local dwellers have often been vulnerable to its adverse impacts. For example, 25-30% of the population were food insecure (*Bureau of Agriculture and Rural Development annual report 2017*). Even at the country level, it has been found that Ethiopia is one of the five largest food aid receivers in the world (*OECD Database 2016*). About 25% of the population in Ethiopia is still poor (National Plan Commission 2017). Furthermore, climate change, the rugged topography, which leads to low productivity and yields, and population pressure have also contributed to this food insecurity. There is, therefore, a need to strengthen the adaptation capacity of local communities to enhance yields and reduce the negative impacts of climate change on livelihoods and the environment.

Even if the government takes positive initiatives, for example, allocation of more funding for agriculture, use of intensive soil and water conservation measures against climate change, more effort is still needed. In doing this, policymakers and development actors need empirical inputs on climate change issues to understand the perception and current adaptation strategies of farmers, given that the impacts, vulnerability and adaptive capacity differ with time, space and people (Singh et al. 2014; Tazeze et al. 2012). This suggests that perceptions of climate change and its impact and adaptation measures vary spatially and across people, and therefore local studies are appropriate.

Currently, the efforts that have been made to understand farmers' choice of adaptation measure to climate change in the area under study are empirically limited. Little is known about how local farmers respond and adjust to climate change as well as what coping strategies (indigenous or introduced) are used to adapt to climate change. Consequently, it seems pertinent to undertake a space-specific research study to gain a better understanding of how local farmers perceive climate change and how it impacts on them.

Therefore, this paper aims to assess what parameters or indicators farmers use to perceive a change in climate. It also explores what impacts they have observed and how they have responded to these impacts. Moreover, the study investigates the factors influencing farmers' choices for climate change adaptation measures.

While addressing these, the research output helps to understand how local farmers in Ethiopia perceive climate change and what indicators or parameters they have often used to identify climate change. It also gives valuable inputs to development practitioners to design indigenous or location-based adaptation strategies, which can strengthen the adaptive capacity of local systems and reduce the adverse impacts of climate change.

The paper is organised into five sections; the necessity, including the logic of this paper, was introduced and justified above. The model is estimated and explained in section two. Section three elaborates the research approach and identifies the farm-level adaptation strategies to climate change. The main findings are discussed in section four. The paper ends with some concluding remarks and policy implications.

7. 2. Model estimation and explanation

The farming environment in less developed countries is uncertain and fragile. It is dominated by imperfect markets and is sensitive to climate change and drought (Debela et al. 2015; Deressa et al. 2011). Together with the use of traditional farming practices, this has resulted in low productivity and yields (IFAD, WFP and FAO 2015). In several studies on adaptation strategies in response to drought, climate change and other shocks, the random utility maximisation theory is assumed. Based on this, an individual farmer makes decisions to maximize expected utility (e.g., increase yields, and reduce risks) by adopting strategies subject to constraints, like demographic characteristics, biophysical factors, climate change attributes, socioeconomic variables and institutional variables. This is given as follows:

$$U = Max(U_0^*, U_1^*, U_2^*, ..., U_k^*) \tag{7.1}$$

Where U denotes the expected utility or benefits farmers obtained. Suppose that an individual farmer is rational. He will choose and decide to implement a specific strategy from a set of 'j' adaptation strategies if the anticipated benefits from the strategy (U_{ij}) exceed the perceived benefits from other possibilities, for example, not adopting the strategy (U_{i0}). However, the expected benefit of choosing alternative strategies to adapt to climate change and to maximize yields is not directly observable, while the adaptation choice made is observable (Addisu et al. 2016). The latent variable (CA_{ij}) can be derived from the observed variable as follows:

$$CA_{ij} = \begin{cases} 0\, if \quad Q = U_0^*(\theta_{i0} X_{ij}) = P(U_{ij} \le U_{i0}) \\ j\, if \quad Q = U_j^*(\theta_{ij} X_{ij}) = P(U_{ij} > U_{i0}) \end{cases}, \text{ where j=1, 2... k} \tag{7.2}$$

Where CA_{ij} is the climate change adaptation strategy 'j' adopted by individual farmer 'i' to maximize expected utility (for example, mitigate climate change impacts and enhance agricultural yields) that depends on a vector of explanatory variables (X) and θ is a corresponding vector of unknown conformable coefficients. The exact distribution of this function depends on the distribution of the random disturbance term. Depending on the assumption of the disturbance terms and the nature of the response variable, different estimation models are applied to estimate climate change adaptation decisions.

For example, several studies have used binary choice models when the response variable is assumed to be binary (1 for adopting the strategy and 0 for not adopting). However, the binary response model ignores the presence of various types of adaptation measures. Another shortfall of this model is its bias from unobserved factors (Greene 2003). Others also used a count data model by assuming that adoption of climate change response strategies occurs sequentially and farmers can often adopt one, two or more strategies (adoption=1, 2,…,n) (Jara-Rojas, Bravo-Ureta, and Díaz 2012; Park and Lohr 2005; Ramfrez and Shultz 2000). Moreover, a multivariate probit model is used by assuming the choices of the strategies are interrelated. Furthermore, some studies have also applied the multinomial discrete choice model, assuming a multinomial response variable (Atinkut and Mebrat 2016).

In this study, since the purpose is to identify factors that affect the number of adaptation strategies or sustainable agricultural practices in relation to a reference group, for example, non-adoption of any strategy, a multinomial logit model is used. Farmers in the area were allowed to list however many strategies they applied in response to climate change. These strategies are nominal or unordered categories and they are assumed to be unrelated or independent. Following this, a multi-category/polytomous response variable is expected. Each category tells the effect of the predictors on the probability of success in that category in comparison to the reference category. The choice probabilities for the Multinomial Logit model are given by:

$$P(CP = j / X) = \frac{\exp(\theta X)}{\sum \exp(\theta X)}; \quad j = 0,1,...,k \tag{7.3}$$

In the multinomial logit model, the error term is assumed to be independently and identically Gumbel distributed. This model is also more restrictive as it assumes the Independence of Irrelevant Alternatives (IIA) [2] property of the error terms. However, the multinomial model fails to take into account the relationships between the adoption of different adaptation measures. In addition, the multinomial model is more robust to violations of assumptions of multivariate normality. Furthermore, it is also difficult to interpret the influence of the variables on the choice of each separate adaptation strategy (Greene 2003).

Eq.7.3, however, has a sample selectivity problem. It is assumed that a farmer who perceives a change in climate can adapt to the adverse impacts of climate change. A climate change adaptation strategy follows two sequential processes: perceiving a change in climate (perception model) and then deciding to adopt a particular adaptation choice (adaptation model). Normally, farmers first notice climate change and its impacts. Afterwards, they use different strategies to reduce the impacts of climate change. To this effect, the issue of selection bias occurs if there are common factors that affect the perception and adaptation models and if there are unobservable factors. Understanding of those factors influencing farmers' perceptions of climate change is vital and is modelled using a binary logit model as follows:

$$CP_i = \alpha Y_i + v_i \tag{7.4}$$

Where CP_i is the probability whether (or not) the farmer perceives climate change (1 if the farmer perceived a change in climate and 0 otherwise). This climate change perception model depends on the vector of explanatory variables (Y_i) and disturbance terms (v_i). There are two alternatives to avoid the sample selection bias in the model. Firstly, we can use only farmers who perceived climate change in the climate change adaptation model. Secondly, we can use error correction multinomial logit that includes the selectivity term from the climate change

2. In discrete choice theory, Independence of Irrelevant Alternative (IIA) states that the ratio of (relative) probabilities of choosing any two alternatives from the choice set is independent of the attributes or the availability of other alternatives. For example, θ_1 and θ_2 are the coefficients for strategy one and strategy two. θ_1 is the same regardless of whether there is strategy three and that θ_2 is the same regardless of whether there is strategy one or strategy three. This is checked by the Hausman-McFadden test (1984), the Small-Hsiao test (1985) and others.

perception model. This bias-adjusted model helps us to estimate the probability of adoption of climate change response measures relative to the reference category and is given by.

$$P(CP = j / X) = \frac{\exp(\theta X)}{\sum \exp(\theta X)} + \delta\lambda + e \qquad (7.5)$$

Where λ is the error correction term between the error terms of eq.7.3 and eq.7.4 and is known as the selectivity term or the Inverse Mills Ratio derived from eq.7.3, while δ is a coefficient of this selectivity term.

7. 3. Research methods and data

7. 3. 1. Research approach

As indicated previously, agriculture is a dominant sector in the area even if its productivity is low because of the unpredictable rainfall, poor quality of the soils, and the low use of improved inputs. Climate change and population pressure are other challenges. To understand how local people adapt to climate change and other challenges, primary data was collected from farmers using a standardised questionnaire and focus group discussions. The farmers were asked their opinions about the local climate over 20 years (1996-2015). This time frame is similar to most previous studies (e.*g., Deressa et al. 2011, Debela 2015*).

In addition, climate data was obtained from the Meteorological Agency of Ethiopia. We obtained long-term historical data on daily rainfall, daily minimum temperature and daily maximum temperature for 33 years in five different locations in the area under consideration. There are some meteorological stations in (and around) the study area, which were installed more recently (15-20 years) but only rainfall and temperature are recorded. In addition to the lack of longer-term data, these stations are poorly monitored and have some missing or incomplete data. Accordingly, we used hybrid data (TAMSAT) that combines satellite data with data from ground stations to obtain complete and long-term data.

The purposes of the study are to measure climate change trends and their impacts on livelihoods and the environment. After the field and climate data were collected and edited, descriptive statistics (e.g., the percentage ranking method) were used to assess and evaluate climate change experiences, to describe farmers' perceptions of climate change, and to identify strategies adopted by farmers to reduce the adverse effects of climate change on their livelihoods. The error correction multinomial logit model was also used to estimate the factors that affect the adoption of climate change adaptation strategies vis-à-vis the non-adoption group.

7. 3. 2. Farm-level adaptation strategies to climate change

As indicated in the literature, various types of strategies have been implemented to adapt to climate change, drought and other hazards. Farmers in the area were asked an open-ended question to list their climate change adaptations and they have mentioned several strategies which they adopted at farm level. These can be summarized into eight adaptation strategies (see Table 7.1). As can be seen from Annexe 7.1 (*statistical summary of strategies*), about 66% of the respondents have diversified crop and livestock production while about 33% of them have partially shifted their livelihood portfolio from agriculture to non-agriculture, such as petty trades, small businesses and casual work (*detailed discussion 7.4.3).* Soil and water conservation measures, as well as the application of organic fertilizers, are also used as adaptation strategies because they can reduce land degradation, including soil erosion, and improve agricultural productivity.

Since the aim of the study is to identify factors that influence farmers' decisions to adopt strategies in response to climate change, climate change adaptation strategies can be adopted separately or in combination. While adopting them in combination, farmers can implement one, two, three or more strategies simultaneously (regardless of the combinations) (1=one strategy, 2=two different strategies, etc.). Annexe 7.1 shows that about 24% of the samples have adopted none of the eight strategies. They are used as a reference group or base category, and adoption of other adaptation strategies is evaluated in reference to this. None of the farmers adopted one strategy in isolation nor did they adopt all eight adaptation strategies together. About 12% and 18% of the farmers have implemented seven and six strategies, respectively. Therefore, about 75% of the farmers in the area have adopted three or more strategies to reduce the adverse impacts of climate change and improve resilience.

Table 7. 1. Types and definition of farm-level climate change adaptation strategies adopted by smallholder farmers in the area

Strategy types	Explanation and description of climate change adaption strategies
Expansion of irrigation	Increased use of rivers and streams, developed springs, dug ground wells, constructed ponds and dams, and collected roof water
Soil and water conservation	Creation of physical contour bunds, such as soil bunds, stone walls, bench terracing, and gully treatment
Livelihood diversity	Diversified portfolio into petty trade, casual work, small businesses, non-farm works such as a quarry, selling of firewood and charcoal,
Remittance and support	Received income from migrants, sent children to relatives, borrowed money (foods) from others, safety nets, food-for-work, emergency support
Diversify crops and livestock	Used improved and early maturing varieties, drought-disease-pest-resistant varieties, varieties with better WUE, applied horticultural crops, livestock destocking and restocking, shifted temporal and spatial planting
Use of organic fertilizers	Applied compost, animal manure, crop rotation and intercropping systems on private field plots to enhance productivity and yields
Use of inorganic Inputs	Used synthetic fertilizers, insecticides, pesticides and herbicides to maximize productivity
Agroforestry systems	Planting of multipurpose trees, for forage and fodder, commercial fruit, e.g. cactus, acacia trees, silkworm trees, other permanent trees

7. 4. Results and discussion

7. 4. 1. Trends and patterns of climate change in the area

This section assesses farmers' perceptions of climate change since perception affects how farmers deal with climate-induced risks and opportunities (Debela et al. 2015) and it also shapes their behavioural responses and adaptation choices. To understand how farmers perceive a change in climate over the last 20 years, several studies were reviewed to identify indicators or parameters, for example, factors attributed to climate change including droughts, temperature, rainfall and floods (Teka et al. 2013); rainfall, temperature, and frequency of extreme weather conditions (Debela et al. 2015; Legesse, Ayele, and Bewket 2013; Roco et al. 2015); and non-consistent rainfall patterns, extremes in temperature, delayed start of the rainy season, long dry seasons and reduced rainfall (Egyir et al. 2015).

Considering these climate change indicators, a preliminary discussion with extension agents, some farmers and development practitioners in the area was conducted to contextualize them and to identify local parameters. Accordingly, temperature, humidity or moisture, extreme weather events, the occurrence of Nimbus clouds (dark clouds) without rain, wind and rainfall (amount, timing, coverage and duration) were identified as parameters often used by local people to identify changes in climate. Following this, climate-related questions were prepared. Farmers have been requested for their observations as to whether there has been a change in local climate over the last 20 years. They answered using a five-point Likert item that includes 'significantly decreased', 'decreased', 'no change', 'increased', and 'significantly increased'. For statistical purposes, the five-point scale was later converted into a three-point response item (decreased, increased and unchanged).

Figure 7.1 presents the results. About 76% of the farmers noticed an increase in temperature and they experienced unusually high temperatures, especially from February to May. On the other hand, about 5% perceived a reduction in temperature, while others (19%) were unaware of any change. The participants in the focus groups indicated that the temperature had been unusually high, especially during the night. Similar results were documented in other studies. 51% of farmers in the Nile basin of Ethiopia perceived an increase in temperature over the last twenty years (Deressa et al. 2011). A review of 19 papers in 14 countries also shows an increase in average temperature (Fisher et al. 2015). Others have also reported similar results (Menike and Arachchi 2016; Taruvinga, Visser, and Zhou 2016; Debela et al. 2015; Gadédjisso-Tossou 2015; Mwalusepo et al. 2015; Calzadilla et al. 2014; Nhemachena et al. 2014).

Wind (or storms) is also viewed as an indicator of climate change. Winds that blow from the Afar depression (eastern parts) have meanings for the highland farmers. Sometimes, dry and hot winds occur, especially from February to April. This indicates a bad year (little or no rain from June to September and then drought occurs). To this effect, farmers were asked whether the occurrence of these dry and hot winds has changed over the last 20 years. About 69% of the farmers perceived an increase, while some farmers (13%) claimed a decrease and about 18% did not notice any change. In the focus group discussions, there was agreement on the change in the intensity and moisture content of the winds. The wind was also claimed to carry more dust and to sometimes remove roofs and destroy crops.

With regards to clouds, during the rainy season, the local people knew that the sky was often full of very intense or dark clouds, which made it difficult to see distant areas. During the dry season, the sky was clear. A thin or light cloud was seen during May and this gradually changed into heavy or dark clouds from the middle of June and remained until the middle of September. Accordingly, if a dark cloud covered the sky, local people would expect rain. Such a pattern of clouds during the summer or rainy or wet season is considered as an indicator of climate change. Farmers were asked whether there had been a change in this respect.

About 52% of the farmers perceived a decrease in the intensity of clouds during the wet season, while about 26% did not see any change. In the focus group discussions, it was understood that the intensity of clouds has been decreasing. Unlike before, the sky remains cloudless until the middle of July and starts to form very light cloud in August. This often disappears soon without the appearance of dark clouds. Sometimes, the sky is covered either by fog and mist or dark clouds, but with little or no rain. According to the farmers, such changes are the result of climate change. However, it should be noted that there may be either thick or dark cloud without droplets, or strong wind may either shift or remove the clouds.

Globally, the amount of rainfall is a good proxy variable of climate change. Farmers can easily understand and perceive this since it is directly linked to crop and livestock production. Farmers were asked whether there has been a change in the amount of rainfall in their villages. About 59% of them perceived a significant reduction in the amount of rainfall year after year. Almost half of the households believed there has been an increase (18%) or no change (23%) over recent decades. As stated in the focus groups, the rain did not only significantly decline in terms of amounts but also became highly unpredictable. Rain or precipitation has often been drizzle, which is unusual during the rainy season.

Similar findings have also been reported previously. About 53% of the farmers perceived a decrease in the amount of rainfall over the last 20 years (Deressa et al. 2011). 75% of farmers perceived a decrease in rainfall, while about 7% did not see any change (Gadédjisso-Tossou 2015). While reviewing 19 previous climate change studies, it was found that most farmers perceived a decrease in mean rainfall over the last two decades (Fisher et al. 2015). Others reported similar results (Calzadilla et al. 2014; Debela et al. 2015; Menike and Arachchi 2016; Mwalusepo et al. 2015; Nhemachena et al. 2014; Singh et al. 2014; Taruvinga et al. 2016).

Additionally, the length of the rainy season is an important indicator of climate change. About 70% of the farmers and many focus group participants observed not only a shortening of the rainy season, for example from three months to one and a half months, but also a shift in the rainy season from May-September to July-August. However, some farmers (13%) reported the opposite and saw an extension of the rainy season, while 17% were also unaware of any change in the timing of the rainy season. Berhe et al. (2017) also reported untimely rain and changing patterns as major indicators of climate change. Thus, shortening of the rainy season and extending the dry season is a typical indicator.

In parallel, the spatial variability of rainfall - the distribution of rainfall across the location - is also taken by the local people as an indicator to understand whether or not the climate has been changing. About 60% of the farmers perceived a reduction in rainfall coverage across and within the villages, while 16% did not notice any change. In the focus groups, it became clear that the distribution of rainfall has become highly unusual in terms of its spatial coverage. Unlike in the past, rainfall is fragmented across field plots. For example, some parts experience a good quantity of rain, some parts receive a little rain and others none. It has also become more irregular from year to year.

Furthermore, another indicator is humidity (moisture) which relates to both temperature and rainfall. About 52% of the farmers perceived a decrease in moisture while other farmers nuanced this view, for example, 27% perceived increasing moisture and 21% no change in moisture. Almost all participants in the focus groups confirmed a significant decline in moisture despite implementing soil and water conservation and plantation programmes. This has resulted from an increase in temperature and expansion of desertification from the Afar region.

In the focus groups, the appearance (frequency and intensity) of extreme weather conditions, such as excessive rainfall, the prevalence of droughts, flooding, dust storms, strong winds, rust and frost are considered indicators of climate change. Excessive rainfall and serious flooding problems were observed in the area four times over the last 20 years, which has resulted in starvation and livestock deaths. In some parts, crops were completely destroyed because of the incidence of heavy frost and rust. Unusually strong winds ruined some houses and destroyed or damaged several trees. It was reported in the literature that extreme weather events, such as extreme warm temperatures, and heavy precipitation have been observed since 1950 (IPCC 2014). During the focus group, an old farmer aged 70 years summarized climate change as:

> *"….20 years ago, since we knew when to start and end rainfall based on our local indicators such as clouds, winds and animals, we knew when to prepare farmland, and when and what crops to sow…but recently local indicators are highly variable and unpredictable, it becomes very difficult to understand and use them. Therefore, we are waiting for the rain to prepare our lands and plant crops….The problem we are encountering now is that the rain ends soon and the moisture in the land disappears rapidly due to the high temperature….*"

Apart from the perception data, we also used meteorological data, which was obtained from the Metrological Agency of Ethiopia. The reason is that perception data might not always be in line with the actual climate data because farmers' memory of past events might not be accurate or might be shaped by personal characteristics (Bryan et. al 2009). For an event a long time ago, people can wrongly perceive, mistakenly recall or may understand differently and therefore respond incorrectly. This suggests that fruitful results can be produced if meteorological data complements perception data. In accordance with this fact, historical data over 33 years was utilised. This period seems sufficiently long to quantify the magnitude and effect of climate change since other studies have used a period of 24 years (Roco et al. 2015) or even only 20 years (Deressa et al. 2011; Gadédjisso-Tossou 2015).

Annexe 7.2 presents the average temperature over time (1983-2015)[3], especially during dry and rainy (wet) seasons. The average temperature in the rainy season is higher than that for the whole year. In the area, the mean maximum temperature has, on average, increased annually

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[3]. *In this, we used the dry season in the Tigray region from October to May while the rainy or wet season runs from June to September. In reality, short rains have been observed, especially during the spring season, which ranges from April to May.*

by about 20% for the last 33 years, while the mean minimum temperature has increased by 36%. This suggests that temperature has increased by around 0.1°*C* over the last 33-year period. If this trend continues, the surface temperature in the area would increase and may have adverse impacts on livelihoods and ecosystems in the country.

As indicated in Annex 7.3, the rainfall trend partly indicates the presence of climate change in the area across three decades. Total rainfall during the rainy season is lower than the total rainfall during the whole year because there is also little rainfall during the dry season, especially short rains during March, April and May, where farmers can grow crops depending upon the amount of rainfall. The mean annual rainfall decreased from 448mm in the 1980s to 420mm in the 1990s, and to about 300mm in the 2000s. However, the mean annual rainfall has increased to about 400mm in the 2010s, where it exhibited a breakthrough point especially before 2006. The mean annual rainfall for the last 33 years was about 400mm with a coefficient of variation of 34% while the coefficient of variation of rainfall during the rainy season is 48%.

With regard to dry spell days, Annexe 7.4 shows the percentage of dry days during the dry season, wet season and the whole year. Of the 90 days in the winter season, which includes December, January and February, almost 97% were dry days during the last 33 years, while nearly 45% of the 92 days during the wet season (June, July and August) were dry days. Considering the whole year, about 80% were dry days over the last three decades. This suggests that roughly speaking, for the last 33 years, only two months were wet periods, while the remaining 10 months in a year were dry periods.

Both perception and meteorological data generated similar results and confirmed the presence of climate change in the area. Farmers were also asked to identify the cause of climate change. The responses were variable among farmers and across the focus groups. Some suggested reasons for climate change included felling of trees, traditional farming practices, overgrazing, erosion, degradation, population pressure, poor economic status and spiritual reasons. The focus group discussions also mentioned the expansion of industries, especially in rich countries. 25 farmers believed that climate change is '*a punishment from our God due to our intolerable sins*'. With regard to drought, farmers did not mention it as a driver or consequence of climate change. This means that they either used it interchangeably with climate change or are overlooking it. Focus group participants perceived drought as a consequence of climate change. Due to increasing temperature and declining rainfall, drought occurs more frequently.

In general, many farmers have perceived an increase in temperature, an increase in hot and strong winds blowing from the Afar region, a decrease in the amount of rainfall below the normal, shortening and shifting of rainy seasons, falling humidity and increasing irregularity of rainfall. While evaluating the geographic distribution of rainfall and temperature using the coefficient of variation, we found statistically insignificant differences across these station sites (coefficient of variation varies from 0.36 to 0.40). But some of these events (impacts of climate change) could be opportunities for farmers. This could push them to rethink and readjust possible mitigation measures. A decrease in the amount of rainfall could stimulate farmers to focus on crops with better WUE. The delayed arrival and immediate end of rainfall (shortening effect) with unusual patterns could induce them to use crops that mature more quickly.

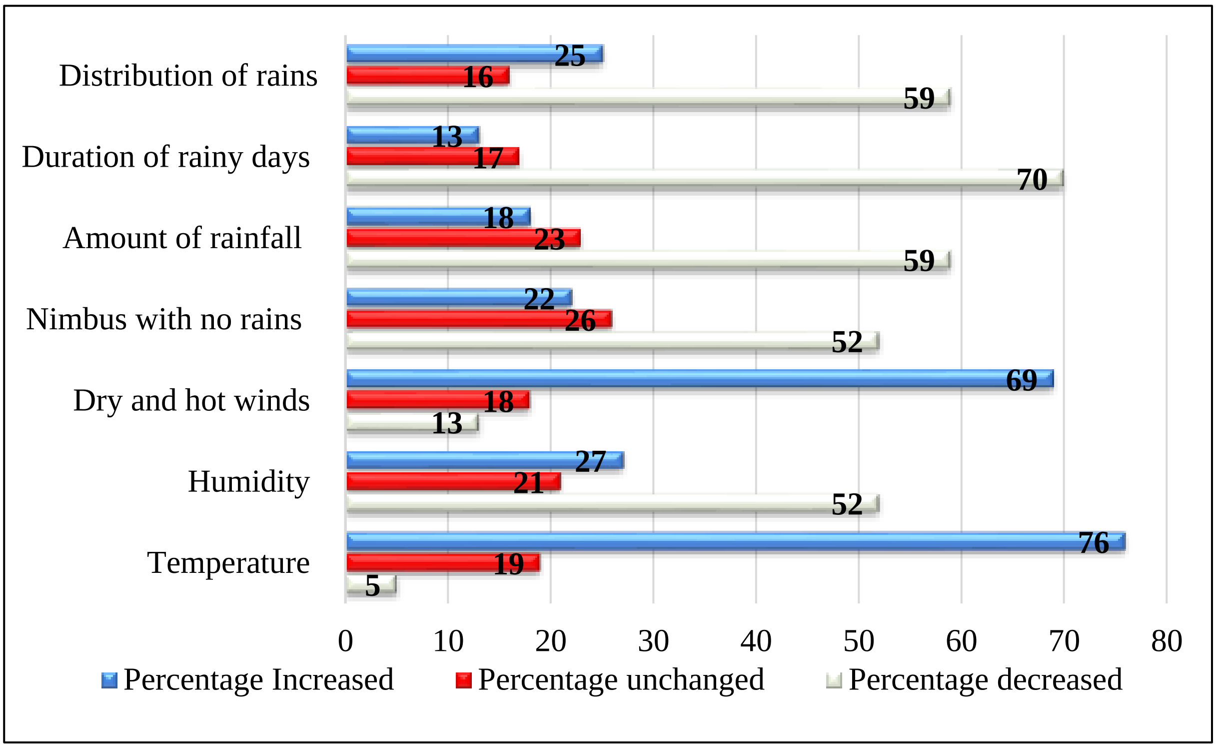

Figure 7. 1. Farmers perception of climate change over the last 20 years (percent)

7. 4. 2. Potential impacts of climate change on agriculture, livelihoods and ecosystems

This section assesses whether local people are sensitive to, and impacted by, climate change, and how they have perceived the impacts. Farmers were asked an open-ended question to identify some impacts of climate change, and they reported impacts relating to water, health, livelihood, biodiversity, livestock and crops. These lists are summarised into eight major impacts (see the table below) and reported using a percentile ranking method.

Description and explanation of impacts of climate change identified by local farmers	
Crop failure	Reduced crop yields from the incidence of pests/diseases or late rains
School withdrawal	Students (children) withdraw from schools due to specific challenges
Reduced water	Reduced water availability, retention and discharge, for example, dams, springs, wells and rivers
Livestock deaths	Death of livestock, lack of fodder, reduced market value for livestock, destocking of livestock
Biodiversity losses	Cut giant trees for firewood and construction, sent livestock to exclosure and protected areas, deforestation and degradation
Inadequate food	Shortage of human food, lack of credits, lack of money to buy food
Migration/support	Moved to urban or Arab countries and sought help from others (NGOs)
Health problems	Incidence of human disease/illness (malaria, pyrexia, eczema, glaucoma)

Similar impacts are reported in the literature, for example, spread of diseases, shortage of forage, reduced solidarity, deforestation and migration of young people (Mertz et al. 2009), drying up of water resources, crop failure, increase in food prices, poor health, declining price of livestock, and increased crop diseases (Udmale et al. 2014), a reduction in crop yields (Deressa et al. 2011), decline in farm incomes (Addisu et al. 2016) and worsened food security (Bozzola 2014). Crop failure, droughts, lack of fodder, rainfall variability, drying up of rivers, temperature change, the prevalence of human and animal diseases, untimely rains and flooding, and lack of human food were found to be the main effects of climate change (Berhe et al. 2017).

Figure 7.2 indicates the percentage of farmers who perceived a particular impact from climate change. A lack of food or lack of money to purchase food and non-food items, which is mentioned by 82% of the farmers, is the main detrimental impact of climate change. Farmers are unable to buy clothes, school materials and farm tools, as well as being unable to pay loans, land rent and other fees. In the previous study in Ethiopia, about 96% of farmers claimed a significant reduction in their income and livelihood due to climate change (Debela et al. 2015) and 80% of local communities (pastorals, semi-pastorals, agro-pastorals and mixed farmers) noticed a lack of human food as the highest impact of climate change (Berhe et al. 2017).

Climate change affects water endowment, soil moisture and increases the water requirements of crops and livestock (Singh 2014) and reduces crop productivity and yields, which might lead to crop failure (Calzadilla et al. 2014; Nhemachena et al. 2014). A decline in crop yields is perceived by most farmers (76%) as the second potential impact of climate change. According to the focus group discussions, crops have failed due to a shortage of rainfall, early rain withdrawal or the prevalence of frost and the rust - a fungal disease that affects wheat, barley, tomato, peas, beans and so forth. This is confirmed by previous studies, where crop failure is due to climate change (Berhe et al. 2017; Debela et al. 2015; Li et al. 2014; Mwalusepo et al. 2015; Singh et al. 2014), for example, strong winds, intensive rainfall, erratic rainfall and extended periods of cloud cover (Mertz et al. 2009; Obayelu et al. 2014).

Obviously, water is a basic need for crops, livestock and humans. Singh et al. (2014) showed that, in Asia, water availability is adversely affected by climate change. This indicates that climate change affects water resources across different locations. A reduction in water availability and discharge is perceived by about 65% of the farmers as the main impacts of climate change. As indicated in the focus groups, ground wells have become non-functional. Dams, streams, springs and rivers have frequently exhibited reduced volume or sometimes dried up. Berhe et al. (2017) also found the drying up of existing streams and rivers and scarcity of water as major effects of climate change in the Afar and Tigray regions of Ethiopia.

In Ethiopia, mixed farming is a dominant activity, where livestock plays an important role in livelihoods. However, as expressed by half of the farmers (54%), animals are highly affected by climate change. The death of livestock and a reduction in their market value are major adverse impacts of climate change. These result from a shortage of water, lack of pasture or grazing land, unavailability of forage, and prevalence of diseases and parasites. The frequent drying up of rivers, streams, springs and other water sources also has a direct or indirect impact on livestock populations. As explained in the focus groups, the area is favourable for apiculture and small ruminant production, but many bee colonies have disappeared and moved elsewhere to search for water and flowers. A number of animals have died due to diseases. The detrimental impacts of climate change on livestock due to heat and cold, along with a shortage of pasture and water (Mertz et al. 2009) and lack of fodder, the prevalence of animal diseases and water scarcity have also been reported by others, e.g., Berhe et al. (2017).

In the area, farmers have noticed a significant detrimental impact of climate change on human health and farm production. For example, as a result of migration, only old people stay in agriculture. This tends to lead to unused farmland due to labour bottlenecks. As explained in the focus group discussions, the occurrence of human diseases has made farmers stay at home rather than working on farms. Dust carried by the wind causes eye irritation and injury. Dry and hot winds during the dry season also have a negative effect on facial skin. These together with the lack of sanitation and lack of water have resulted in outbreaks of disease.

Because of the unavailability of livestock forage, farmers are forced to send their livestock to the already managed and enclosed areas. Sometimes even trees are cut for the leaves to serve as animal feed. Farmers have engaged in the illegal felling of giant trees to sell them in the market for charcoal, firewood and construction, which aggravates deforestation and degradation and facilitates a decline in biodiversity and wildlife, such as grasses, vegetation and wild animals, gradually leading to extinction. A similar result has been previously reported, including a decline in wild plants, increased human health problems, and loss of natural systems and resources due to climate change (Mertz et al. 2009; Obayelu et al. 2014).

As stated in the focus groups, the negative effects of climate change on livestock and crops, such as the death of animals, crop failure, and a decline in animal products (eggs, milk and honey) can lead to a shortage of food supply and an increase in the price of food items, which puts livelihoods at risk. The adverse effects of climate change on food and water security are widely reported in the literature, including booming commodity prices, retarded economic growth and disruption to the whole economy (Kansiime, Shisanya, and Wambugu 2014; Nhemachena et al. 2014; Singh et al. 2014; Udmale et al. 2014).

Besides looking at the impacts themselves, tests were undertaken to assess whether a significant difference in adverse impacts from climate change occurs across certain variables, such as location (villages), agroecology and gender of household heads (see Annexe 7.5). According to the chi-square test, there is a significant difference in livestock deaths and destocking, and student school withdrawal between male and female-headed households, and across villages. When evaluating the mean score, the proportion of livestock deaths is higher for female-headed households and villages closer to the Afar region, while withdrawal of students from school is higher for male-headed households than for female-headed households, and higher in villages near to urban areas, such as Atsbi, Wukro and Haikimesihal, even if migration is higher in villages near the Afar region. Loss of biodiversity and natural resources is more severe in the temperate zone than the warm temperate zone due to population pressure, and susceptibility to erosion and degradation.

Finally, even if climate change has multiple adverse impacts, there is a potential for farmers to divert this into positive opportunities. For example, some farmers have moved to towns and started small businesses, such as petty trade. This can stimulate farmers to gradually shift from farming to non-farm activities. This can also promote the development or expansion of small businesses or agro-processing enterprises. Furthermore, some farmers have started to rethink how to cope with future challenges, for example, increased use of small-scale irrigation, construction of alternative water harvesting schemes, planting of multipurpose trees and use of improved varieties. Therefore, smallholder farmers can convert these adverse impacts into opportunities and look for alternatives to build their adaptive capacity.

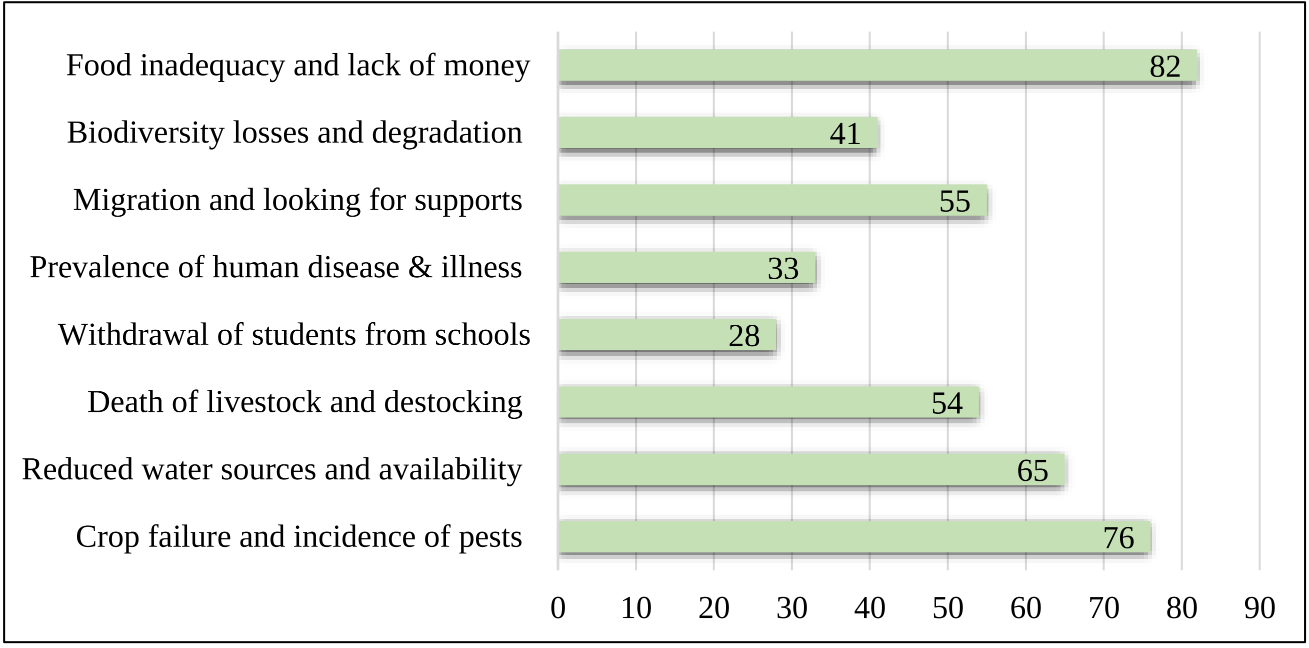

Figure 7. 2. Impacts of climate change on livelihoods and the environment by farmers who are aware of climate change (percent)

7. 4. 3. Adaptation strategies to reduce the impacts of climate change

As explained above, most farmers have perceived a change in climate and have evidently recognised its impacts on crops, livestock, water, the environment and their livelihoods. The adverse effects will increase and become more widespread unless some responsive measures are taken because the climate will continue to change (Deressa et al. 2011; Singh et al. 2014; Tazeze et al. 2012). Here, farmers are advised to implement carefully planned strategies to reduce the severe consequences.

This section aims to assess how farmers in the area have adapted and behaved in response to climate change. To understand the adaptive strategies of farmers, two sequential questions were prepared. Initially, farmers were asked a closed-ended dichotomous question to indicate whether or not they were sensitive to climate change over the last 20 years. About 83% of them perceived a change in climate, while the remaining (17%) did not. In previous studies, 4% of farmers in Ethiopia and 30% of farmers in Togo did not perceive any change in climate during the last 20 years (Debela et al. 2015; Gadédjisso-Tossou 2015).

Following this, an open-ended question was asked to those who were aware of climate change to indicate the strategies they have undertaken to reduce their exposure and vulnerability to climate change. About 92% of the farmers who were aware of climate change have adopted different types of strategy as a response, although there is significant variation among farmers.

However, about 8% (n=24) had not implemented any adaptation measures. In a similar study in Togo, this number was much higher, with 42% of farmers not taking action (Gadédjisso-Tossou 2015). Berhe et al. (2017) also found some farmers who did not adopt strategies against climate change. Following the responses, farmers in the area have identified multiple and heterogonous strategies. As explained in section 7.3.2, these are summarized into eight strategies based on their similarities (see Table 7.1).

Berhe et al. (2017) encountered the following adaptation methods in Ethiopia; zero grazing, livestock mobility, pasturing in own-village, use of selected breeds, off-farm, livestock diversification, destocking, feed storage, and spate irrigation. Planting short season varieties, changing planting dates, crop diversification and finding off-farm jobs were listed as strategies in Togo (Gadédjisso-Tossou 2015); and using new crop varieties, re-sowing, collecting and cultivating of fodder, more wells and boreholes, use of manure, gardening and planting trees in Senegal (Mertz et al. 2009). A similar study in South Africa also found related adaptation strategies, such as the use of compost (77%), intercropping systems (69%), changing crop varieties (77%), staggering planting dates (69%), supplementary irrigation (62%), shifting cultivation (60%) and selling firewood (26%) (Taruvinga et al. 2016) while use of improved crop varieties (80%), laser land levelling (42%), crop rotations (23%) and zero tillage systems (11%) were reported for India (Khatri-chhetri et al. 2016); and planting short season crops (87%), planting crops resistant to drought (7%), changing planting dates (3%) and planting trees (3%) in Sri Lanka (Menike and Arachchi 2016).

Figure 7.3 shows that the main measure in response to climate change in our study was to diversify crop and livestock production, which is used by about 80% of the farmers. Many farmers in the area have used new (improved) varieties (crops and livestock) that are drought-tolerant, pest/disease resistant and varieties with better WUE. Some farmers have also shifted the planting period over the fragmented field plots and over time (adjusting the timing of sowing dates) waiting for rainfall. They have also sent their livestock to protected or communal exclosures to save them from drought and disasters. Some farmers have either destocked or restocked depending on the weather conditions. In other countries, related adaptation strategies were reported by Menike and Arachchi (2016) and Taruvinga et al. (2016).

Another common response to climate change in the area, which is followed by about 74% of the farmers, is undertaking different soil and water conservation measures. Since the area is characterised by mountains and rugged topography, land conservation, including the creation of soil bunds, stone walls, terracing and gulley reclamation, has been commonly implemented. These activities often have a dual purpose. On the one hand, they reduce erosion from wind and runoff and prevent degradation and deforestation; on the other hand, they improve the quality of farmland conditions, especially soil fertility and micronutrients, and increase water retention and discharge capacities, which ultimately increase productivity and yields. Abdulai & Huffman (2014) also found the construction of earthen bunds or small ridges to improve soil fertility, conserve water and boost rice yields.

Next, about 59% of the farmers have implemented agroforestry systems; and about 60% have been involved in the expansion of irrigation and water harvesting schemes. Finally, the use of organic fertilizers was also adopted by about 68% of farmers. These adaptation strategies have helped to reduce the adverse effects of climate change. Farmers have planted multipurpose trees for human food, animal fodder, wind protection and enhancing soil fertility. Farmers have often increased the use of irrigation by diverting rivers and streams, developing spring and ground wells, constructing ponds and dams, and using other water harvesting schemes. The use of compost, animal manure, crop rotation and intercropping has also been widely applied (see Table 7.1). Singh et al. (2014) report the use of organic manure and agroforestry systems as adaptation measures to climate change and drought.

In the area, crop production and animal husbandry are primary sources of livelihoods for smallholder farmers. However, both are very sensitive to climate change. For this reason, some farmers (39%) have preferred to diversify their sources of livelihood to petty trade and small business, while some have participated in casual labour and others have been involved in the collection of permanent trees from communal and protected areas to sell them for firewood, charcoal, housing and construction purposes. Therefore, shifting from agriculture to non-agriculture has recently gained importance in the area as a mechanism against climate change and other shocks.

Remittance and reliance on external support, especially on the government and NGOs, are also viewed as possible options to reduce the adverse effects of change climate. This choice is followed by about 45% of the farmers who have perceived a change in climate. When drought and other threats have occurred as a result of climate change, many farmers have often waited for an emergency, food-for-work, safety nets and food aid from various concerned organisations. Some could sometimes temporarily send some of their children to their relatives in the urban areas.

At the worst times, farmers could borrow money from friends or neighbours or take microfinance loans to purchase food and other basic items. There has also been significant migration, especially to Arab countries, in search of income and better jobs. These migrants have sent income (remittances) to their families, which enables them to counter problems directly or indirectly caused by climate change. This is consistent with findings from Senegal, where migration, support from NGOs and aid from relatives were found to be an important coping mechanism for the adverse impacts of climate change (Mertz et al. 2009).

Surprisingly, the use of chemical fertilisers, insecticides, herbicides and pesticides is viewed by farmers as an adaptation option in response to climate change. About 43% of the farmers have applied these inputs to boost agricultural productivity and production, thereby increasing farm income because such inputs have the potential to significantly improve yields. This strategy was also reported in India, where farmers have increased the application of inorganic fertiliser as an adaptation strategy to climate change (Singh et al. 2014).

In the focus group discussions, similar adaptation strategies were identified, except for remittance and the use of inorganic fertilisers, which were not mentioned as adaptation strategies to climate change. Additionally, the focus group participants mentioned access to credit schemes as a major response option to climate change. This also observed Senegal by Mertz et al. (2009), as they indicated that financial constraints limit their ability to adapt to climate change and reduce their resilience capacity.

In a nutshell, most farmers have implemented different adaptation strategies to improve agricultural productivity and cope with the adverse impacts of climate change. Following this, some points seem particularly important. Firstly, some adaptation strategies, such as migration, the use of chemical fertilizers and seeking external support from the government and NGOs cannot be considered as sustainable agricultural practices because these may have long-term environmental implications and social concerns, for example, dependency syndrome. However, they are still helpful in coping with the adverse impacts of climate change.

Secondly, the contingency coefficient chi-square test is used to assess whether there is a significant difference in climate change adaptation strategies across villages, and between the temperate and warm temperate agro-climatic zones (=agro-ecological zones). The results of the study, however, indicate either weak difference (for example remittance and support, and the use of chemical fertilizer) or statistically insignificant difference in these strategies across villages, as well as between agro-ecological zones and across the villages (see Annexe 7.6). Therefore, adaptation strategies against climate change do not vary across locations and agroecology. This might be due to the small geographic coverage of the study.

Thirdly, some farmers have not taken any adaptation measures, although they are aware of climate change. As stated in the focus groups, this could be linked to a lack of information, lack of awareness of adaptation measures, insufficient landholdings, lack of money, shortage of family labour, limited access to credit, limited institutional support and specific personal characteristics (e.g., aversion). Similar barriers were reported in the literature, such as a shortage of finance, shortage of family labour and lack of knowledge (Obayelu et al. 2014), lack of information, and shortages of money, land and labour (Debalke 2013), and lack of farmland, shortage of farm labourers, high price of chemical fertilizers and pesticides, and limited access to credit for farming (Tun Oo, Van Huylenbroeck, and Speelman 2017).

Fourthly, most adaptation strategies are closely related to the practices suggested in sustainable agriculture, for instance, diversification of crop and livestock production, use of organic fertilizers, application of agroforestry systems, diversification of livelihood portfolios, expansion of irrigation and water harvesting schemes, and the use of soil and water conservation measures. These are sustainable and also effective in addressing the economic, environmental and social implications of sustainability.

Finally, since lack of information and lack of institutional support have been frequently mentioning as constraints, farmers need training and institutional support to improve their awareness and build their capacity to successfully adopt both reactive and proactive sustainable agricultural strategies[4] to revert those adverse impacts in a sustainable way.

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[4]. *Adaptation strategies that depend whether they take place before or after the occurrence of a climate change event including: reactive strategy addresses climate change after it has been experienced, for example, control of soil erosion, construction of irrigation dams, improving soil fertility, development of new varieties, shifting planting and harvesting time, whereas a*

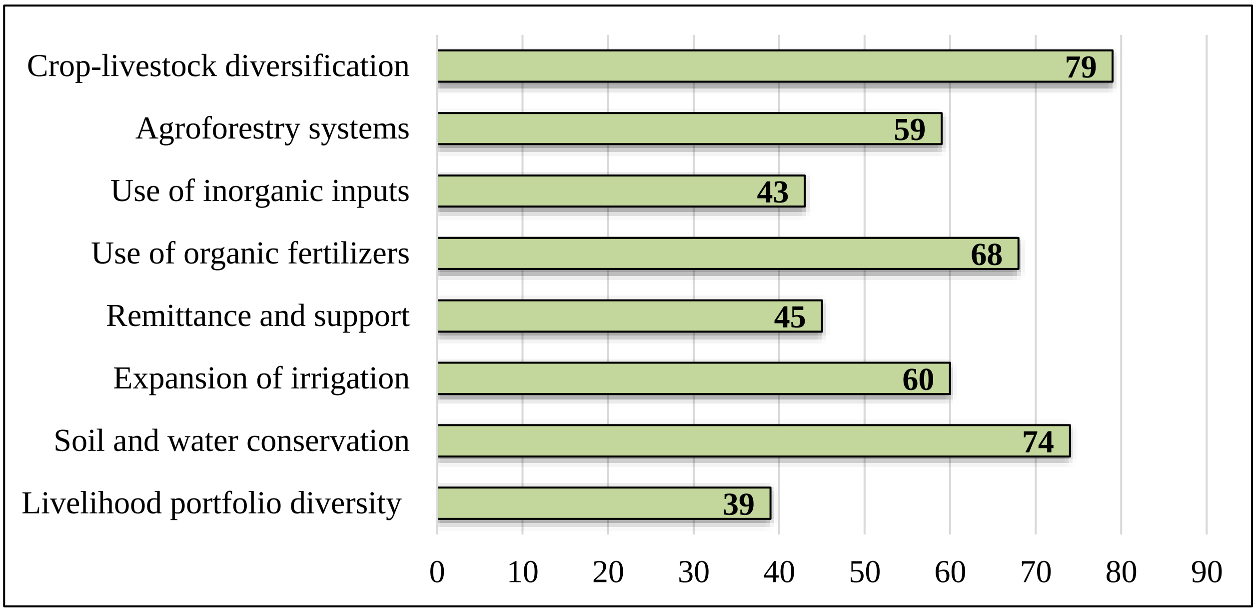

Figure 7. 3. Farmers who are aware of climate change and have adopted strategies to reduce its adverse impacts (percent)

7. 4. 4. Farmers' choice of climate change adaptation strategies

This section aims to investigate the factors that influence the use of adaptation strategies to reduce the potential adverse effects of climate change. As stated in section 7.4.3, smallholder farmers in the area have adopted eight adaptation strategies to reduce the adverse impacts of climate change on livelihoods and the environment. About 24% of the farmers have adopted no strategy. They are used as a reference group. Farmers' decisions to choose adaptation strategies are shaped by demographic characteristics, socio-psychological factors, socioeconomic and biophysical variables and institutional factors (see in Annexe 2.1, Annexe 2.2 and Table 3.1).

These variables are checked for normality and multicollinearity assumptions using Skewness and the Pearson product-moment correlation coefficient. They are normally distributed and multicollinearity is not a problem. Robust variance estimation is used to avoid a heteroscedasticity problem (if any). As explained in section 7.2, a two-stage equation is used: farmers are aware of climate change (selection equation) and farmers adapt strategies to alleviate its effect (outcome equation).

The result of the climate change perception logit model (selection equation) is presented in Annexe 7.6. The overall model is statistically significant (*Wald LR Chi-square:* $\chi^2(18)=102$; $P(\chi^2)=0.014$). Farmers are more aware of the presence of climate change in their respective area, if they have frequent contacts with extension workers, if they have strong relationships and networks with local community groups, if they have received capacity building training and if they are members of formal organizations. Also, farmers solely reliant on agriculture are

proactive or anticipatory adaptation strategy is involved in anticipation of climate change, such as the development of tolerant cultivars, research development, policy measures on taxation and incentives.

highly sensitive to climate change and more aware of changes and impacts than other farmers. Against expectations, illiterate farmers are more aware of climate change than literate ones. Thus, farmers' awareness about climate change is affected by occupation, education, extension services, social capital, capacity building, access to farmer-schools, and stress from shocks.

The result of the outcome equation is presented in Table 7.2. An error correction multinomial logit model is used to capture bias from unobserved factors in the perception model (inverse mills ratio). The Wald chi-square test (*chi-square statistic:* $\chi^2(156) = 1847$ *and* $P(\chi^2) = 0.000$) shows that the overall model is statistically significant. The null hypothesis, which shows no significant difference between the model without independent variables and the model with independent variables, is rejected. The estimated coefficients of the explanatory variables are jointly different from zero and the equality hypothesis for slopes is therefore not supported.

As indicated in the same table, the selectivity term, or inverse mills ratio, which is derived from the climate change perception model, is statistically significant for most climate change adaptation strategies. As a result, the bias-corrected or error correction multinomial logit is an appropriate model to study climate change adaptation because it accounts for unobserved heterogeneities and the presence of variables that simultaneously affect the perception and adaptation models. For most climate change adaptation strategies, since the coefficient of the selectivity term is negative, overlooking hidden bias may underestimate the overall results.

As stated in section 7.2, the multinomial logit model depends on the property of Independence of Irrelevant Alternatives (IIA), which states that the inclusion or exclusion of categories does not affect the relative risks or coefficients associated with the regressors of the remaining categories. For example, when farmers are asked to choose from a set of climate change adaptation strategies, their odds or coefficients for choosing strategy A over strategy B should not depend on whether strategy C is present or absent. This assumption is tested using a STATA command 'mlogtest[5]' and IIA has not been violated through these alternative tests.

Table 7.2 shows that social capital (relational capital and group membership), agricultural extension systems (frequent contact with extension agents and confidence in their competence), education, fertility and slope of field plots, livestock ownership, and rural services (market proximity, accessibility to all-weather roads and capacity building institutions) are found to significantly influence farmers' decisions to adopt different adaptation strategies to reduce the adverse impacts of climate change. In previous studies, using the Heckman probit selection model, factors that affect climate change perception and adaptation were found to be related to education, roads, output markets, extension services and the number of relatives (Deressa et al. 2011). Similar results were also found with the joint use of the Heckman probit selection model and a multinomial logit model (Addisu et al. 2016).

The use of the estimates of the corrected multinomial logit model needs caution because the interpretation is in comparison to the reference category. For example, the likelihood of adopting two different strategies relative to non-adoption is approximately 0.37 units higher for

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[5]. The mlogtest can use various tests, for example, Hausman test, Smhsiao test, likelihood ratio test, Wald test and test for combining dependent categories to evaluate the assumption of the independence of irrelevant alternatives (mlogtest, hausman; mlogtest, smhsiao; mlogtest, combine; mlogtest, iia).

farmers who are located in the temperate zone compared to those who are located in the warm temperate zone (Table 7.2). For simplicity, most studies have used relative risk ratio or odds ratio rather than coefficients, for example, the relative probability of adopting six strategies to reduce the adverse impacts of climate change rather than not adopting any strategy is about 9% higher for literate farmers than for illiterate farmers (see Annexe 7.6).

As also indicated in Annexe 7.6, for farmers who have strong relationships, ties and networks with local community groups, such as relatives, friends and families, relative to counterpart farmers, the likelihood of adopting two strategies relative to not adopting any is expected to increase by 71% given that the other variables in the model are held constant. In a similar way, the likelihood of adopting a combination of six climate change adaptation strategies jointly relative to none is about 32% higher for farmers who are members of formal institutions than for non-members. This suggests that farmers with strong social capital are more likely than farmers with weak social capital (not members and do not have good relationships) to adopt more climate change adaptation strategies.

In concurrent ways of interpretation, male-headed households are more likely to migrate, to be involved in casual work, and to engage in non-farm activities, and thus are less likely to adopt six different adaptation strategies to reduce climate change impact. Since adaptation strategies to climate change need a better understanding of the local dimensions of climate change (IPCC 2007), the age of the farmer is one of the important determining factors. As age increases, farmers are expected to accumulate more experience about climatic conditions and farm management practices. This helps them to better anticipate a change in climate, evaluate the situations rationally, and develop appropriate strategies that respond to climate change.

In rural economies, livestock are important. They are a source of livelihood and can help farmers to improve their adaptive capacity although livestock production itself is also susceptible to climate change impacts. Farmers who owned more livestock preferred specific strategies that focus solely on livestock production rather than adopting more of the other strategies. Household size is also important because labour bottlenecks can constrain the use of some labour-demanding strategies, such as soil and water conservation measures. Plot-specific characteristics, such as soil fertility, size and slopes can be directly or indirectly related to the adoption of various climate change adaptation strategies.

As stated in the literature, financial resources can help farmers to meet transaction costs and invest in improved farming practices to enhance yields and reduce the adverse effects of climate change. Relatively speaking, rich farmers are in a better position to select adaptation measures compared to poor farmers (Jaleta et al. 2016). Following this, perceived resources, access to credits, and special skills, which relax liquidity constraints, are viewed as indicators of financial capacity and have positive implications on choice for some adaptation strategies, but no impact on many adaptation strategies.

Education normally improves awareness, reduces uncertainties and inspires farmers to adopt improved farming practices that reduce climate change impacts. In our study, the results are mixed; on one hand, literate farmers are more likely to adapt to climate change by applying more (six and seven) adaptation strategies; on the other hand, literate farmers are less likely to adopt three and four strategies. This suggests that the effect of education varies depending on the types of adaptation strategy. This could be because literate and illiterate farmers have different preferences. The preferred strategies of literate farmers in response to the risks of climate change may not necessarily be the same as those of illiterate farmers.

Along with this, the multinomial model combines agricultural practices regardless of strategy type because the comparison is with non-adoption or the stated reference group. Among the combined strategies, there may be some that literate farmers are reluctant to adopt, while others are in favour of them. When strategies are used in combination, it is not possible to trace which strategies are combined, but it is possible to know how many strategies are combined. Hence, education has positive impacts on some strategies, while it has negative impacts on some others. Similar findings have also been reported in previous studies, example, Teklewold et al. (2016).

Another variable is information. It is important for farming decisions and technology adoption. Farmers can obtain climatic and agricultural information through mass media, such as television or the radio service and agricultural extension services, which provide free technical consultation. Information enhances their awareness and motivates farmers to adopt different measures in response to climatic change. Farmers who have frequent contacts with public extension agents and have confidence in their skills and competencies are more likely to use some adaptation measures, such as soil and water conservation, and use of compost against climate change impacts, compared to other strategies.

Especially in rural areas, membership in formal organisations, such as resource users' groups, farmers' associations and cooperative societies, and interpersonal communication and relationships with informal community groups, such as relatives, neighbours and families have pivotal roles in the day-to-day activities of farmers. They enable them to have a homogenous understanding of farming management practices, and also to easily exchange climatic and agricultural information. Formal institutions have sometimes organized discussions and experience sharing for group members, which create favourable situations for them to make comparative and better decisions in relation to farming decisions and adaptation strategies. Those positive effects of formal and informal institutions on climate change adaptation strategies are consistent with other studies, such as Wossen, Berger, and Di Falco (2015), Teklewold et al. (2013) and Deressa and Hassan (2009).

Furthermore, infrastructure attributes, such as markets, farmer-school and rural roads also have vital roles in farming decisions and are known to be important. They have implications for transaction and transportation costs, human awareness and overall development. Depending on the distance to those social and physical services, farmers' decisions to adopt strategies in response to climate change vary significantly. Farmers who are located closer to markets and rural roads have preferred to engage in non-farm activities, such as petty trade and small businesses to adapt to climate change instead of adopting more adaptation strategies related to agriculture. Farmers who are located within a mean walking distance (60 minutes) of farmer-school, where farmers receive inputs and training, have higher chances of adopting more adaptation strategies, especially related to crop and livestock production.

In general, farmers who have climatic and agricultural information from different sources have better opportunities to understand climate trends and farming management practices. They also have a better capacity to forecast future weather conditions. They are more likely to adopt different strategies to reduce the impacts of climate change on livelihoods and the environment. Since formal organizations, informal institutions and rural capacity building institutions have positive spillover effects on enhancing understanding and motivating farmers to use adaptation strategies to reduce their vulnerability to climate-related shocks and build local resilience systems, they should be supported, empowered and strengthened.

Table 7. 2. Coefficients of explanatory variables: climate change adaptation multinomial logit selection sample model

Variables	2 Strategies	3 Strategies	4 Strategies	5 Strategies	6 Strategies	7 Strategies
Education	-0.63(1.86)	-0.88(0.41)**	-0.79(0.44)*	-0.26(0.38)	0.74(0.41)*	0.75(0.37)**
Attitudes	0.19(0.59)	0.17(0.28)	0.31(0.12)**	0.08(0.17)	0.22(0.19)	-0.25(0.20)
Family size	-0.58(0.63)	0.27(0.12)**	-0.01(0.10)	-0.03(0.09)	-0.06(0.09)	-0.03(0.10)
Extension service	-0.33(0.94)	0.05(0.03)**	-0.71(0.48)	0.14(0.04)***	-0.31(0.44)	0.18(0.08)**
Media influence	1.57(0.27)***	-2.32(1.72)	-0.22(0.94)	-1.06(0.85)	1.01(0.75)	-0.57(0.84)
Relational capital	1.00(0.17)***	-0.47(1.29)	-0.40(0.78)	0.25(0.13)**	0.05(0.02)*	0.30(0.12)**
Group membership	0.55(0.14)***	0.95(1.20)	-0.55(0.51)	-0.01(0.06)	0.28(0.10)**	0.09(0.04)**
Technical training	1.01(1.20)	0.75(0.38)**	-0.34(0.51)	0.80(0.42)*	0.10(0.04)**	0.58(0.60)
Risk attitudes	1.47(1.11)	0.37(0.52)	0.34(0.42)	-0.18(0.07)**	-0.04(0.02)*	-0.06(0.03)**
Perceived resources	-1.48(1.41)	0.23(0.05)***	-0.28(0.30)	0.24(0.27)	0.31(0.29)	0.15(0.35)
Extension confidence	1.55(0.89)*	-0.42(0.50)	0.70(0.31)**	-0.30(0.34)	-0.55(0.39)	-0.23(0.47)
Gender	0.76(0.82)	0.01(0.53)	-0.03(0.42)	-0.10(0.35)	-0.43(0.18)**	0.55(0.46)
Age (log)	0.36(2.64)	1.27(1.35)	-0.02(0.90)	2.04(0.78)**	1.34(0.89)	2.33(0.98)**
Occupation	-2.02(1.12)*	-0.77(0.76)	0.47(0.52)	-0.06(0.44)	-0.35(0.52)	-0.13(0.61)
Farmland	1.73(0.91)*	-3.36(1.91)*	-0.83(1.22)	-0.04(1.03)	-0.44(1.18)	0.76(1.31)
Livestock	-0.13(0.25)	0.02(0.16)	-0.16(0.13)	-0.05(0.02)**	-0.20(0.17)	-0.11(0.05)**
Flat slopes	0.91(0.24)***	-0.17(0.57)	0.20(0.47)	0.21(0.38)	0.30(0.42)	0.09(0.49)
Fertile soils	-0.94(1.87)	0.49(0.65)	0.05(0.02)**	-0.05(0.44)	1.00(0.43)**	-0.11(0.46)
Agroecology	0.37(1.10)***	-0.15(0.66)	0.71(0.58)	-0.26(0.40)	0.18(0.49)	0.04(0.52)
Market proximity	-0.47(0.77)	-0.07(0.04)*	0.29(0.40)	-0.41(0.06)***	-0.18(0.38)	-0.06(0.02)**
Road access	2.18(1.82)	-0.20(0.73)	-0.05(0.60)	0.15(0.50)	-0.84(0.50)*	-0.36(0.05)***
Farmer school	0.09(1.24)	0.59(0.57)	-0.78(0.15)***	0.30(0.35)	0.24(0.07)***	0.47(0.06)***
Special skills	-0.09(0.91)	0.32(0.53)	-0.17(0.40)	0.20(0.29)	-0.27(0.36)	-0.54(0.41)
Stress	-0.87(1.79)	0.03(0.71)	0.17(0.44)	0.19(0.40)	-0.17(0.44)	-0.30(0.46)
Credit access	2.14(1.67)	-0.23(0.56)	0.17(0.03)***	-0.01(0.37)	-0.51(0.41)	0.13(0.42)
Mills	1.47(0.37)***	-2.61(8.34)	0.49(0.10)***	-2.69(3.34)	-3.80(1.80)**	-0.29(0.10)**
Constant	-5.03(1.44)	-2.63(5.68)	1.17(2.15)	-4.69(2.33)**	-3.27(3.62)	-3.23(4.31)

*Notes: ***, ** and * refers to level of significance at 1%, 5% and 10%. Figures in the parentheses are robust standard errors of respective variables*

7. 5. Conclusion and implications

This paper explores farmers' awareness of, and attitudes to, climate change and its impacts on livelihoods. Strategies that farmers have been applying to reduce these impacts are also investigated. Furthermore, factors that influence the adoption of adaptation strategies are identified and discussed. Cross-sectional primary data was collected using a structured questionnaire and focus group discussions. The results of the farmers' perception data show that temperatures have been increasing and the frequency of flooding, untimely rainfall, distinct rainfall patterns, hot and strong winds and dark clouds without rain have increased. Based on the 33-year meteorological data, temperature and total rainfall have been increasing by nearly 0.30% and 10% annually, respectively. These observations definitely show that there is a change in climate.

In the area under consideration, most farmers are aware of climate change and its impacts, such as crop failure, a shortage of food, livestock deaths, spread of animal diseases, outbreaks of human diseases, loss of vegetation and biodiversity, and a reduction in water availability and discharges, and therefore have been implementing different strategies to reduce these impacts and to increase their resilience. They have, for example, started to cultivate drought/disease-resistant varieties or varieties with short duration, high yielding varieties. Other measures identified are adjustment of the planting calendar based on the onset and offset of the rainfall, use of soil and water conservation measures, use of organic and inorganic fertilizers, implementation of agroforestry systems, use of irrigation and water harvesting schemes, and diversification of livelihoods into non-agriculture.

Disregarding whether or not they are aware of climate change, some farmers do not adopt strategies to adapt to the impacts of climate change and other shocks. As explained in the survey and focus group discussions, this might be due to lack of information about the strategies, limited technical know-how of the strategies, shortage of resources (money, labour and land), and inadequate institutional support. Farmers' choices of various climate change adaptation strategies are significantly affected by farming experience, the educational level of the households, agricultural extension services, the quality of the field plots, farmers' participation in formal organizations and local community groups, and the availability of infrastructure attributes, such as markets, farmer school and rural roads.

Since the government of Ethiopia is aware of climate change impacts, the Ministry of Environment, Forest Development and Climate Change has established climate-related policies and strategies, for example, Climate Resilient Green Economy Strategy, aimed at reducing the adverse effects of climate change on the biosphere and to build a green economy in the country. In roughly speaking, the government has been allocating relatively more funds to conservation and management of the environment. In spite of these efforts, a lack of institutional support and limited technical know-how are still important constraints for climate change adaptation. Therefore, more efforts are still needed, especially at ground level.

The government has also made an investment in social and physical services, such as rural towns, schools, roads and capacity building centres. Since infrastructure, particularly roads and training centres, have the potential to enhance awareness, reduce transportation and transaction costs, facilitate development, and have direct and indirect implications for improving resilience and adaptive capacities, still more investment needs to be made, especially in rural areas, where more than two-thirds of the population resides.

Furthermore, if the current trend of climate change continues, the vulnerability of local farmers to various shocks and risks, such as food insecurity, malnutrition and poverty, will increase. Thus, the pragmatic lessons for policymakers and development practitioners to mitigate climate change include expansion of small businesses in rural areas, efficient use of surface and groundwater for multiple purposes, undertaking plot-level soil conservation and water reservoirs, planting of multipurpose trees, and encouraging farmers to prioritize organic fertilizers and use early maturing and drought-tolerant varieties.

Finally, since indigenous informal institutions, cooperative societies and formal organizations have significant roles in the day-to-day rural economies, as well as motivating farmers to adopt sustainable strategies, policymakers should empower and support them so that they can provide adequate, timely and accurate information to smallholder farmers about climatic and agricultural conditions. This would enable them to forecast weather conditions, readjust their farming practices, and implement resilience strategies. Farmers should also receive capacity building training on preparedness, early warning and coping mechanisms. The government should also introduce (or expand) crop/livestock insurance against natural disasters. Information centres should be established in selected rural areas to provide updated weather information for farmers.

Chapter Eight
Conclusion and suggestions

Overview

This chapter is organized into five subparts. Firstly, the research objectives and major findings of the study are revisited and summarized, in line with the broader research questions. The contribution of this research study to the contemporary theoretical and methodological literature is then outlined. Subsequently, some suggestions are put forward, which are helpful for governments, development practitioners and scholars working in agriculture and rural development, especially in promoting sustainable agriculture to improve agricultural productivity, address food insecurity and to combat the adverse impacts of climate change. Finally, the chapter concludes by acknowledging some limitations of the study.

8. 1. Recapitulation and answering research questions

In most SSA countries, agriculture remains a key sector. It determines the fate of the whole economy. However, traditional practices, population pressure and climate change are major challenges that reduce its productivity and increase the vulnerability of local people to natural and man-made disasters. These impacts are more severe if the countries are susceptible to soil erosion and land degradation, and if they have low financial and institutional capacities to adapt to them. The pivotal question here is how to address these challenges. In the literature, several ways are proposed, for example, introduction of the green revolution technologies, adoption of sustainable agriculture, and the creation of a favourable environment.

In essence, the overall objective of this dissertation is to gain a better understanding of how socio-psychological factors affect the intended and actual behaviour of smallholder farmers towards sustainable agriculture and also to investigate the role of sustainable agricultural practices in improving farmer livelihoods. On a broader spectrum, the focus of this doctoral study revolves around two major research questions that have been developed in line with the conceptual frameworks: how socio-psychological variables affect farmer behaviour, and how sustainable agriculture influences livelihoods. These broad questions are synthesized below.

RQ1: How do socio-psychological issues influence farmers' intended and actual behaviour towards sustainable agriculture?

This addresses specific questions relating to how socio-psychological factors affect farmers' intentions, risk attitudes and (actual) adoption. Farmers' readiness or desire to implement conservation agriculture is captured by intention. It is constructed from six different observed statements. Nearly half of the farmers are found to have positive intentions towards conservation agriculture, while some farmers have low (or negative) intentions towards it, as explained in the focus group discussions, due to a lack of awareness, lack of information, and lack of technical knowledge.

Using the decomposed theory of planned behaviour as a theoretical basis, the study explores how attitudes, normative issues and perceived controls affect intentions. Both the structural equation model and three-stage least squares established relationships between intentions and socio-psychological issues and generated very similar results. Farmers have positive intentions towards conservation agriculture if they have positive attitudes towards this practice; if they have favourable norms regarding the practice; if they have received institutional support; if they are members of formal associations; if they have good relationships and networks with their friends and neighbours; and if the practice is perceived as easy to understand, learn and adopt.

Perceived usefulness, technical training, group membership and personal competence are found to influence behavioural intentions indirectly. These can improve the predictive power of intentions. This implies that attitude mediates the indirect positive relationships between perceived usefulness and intentions, while the indirect significant effect of technical training and group membership on intentions is mediated through normative issues. The competence of farmers (personal efficacy) also has indirect and positive impacts on intentions through the mediation of perceived controls. Therefore, social and psychological factors are important motivators of farmers' intentions to implement sustainable agriculture.

Concerning risk attitudes, farmers in the area have been frequently exposed and vulnerable to crop failure, financial shocks, the prevalence of human diseases, the incidence of (crop and livestock) diseases and pests, input and output price volatility and other hazards. These are mostly linked to drought and climate change. Based on a general self-elucidation question, and k-means cluster analysis from five risk domains (or 22 contextual statements), nearly 30% of the farmers are found to evade risks (more risk averse), while around 45% are willing to take risks (less risk averse). The remaining farmers are risk indifferent. Their decisions depend on other specific characteristics, such as personal issues, instead of the activity itself.

While evaluating the determinants of farmers' risk attitudes, the ordered logit model is used because the parallel lines assumption has not been violated and the problem of residual variability has not been exhibited. The results of the ordered logit show that household size, education, social capital (group membership and relational capital), attitudes and technical training are found to significantly determine farmers' risk attitudes. Farmers who have positive attitudes, those who have strong networks and relationships with local community groups, and those who are members of formal organizations are more likely to be less risk averse.

With regard to the actual adoption of sustainable agricultural practices, such as agroforestry systems, use of crop rotation with legumes and the application of compost, on average, nearly 53% of the local farmers are currently implementing these practices to enhance productivity. About 62% of the farmers who had not adopted these practices at the time of the survey are intending to adopt them in the future (they are now aware of their benefits) while the remaining farmers do not want to adopt them. In the survey and focus group discussions, some reasons for non-adoption are listed, including lack of information, shortage of family labour, limited institutional support and lack of technical knowledge.

After accounting for the interrelationships and interactions between these agricultural practices, the probability of farmers adopting them is significantly affected by labour supply, risk attitudes, social capital, attitudes towards sustainable agriculture, and information. Similarly, household size, education, social capital, livestock ownership, risk attitudes and availability of resources and rural facilities are found by the ordered probit model to be determining factors for the adoption of a greater number of agricultural practices. Therefore, access to information, education and capacity building can enable farmers to understand and evaluate the attributes, potential and constraints of agricultural practices.

In many low-income economies, markets are often imperfect and formal institutions are either absent or weak. In this case, formal organizations, traditional institutions and interrelational networks could play important roles and facilitate the exchange of agricultural and climatic information and knowledge, relax resource constraints, and share potential risks. They can arrange dialogue and exposure visits to enhance awareness, build members' confidence and motivate them to adopt sustainable agriculture. Therefore, farmers are often ready to adopt sustainable agricultural practices if they are supported; if they are aware of the attributes and if they are convinced that the agricultural practices would increase yields.

Overall, there are no uniform factors that affect the intended and actual behaviour of smallholder farmers. As well as the socioeconomic aspects and institutional contexts explained in the traditional literature, socio-psychological factors are also important to sufficiently explain smallholder farmers' intentions, risk attitudes and actual adoptions. Therefore, attention should be given to specific strategies that enhance awareness of farmers about sustainable agriculture, build positive attitudes towards sustainable agriculture, capacitate farmers' knowledge and skills, strengthen formal organizations, and empower informal institutions and local community groups to effectively use their positive spillover effects in motivating smallholder farmers to adopt sustainable agricultural practices.

RQ2: What roles can the practices of sustainable agriculture play to improve livelihoods?

Specific questions that are addressed here include whether sustainable agricultural practices can make a significant contribution to agricultural production, food security and household welfare; and whether farmers have perceived climate change; and whether they have adopted strategies to reduce the adverse impacts of climate change. The factors that influence farmers' decisions to implement strategies to adapt to the impacts of climate change are identified and analysed.

In the livelihood impact assessment, agricultural practices such as application of soil and water conservation, use of animal manure as organic fertilizer, and retention of crop residues are used as choice variables, while cereal (wheat and barley) yields, per capita grain harvests, per capita income, per capita assets, per capita expenditure and the household food insecurity access scale (HFIAS) are used as outcome variables. The endogenous switching regression model, which can better control for both observed and unobserved biases, is used to examine and estimate how the application of these agricultural practices affects these outcome variables.

With regards to the household food insecurity access scale (HFIAS), about two-thirds of the local farmers in the area under consideration have no concerns about food and therefore have access to relatively diverse and sufficient food. Specifically, about 27% of the farm households are highly food secure, about 40% are fairly food secure and about 25% are occasionally food insecure, while about 8% are chronically food insecure. However, these results vary between smallholder farmers who had adopted the agricultural practices and those who had not adopted them, at the time of the survey.

Before controlling for bias from unobserved factors, our outcome variables vary significantly between farmers who adopted the agricultural practices and those who did not adopt them; being higher for adopters. Similarly, after accounting for both observed and unobserved heterogeneities, farmers who adopted the practices have significantly higher outcomes compared to what they would have had if they had not adopted them. They obtained higher outcomes if they used the agricultural practices in combination rather than in isolation, taking into account the impacts of substitution and complementary effects.

The implication of the results is that sustainable agricultural practices, whether they are adopted in isolation or combination, in relative terms, generate higher cereal yields, harvests (cereal and legumes), total income and assets compared to not adopting them. In practical terms, smallholder farmers who actually adopted sustainable agricultural practices would have achieved lower levels of these outcomes if they had not adopted the practices. However, this does not capture bias within the group. There may be a bias within-pair estimates on the average treatment effects, even if this bias disappears as the sample size increases (Imbens, 2004).

In parallel, this study assesses how farmers perceive climate change in order to understand farmers' awareness of, and attitude towards, climate change. Farmers have often used parameters or indicators, such as temperature, moisture, rainfall (amount, timing and distribution) and extreme weather events to understand and identify whether the climate in the district has been changing. Most farmers perceived that temperature has been increasing, while rainfall and humidity have been declining. The incidence of nimbus clouds without rains and the blowing of dry and hot winds from the Afar depression have been increasing.

To validate this, rainfall and temperature data for 33 years (1983-2015) have been used. The results indicate that there is a small increment in temperatures, on average, by 0.06 °C annually for minimum temperature and by 0.05 °C for maximum temperature (nearly 0.3% annually). Concerning the total rainfall in the area, with a lot of ups and downs, the mean total rainfall has increased by nearly 10% annually and 23% during the rainy seasons. Over the last 33 years, about 83% were dry periods while the remaining were wet periods.

With respect to climate change impacts, local farmers have mentioned several impacts, for example, drying up of rivers, streams and springs, declining volume of communal dams and ground wells, frequent prevalence of human diseases, loss of natural trees, grasses and shrubs, incidence of (crop and livestock) pests and diseases, lack of animal fodder and forage, shortage of human food, deaths of livestock, crop failure, and migration of bee colonies to search for water and flowers. In general, climate change has (direct or indirect) impacts on crops, animals, water, plants, and livelihoods.

Most farmers have used several strategies to adapt to these adverse impacts of climate change, for example, use of soil and water conservation measures, construction of various water harvesting schemes, use of early maturing varieties, use of drought/disease-tolerant varieties, planting of multipurpose trees, use of varieties with better water use efficiency (WUE), use of organic fertilizers, and livelihood diversification into petty trade and small businesses. Most strategies are effective in increasing water retention capacities, expanding irrigation and improving productivity. However, some farmers have not adopted adaptation strategies, as stated in the focus groups, owing to lack of information, lack of technical knowledge, lack of financial support and personal characteristics, such as ageing and aversion behaviour.

Furthermore, factors that affect smallholder farmers' willingness-to-adopt alternative climate change adaptation strategies are identified and discussed. Generally, variables, such as household characteristics (age, size and education), farm conditions (size, fertility and slopes), social capital (relational capital and membership in formal institutions), information (extension services, training and mass media) and rural institutions (markets, roads and farmer-schools) are found to significantly influence the adoption of the different strategies in response to the adverse impacts of climate change.

In summary, adoption of sustainable agricultural practices that are either indigenous or introduced (Mwalusepo et al. 2015) seems a successful option to move away from low productivity and food insecurity. Some practices are also partially helpful and effective in adapting to climate change. Because of synergetic and multiplier effects, the positive spillover effects are high when these sustainable strategies are adopted in combination. In short, the choice to use these agricultural practices or adaptation strategies depends on institutional, social, economic and psychological factors.

8. 2. Research contributions

This dissertation contributes to the existing empirical and methodological literature on smallholder farmers' behaviour, sustainable agriculture and livelihoods. The paper also has practical relevance for development actors, especially those working in agriculture and rural development in the Sub Saharan African countries, where empirical studies are relatively scarce in comparison to other regions of the world. These contributions are outlined briefly below.

1. Conceptual contribution

The theoretical basis for this study on stated behaviour towards sustainable agriculture is the decomposed theory of planned behaviour. This splits attitudes and perceived control into three and two components, respectively (Taylor and Todd, 1995). To look at the adoption of new technological innovations and new products, some authors have also dismantled subjective norms into peer influence and superior influence (Shih and Fang, 2004; Nor, 2005; Hsu *et al.*, 2006; Pavlou and Fygenson, 2006; Shiue, 2007; Ghyas, Sugiura and Kondo, 2012; Sadaf, Newby and Ertmer, 2012; Cheng and Huang, 2013; Kazemi *et al.*, 2013).

In the same way, this study has modified the theory of planned behaviour and has decomposed the normative issue (=subjective norm) into five components, such as media influence, extension services, relational capital, group membership and technical training. These components are found to jointly affect farmers' normative issues (directly) and farmers' intentions (indirectly) towards sustainable agriculture. This suggests that formal organizations, informal institutions, extension workers and mass media are important factors that affect the stated (or intended) behaviour of smallholder farmers in less developed countries.

In parallel, this extended decomposed theory of planned behaviour has been validated as a good theoretical framework to explain farmer behaviour and therefore can be replicated in future research studies, especially those related to natural resource management, sustainable agriculture and rural development. Since the study findings provide very important information for researchers and academicians, this is, therefore, regarded as a conceptual or theoretical contribution to the adoption literature.

2. Empirical contribution

The empirical contribution of this study lies in the research questions assessed and investigated. Several studies have assessed and evaluated how socioeconomic characteristics and biophysical factors affect technological innovations and new products. However, there are few studies on how socio-psychological factors influence smallholder farmers' stated and revealed behaviours towards the practices of sustainable agriculture, especially in SSA (Meijer *et al.*, 2015; Bonabana-Wabbi *et al.,* 2016).

To this end, the findings of this study confirm that developing strategies targeted at socio-psychological issues is important in understanding the behaviour of smallholder farmers. Adoption of sustainable agriculture can be effective and easily scaled-up if formal and informal institutions are potentially strengthened; and if farmers have participated in the planning, implementation, monitoring and evaluation of the adoption process.

There are also relatively limited studies on how the practices of sustainable agriculture influence agricultural production and household livelihoods. Some empirical studies, for example, Abdulai and Huffman (2014), Abebe and Bekele (2014), Asfaw *et al.* (2012) and El-Shater *et al.* (2016) largely estimated the impact of technologies or improved farming practices on maize yields and income from maize. Accordingly, the effects of sustainable agriculture on crop yields, income, assets and food security are empirically assessed and investigated. Therefore, this study can serve as an additional case study for future research.

Furthermore, this study also linked the practices of sustainable agriculture to climate change adaptation strategies. Since adaptation strategies are highly variable across locations, this study assessed how farmers have perceived changes in the local climate; how they are exposed to the impacts of climate change; what strategies they have used to adapt to the adverse impacts of climate change; and what factors prevent farmers from implementing adaptation strategies. The findings indicate that local people have used several sustainable agricultural practices to adapt to the adverse impacts of climate change.

In general, this doctoral paper brings socio-psychological issues, sustainable agriculture and livelihoods together in the literature interface although these are not new concepts. The contextual aspects, i.e., how these issues are diagnosed, disaggregated and investigated determine the originality and novelty of this study. Therefore, the findings of the study add to the existing limited contemporary literature on socio-psychological issues and sustainable agriculture, especially in SSA.

3. Methodological contribution

This dissertation contributes to the methodological literature. The structural equation model and endogenous switching regression, which have received attention in recent literature, are infrequently used and validated in the adoption and impact literature. Some exceptions are Manda *et al.*, (2016), Teklewold *et al.* (2017), and Jaleta, Kassie and Marenya (2018). Therefore, this study can further open a path for researchers and academicians to conduct studies in rural development and natural resource management using similar approaches.

The study also used the structural equation model together with three-stage least squares to analyse farmers' intentions; the ordered logit model and heterogeneity choice model to understand and investigate farmers' risk attitudes; the multivariate probit model with the ordered probit model to examine and estimate farmers' actual adoption of sustainable agriculture; and endogenous switching regression with inverse-probability weighted regression adjustments to analyse the impacts of adoption. Therefore, the combined use of estimation models is a further contribution from a methodological viewpoint, because each model has its limitations and the combined use of different models can compensate for weaknesses that stem from a single model.

4. Practical contribution

The findings of this study have practical implications that might be useful for farmers, NGOs, governments, researchers and academicians. For example, farmers always search for alternatives to improve their yields. After evaluating the potential of sustainable agriculture vis-à-vis industrialized agriculture, farmers can be stimulated to readjust their current farming practices. They can also easily differentiate the attributes of agricultural practices to identify which practices offer the greatest benefits for them.

In addition, the outputs of the study have been disseminated through presentations at international conferences and by publishing in peer-reviewed journals. Essentially, this shares knowledge with the existing adoption and impact evaluation literature. Furthermore, this can also further motivate some researchers and academicians in the Sub Saharan African countries in general and Ethiopia, in particular, to undertake research studies in the conservation and management of natural resources, and evaluation of rural development programs using a related approach, for example, the behavioural and decomposed frameworks.

The study also provides insight for governments (or policymakers) and development practitioners to sharpen their awareness of sustainable agriculture and socio-psychological issues. For example, they can learn and understand the importance of social capital (formal organizations and interpersonal relationships) in the adoption of sustainable agriculture and risk/resource-sharing behaviours. In turn, this could inspire them to prepare suitable strategies to empower formal and informal institutions in order to positively exploit their potential.

Moreover, extension workers and development practitioners could be inspired to give more attention to create model farmers in sustainable agriculture. They have the potential to easily convince and motivate friends, neighbours and other farmers to adopt sustainable agricultural practices to reduce soil erosion and land degradation, improve moisture and soil fertility, increase vegetation and biodiversity coverage, improve water availability and discharge, and increase agricultural productivity, thereby increasing their income and overall welfare.

Furthermore, researchers and academic scholars can be inspired to provide capacity building training to enhance overall awareness of extension agents and farmers, especially climatic and agricultural conditions. Similarly, extension agents can be motivated to organize regular agricultural field days, on-farm demonstrations and experience sharing to improve farmers' understanding of sustainable agriculture, climatic change and other general situations.

Finally, the results are useful inputs for concerned economic actors to accommodate pro-sustainable agriculture in preparing specific strategies, and to promote sustainable agriculture as a means to move away from food insecurity, conserve the natural resource base in a sustainable way, reduce the adverse impacts of climate change, and enhance the resilience of local systems. In general, this study shares theoretical and empirical knowledge with the contemporary literature.

8. 3. Policy implications

As explained in section 8.2, especially in the practical contribution section, the findings of this study have some implications for development actors, for example, policymakers, NGOs and researchers. Accordingly, based on the analytical results, the following points are suggested that are helpful in the promotion of sustainable agriculture to simultaneously address the concerns of low productivity, food insecurity and environmental degradation.

Strengthening local institutions: formal organizations, such as farmers' associations, resource users' groups and cooperative societies, as well as traditional institutions, such as *Equb and Idir* have great potential for information exchange about agricultural, socioeconomic and climatic conditions, and sharing of losses and risks from unanticipated events. Group members also help each other, especially in terms of labour, oxen and other inputs. In addition, they sometimes arrange training, panel discussions, and experience sharing to enhance the awareness and understanding of members about technological innovations and general issues. Moreover, they either provide loans for farmers or assist poor farmers to relax their credit constraints. In this research study, these formal and informal institutions are also found to be important in enhancing intentions, reducing aversion and promoting the adoption of sustainable agriculture.

Overall, they have indispensable roles and therefore should be strengthened, supported and empowered to exploit their potential effectively.

Promote peer learning: in this study, peer learning involves interpersonal communications, relationships and sharing of knowledge, skills, ideas and experience informally among farmers. The idea is that people living in the villages and environs have the same norms, similar interests and also shared problems. As a result, they have strong bonds and trust each other. They have confidence in group actions and decisions. This suggests that the decisions and actions of some farmers can directly or indirectly influence the actions and decisions of others. This can work better and more effectively, especially in the absence of strong formal institutions. For example, if there are a few model farmers (or elder farmers) they can more easily persuade the local communities than can extension agents and the local government. Similarly, if there are model farmers in sustainable agriculture, neighbours, friends and other farmers can visit their farms and see for themselves that the practices are effective in raising yields, improving water availability and increasing income. Thus, the presence of strong interpersonal relationships can be used to promote and expand sustainable agriculture with minimum effort and resources.

Awareness enhancing initiatives: some farmers are observed to use compost or animal manure together with chemical fertilizers, even though they are theoretically expected to generate equivalent yields. If farmers use solely organic fertilizers, they can save the money that they would have used to purchase chemical fertilizers. Farmers can also save their time and labour if they use solely chemical fertilizers. Likewise, a significant number of farmers are more risk averse and are reluctant to change the traditional farming practices. They are less likely to invest labour, time and money in adopting sustainable agricultural practices. This suggests that awareness-enhancing strategies, training and encouragement are important for farmers to raise their awareness and change their mindset. They should be convinced that the practices are compatible with their existing norms and traditions, as well as improving productivity.

Stimulate access to credit: as explained in the previous chapters, the availability of financial resources is found to enable farmers to adopt some sustainable strategies against food insecurity and climate change. Some farmers are also able to start small businesses to diversify their livelihoods to adapt to climate change. However, there are some problems. As stated in the focus group discussions, farmers do not have access to formal banks due to collateral issues. Secondly, the rate of interest of local MFI (Dedebit) is very high, noted at about 15-18%. Finally, the loan amount obtained from MFIs is very small. Therefore, the government should negotiate with formal banks about possible ways to provide loans for smallholder farmers. For example, the government could serve as collateral or it could arrange ways to use rural houses or cultivated farmlands as collateral. Besides, a negotiation is needed with MFIs to reduce the rate of interest charged to an affordable level. Furthermore, the government could give long-term loans to MFIs (with very low or no interest). This increases MFI's financial capacities and enables them to provide a reasonable quantity of loans for smallholder farmers.

Improve agricultural extension systems: the country has an agricultural extension system strategy. By allocating more funding to the agricultural sector, farmer training centres (farmer schools) have been established in each rural village. At least three agricultural development agents or extension agents (for natural resources, livestock and crop sub-sectors) are assigned to each farmer training centre. However, several farmers' training centres are only partially equipped. Many extension agents have been largely involved in political issues, which are not related to their regular duties. Many extension agents are reluctant to hear and answer the farmers' questions. They are not ready to listen to farmers' opinions and also to learn from farmers' traditional knowledge. Extension agents who are familiar with the potential and limitations of sustainable agricultural practices, for example, are very limited in number. The results of this study show that around 60% of smallholder farmers in the area do not have confidence in the knowledge, skills and overall competence of agricultural extension agents. Therefore, farmer training centres (FTCs) should be equipped with qualified manpower and the necessary inputs. Regular capacity building training and exposure visits are needed for extension agents to build their competence and improve their poor commitment.

Improve social and physical infrastructure facilities: as stated in the traditional and contemporary literature, infrastructure services, such as rural roads, schools, health centres, capacity building centres, power supplies and input-output markets play significant roles in raising awareness and understanding, and advancing overall development. In this research study, for example, rural roads, farmer training centres and input-output markets are found to be important in accelerating the adoption of sustainable agriculture, improving agricultural productivity and increasing farmers' welfare. However, the coverage of these facilities remains low, especially in the area under consideration. As a result, the adoption of sustainable agriculture and economic growth could be delayed. Therefore, government, NGOs and others should exert joint efforts to expand rural services, especially those that have direct links with agricultural production and human capital.

Encourage collaboration: as stated above, climate change and its impacts are projected to rise globally in the future (Hoffmann, 2011; IPCC, 2014; Kreft et al., 2015). Since these challenges are not solved solely by the government, the different actors in the economy, for example, NGOs, governments (central, regional and local), researchers, academicians and others should work together and prepare collective actions to transform the weak agricultural sector and combat these adverse impacts. In conjunction with this, we observed that various community-based development projects have been widely carried out by different development actors. However, they do not have proper (or only weak) coordination and integration between them, even if they are working towards common goals. In most cases, this has led not only to overlapping of activities but also to redundant effort and wasted resources. Therefore, joint efforts and greater investment by development actors are needed to (a) improve the skills and knowledge of extension workers (b) equip farmers' training centres with the necessary equipment, (c) empower local institutions (d) learn lessons from countries well-known for sustainable agriculture on how they have established and strengthened pro-sustainable agricultural institutions.

In general, governments (local, regional and federal), NGOs, research institutes, academic centres, local community, and development actors should play their utmost efforts in strengthening local institutions, simulating credit access, improving agricultural extension systems, and providing capacity building training. For example, formal and informal institutions should be recognized by the government for their contributions and potential. They should also be empowered financially and technically. Besides, extension agents and farmers should receive training and participate in agricultural field days to enhance their understanding of sustainable agriculture vis-à-vis industrialized agriculture, and improve their knowledge and skills. Moreover, farmers training centres should be randomly visited by government officials, and public discussions should be regularly organized to evaluate the performance of extension agents. Furthermore, these economic agents should pool their resources and efforts to get multiplier and synergic effects, as well as coordinate their activities to avoid overlapping, redundancy and resource waste.

8. 4. Scope and limitations

The data used in this dissertation were obtained from six rural villages in northern Ethiopia situated in the temperate and warm temperate agro-ecological zones. For this reason, the findings are useful and valid for these sample villages and (maybe) partly for other areas in the country with very similar characteristics in terms of agro-climatic conditions, agricultural practices, and socio-cultural aspects.

While the overall results of this doctoral research are valuable and timely to address the limited understanding of how socio-psychological issues influence smallholder farmers' intended and actual behaviours, as well as the contribution of sustainable agricultural practices to agricultural production and farmers' livelihoods, there are some limitations that might lead to reservations and caution in terms of the interpretation and generalization of the results.

Firstly, the sample size did not fully represent the whole population of the Tigray region (Ethiopia). With the very limited area covered, along with the small sample size, the results of the study cannot be assumed to be universally applicable and are, hence, unlikely to automatically extrapolate or replicate to the entire country. In addition, endogenous switching regression requires a large sample size, especially the counterfactuals. However, our findings are subject to the potential issues of small sample size (the sample size for the counterfactual group or for the non-adopter group is small). Therefore, caution needs to be taken in generalizing the results and drawing conclusions.

In comparison to cross-sectional studies, panel studies reduce errors and produce more reliable results. In this study, we had to undertake multiple visits and surveys to reduce memory and recall biases. However, this was impossible in the context of this PhD study. To this effect, the findings were unable to show prolonged duration and might have various forms of biases from the ever-changing psycho-socio-economic-demographic factors. There might also be a problem with temporal confusion or protopathic bias. This relates to the establishment of an associated factor that may be wrongly attributed based on the results or inferences of a cross-sectional study. Hence, even if a cross-sectional study has its advantages, for example, generally quick, easy and cheap to perform, and no loss to follow-up, our results may suffer from some limitations of the cross-sectional survey.

In addition, each chapter has a specific objective and, accordingly, some variables are selected to fit the objective. It is not possible to include all the variables. For example, in chapter three, demographic characteristics are excluded even if they are expected to affect intentions. Accordingly, the problem of omitted variable bias may exist. Moreover, it is also not possible to test the presence of unobserved heterogeneity in a multivariate analysis. Furthermore, due to our survey design, establishing reversing causality for some seems less likely even if it is validated in some chapters, and this may cause an endogeneity problem.

In the focus group discussions, the purposive sampling method was used to select one representative from the sampled rural organizations and civic societies. Accordingly, extension agents in each sample village were delegated to select one from each identified organization. However, this procedure might be exposed to a subject self-selection problem, which limits the interpretation of the results of the focus group discussions in terms of representing the whole organization.

In low-income economies, data recording and management systems are very weak. As a result, it is often very difficult to obtain actual production and income data. It is also challenging to obtain longer-term data on rainfall and temperature, especially in the absence of well-functioning ground stations. As a remedy, perception data is used for harvests, income, assets and expenditure. Similarly, TAMSAT data is used for rainfall and temperature.

However, perception data may over-or-under estimate the actual figures (recall error) because it is subject to a number of biases, such as strategic motives, social desirability and other self-serving bias (Dohmen *et al.*, 2011). Also, the accuracy of the satellite data can be affected by several factors, such as clouds. During the data collection period, there was also a drought in the area. The data for crops, income, assets and household food insecurity might be inversely affected. Therefore, these data may not be free of errors.

Furthermore, the best way of measuring the true impacts of adoption is to use experimental methods, or approaches with baseline and follow-up methods (before-after and with-without) (El-Shater et al. 2016), but the use of quasi-experimental approaches or cross-sectional surveys does not completely remove biases from unobserved factors (United Nations Development Programme, 2009). Even though several studies in the literature have still employed cross-sectional data, our one-time data lacks dynamism and the research results might not adequately capture the net impact of adoption. Therefore, our results do not infer the temporal associations between smallholder farmers' intended and actual behaviour towards adoption of sustainable agriculture and the outcomes.

While measuring and evaluating risk attitudes, the combined use of experimental (advanced utility) and psychometric approaches are pragmatic and preferable for capturing real risk attitudes of economic actors, for example, producer and consumer agents (Dohmen *et al.*, 2011; Lönnqvist *et al.*, 2015; Crentsil, 2018). The use of solely psychometric methods may be subject to personal prejudice and bias. Accordingly, although possible efforts are made to reduce the biases, the results that are subjected to such flaws may either not reflect the true attitudes of farmers towards risks or may obtain different results if they are assessed and evaluated using advanced utility methods.

Many variables in the study are latent (or unobserved in the dataset) and are constructed from observed statements. While operationalised, responses to these statements are recorded using a five-point Likert scale, unlike many previous behavioural studies that used seven to ten-point Likert scales. This is to reduce confusion when translating into the local language, because it becomes very difficult (or indistinguishable) to use Likert scales exceeding five-points. Even if doing this is supported methodologically and theoretically, our results may not be the same when they are evaluated and validated against other studies that used Likert scales with more than five points.

This doctoral dissertation largely depends on categorical data, which are measured using a five-point Likert scale. Micronumerosity and multicollinearity are typical problems which might be associated with the use of categorical data. However, they do not form a serious problem in this study for the following reasons. Firstly, pairwise correlation coefficients and VIF are used to check for them, and highly correlated variables were removed from the model. For example, the age of the farmer and farming experience are never used together due to high correlation. Secondly, in the case of many predictors, the sample size is large enough to compensate for the loss of degrees of freedom (for example, for a good degree of freedom, sample size/number of predictors is never lower than eight). In addition, categorical variables with a response based on a Likert scale, especially where there are more than three response levels, are often regarded as interval scale or continuous variables in socio-psychological literature.

Furthermore, most categorical variables in this study are latent, and are derived from other observed statements using factor analysis. The variables constructed from this are unlikely to correlate, and factor analysis is the best method to overcome micronumerosity and multicollinearity. Finally, Oyeyemi et al.'s (2015) formula is used in each chapter to determine and specify the number of predictor variables ($n = 71.1 + 1.7P - 73.2r$; n=minimum sample size not affected by the micronumerosity problem, P=number of parameters to be estimated in the model and r=the minimum correlation value between the variables acceptable in the model). However, despite these embedded facts, micronumerosity and multicollinearity still remain concerns in the study.

Finally, in the areas under consideration, farm households have a small landholding size with very fragmented field plots. For example, each respondent has a mean of four different field plots, even if it significantly varies from three to seven. As explained in the group discussions, the distance from home to each field plot ranges from 1 to above 60 minutes. Such long distances and plot fragmentation definitely affect the adoption of sustainable agriculture and climate change adaptation strategies. However, plot-varying characteristics are not captured and addressed in this study.

8. 5. Suggestions for further research

In each chapter, a number of directions for future research are described and it does not seem necessary to repeat them here. Instead, it is pivotal to focus on some general themes, for example, undertaking comprehensive research studies and including multi-cultural agricultural practices to further understand the importance of sustainable agriculture and to generalize the research findings for the whole of Ethiopia. These could give pertinent information to concerned bodies (e.g., development practitioners, researchers, academicians and governments) to craft specific strategies that can stimulate farmers to adopt sustainable agriculture to improve productivity, reduce the risks of climate change, and improve the resilience of local systems.

Future research studies are needed that are used a more representative sample size with different sustainable agricultural practices, wider geographical coverage across different agro-ecological zones and incorporating time-variant aspects to increase our understanding of the subject matter and allow us to design specific interventions to motivate farmers to adopt sustainable agricultural practices, and thereby create positive effects on food security and the environment.

The present dataset can be used to complement future research on the same farm households to build up a panel dataset. This could help to better capture the evolution of the intended (stated) and revealed (actual) behaviours of farm households with regard to the adoption of sustainable agricultural practices, as well as to better understand the consequences of these agricultural practices on agricultural production and the overall livelihoods of smallholder farmers.

Farmland conditions, such as number, slopes and fertility of field plots, farm size and distance to field plots, which are known as field plot-varying characteristics, are important to determine the quality of the farmland. These are overlooked, especially at the field plot level, although they can (directly or indirectly) influence adoption of sustainable agriculture or adaptation strategies and farming production as a whole. Consequently, we suggest a further plot-level study to understand whether the adoption of adaptation strategies varies with these plot-level factors and evaluate whether the current results change in response.

As indicated in each chapter, the study focused on the adoption, behaviours and risk attitudes of the household heads. However, their respective partners have pivotal roles in such decisions. This meant that joint decisions with a partner are overlooked. The inclusion of partners in the decision-making process might lead to quite different results. Therefore, the role of the partner of the household head in risk and adoption decisions remains a field for future research.

Furthermore, we find that nearly half of the smallholder farmers are less risk averse (or risk seekers). It is uncommon to find a similar result in the traditional economic and psychometric literature, because they are normally regarded as more risk averse. However, this result might be due to risk attitude elicitation method and other factors. Therefore, we suggest further research to validate and evaluate the attitudes of smallholder farmers in the area towards risks, uncertainties, shocks, hazards and worries, using advanced elicitation approaches.

Finally, social behaviour, adoption and impacts of climate change are expected to vary spatially. In reality, development strategies have been observed to be successful when they are prepared considering the agro-ecological setting. However, the spatial effect (agro-ecology) was found insignificant for risk attitude, actual adoption of sustainable agricultural practices and climate change adaptation strategies. Thus, the spatial effects need to be further investigated. In general, detailed assessment and deep knowledge of the local context are required to understand how socio-psychological issues affect smallholder farmers’ stated and revealed behaviours thereby prepares effective and viable strategies, which helps to the promotion of socio-psychological based sustainable agricultural practices.

Annexe

Annexe 2. 1. Definition and explanation of demographic and socioeconomic variables

Variable	Description and measurement of the variables
Gender	Sex of the household head (1 for males otherwise 0 for females)
Age	Age of the household head at the time of data collection (years)
Experience	Experience of household head in farming or agriculture (years)
Religion	1 if the farmer adheres to Orthodox Christian beliefs and 0 for others
Marriage	Marital status of the household head (1 for a married person and 0 if not)
Special skills	1 if the farmer has skills (hairdressing, basket making, weaving, spinning, and others) and has received additional income from that and 0 if not
Occupation	1 if the prime livelihood source for the head is agriculture and 0 if not
Family size	Number of persons living together with the head (household size)
Education	Dummy for educational level of the head (1 for literate and 0 if not)
Livestock	Total livestock assets owned by the household head (TLU)
Farmland	Landholding size of the household head (hectare)
Flat slopes	1 if the farmland of the farmer is perceived on average flat slopes and 0 if not
Gentle slopes	1 if the farmland is, on average, moderately sloped and 0 otherwise
Fertile soil	1 if the soil quality of farmlands is perceived to be fertile and 0 if not
Medium soil	1 for moderately fertile soil is perceived by the farmer and 0 if not
Shallow Soil	1 if the depth of the soil is perceived to be shallow, otherwise 0
Agroecology	1 if the village is from the temperate zone and otherwise 0
Credit access	1 if the farmer wants and obtains credits and 0 otherwise
Drought	1 if the farmer experienced moderate or severe drought four and more times during the last 20 years (1996-2015) and 0 otherwise
Stress	1 if the farmer said diseases, pests and other shocks are major problems for crop and animal production in the village and 0 otherwise
Extension confidence	1 if the farmer has confidence in the technical knowledge, skills and competence of agricultural extension agents in the village and if not 0
Gov’t support	1 if the farmer depends on government and nongovernment support in case of crop failure, drought and shocks, and otherwise 0
Market proximity	1 if the distance from residence to input-output market (mainly district markets) is within 80-minutes walking distance and 0 otherwise
Rural road accessibility	1 if the farmer has access to all-weather rural roads (gravel or asphalt) within a radius distance of 6km (60 minutes walking distance) and 0 if not
Farmer schools	1 if the farmer has access to farmers’ training centres within a radius distance of 6km or one-hour walking distance and otherwise 0

Annexe 2. 2. Observed socio-psychological statements towards sustainable agriculture used to construct our latent variables (1=strongly disagree, 2=disagree, 3=not sure about 4=agree and 5=strongly agree)

Latent variables	To what extent do you agree with the following observed statements or indicators, mostly about sustainable agriculture?	1	2	3	4	5
Attitude	I feel that use of various sustainable agricultural practices is advantageous to raise the fertility and quality of farmlands (not very advantageous-very advantageous)					
	I believe that adopting sustainable farming practices is important for me for improving agricultural productivity and yields (not very important – very important)					
	I think the use of sustainable agricultural practices is a wise idea to reduce land degradation and soil erosions in the areas (definitely false – definitely true)					
	I perceive, from my lifetime, that use of sustainable agricultural practices is necessary to improve farm income indirectly (not very necessary – very necessary)					
Relational capital	My fellow friends who are important to me would influence my behaviour and adoption decisions (totally false – totally true)					
	My adoption decisions to improved farming practices and technologies determined by how close are the relationship I have with my neighbours (very low – very high)					
	My families (children and spouse) are important whom I immediately consult them to adopt improved farming practices & technologies (completely false-completely true)					
	Membership in traditional social groups, like Equb, Idir and other endogenous group affects my decisions, especially related to sustainable practices and technologies					
	To what extent do you trust the information you get from neighbours, friends, families and community groups like Equb and Idir (known as informal institutions) (very low - very high)					
Technical training	Different organizations are available in the district that provides me capacity building training and institutional support on general agricultural issues					
	Information obtained from agricultural field days, farm trials, and workshops are trustful and reliable for me (totally false – totally true)					
	I attended agricultural field days and on-farm demonstrations that stimulate me to adopt sustainable agricultural practices and technologies					
	Participation in different workshops and/or attending short-term course inspires me to adopt sustainable agricultural practices					
Extension service	The presence of agricultural extension workers in the village are helpful to bring positive change in the awareness and overall behaviour of local people (totally false – totally true)					
	How frequently do you contact extension agents to get information and technical advice? (none, rare, sometimes, often and very often)					
	Information obtained from agricultural extension workers are trusty so that positively contributes to me to adopt sustainable agricultural practices (completely false-completely true)					
Personal efficacy	I believe that I have satisfactory skills and knowledge to adopt different sustainable agricultural practices					
	I would have no difficulty explaining to other individuals on the importance of improved agricultural practices and technologies					
	I think my competence is the only concern in my decisions to adopt agricultural practices					
	It is mostly up to me whether I have to change my behaviour and adopt sustainable agricultural practices in my field plots					
	According to my personal judgment, it is possible to use various sustainable agricultural practices in my field plots					
Media influence	I use television to update myself on climatic and agricultural information, particularly improved agricultural practices					
	I believe that radio is helpful for me to adopt sustainable agriculture					
	I confidently trust the information I obtained from radio, television and other formal media (definitely false – definitely true)					

Group membership	How your membership in farmers'/women's associations affects your decisions to adopt sustainable agricultural practices To what extent saving & credit associations, cooperatives or resource users' group affect your decisions to the adoption of sustainable agricultural practices To what extent do you trust the information you get from farmers' associations, resource users' group, cooperatives, saving and credit groups and others (formal institutions)
Perceived resource	I think I have enough labour supply to use sustainable farming practices at my field plots I think time would not be a problem for me to adopt sustainable agricultural practices I can adopt agricultural practices with what resources and facilities I currently have
Perceived usefulness	I am in favour of adopting sustainable farming practices as long as advantages of adopting outweighs the advantages of not adopting them I believe that adoption of sustainable farming practices will reduce weeds, pests, diseases and erosions I notice that the benefits to improve yields and farm incomes would motivate me to adopt sustainable farming practices
Perceived easiness	I believe that many sustainable farming practices are easy for me to understand their attributes I believe that many sustainable agricultural practices are simple to learn their attributes I think that improved farming practices are not difficult and complex to adopt them in my field plots
Perceived compatibility	I recognize that my previous farming experience helps me to easily operate many improved agricultural practices on my field plots I believe that many sustainable farming practices that have been implemented in the village are compatible with my current farming practices and needs I feel that agricultural practices that have been implemented in the village do not violate existing social farming traditions and norms
Intention	I plan to use conservation minimum tillage in my farmlands in the next growing seasons I have the intention to replace chemical fertilizers and pesticides by minimum tillage to improve productivity and yields I target for frequent use of minimum tillage in my field plots to improve agricultural productivity and yields I am intended to encourage neighbours to implement minimum tillage in their field plots How strong is your intention to adopt minimum tillage in the future (very low – very high) How likely do you believe that adoption of minimum tillage will increase farm incomes? (more unlikely – more likely)
Normative issues	There are external forces, like media, extension workers, and friends who influence me to adopt technologies and improved farming practices When I adopt sustainable farming practices to improve productivity, most people who are important to me like families and extension workers think that it is desirable & approve it Most people like friends and neighbours who are important to me think that I should use sustainable farming practices to reduce erosions and retain water resources Information exchanged among members of Equb and Idir influence me to change my behaviours and adopt sustainable farming practices Most people like me will use sustainable agricultural practices in their field plots
Perceived control	How difficult would it be for you to adopt those sustainable farming practices on your field plots (not very difficult - very difficult) I believe that adopting agricultural practices in my field plots is entirely within my control As I understand, it is not expensive for me to adopt sustainable agricultural practices that improve productivity and yields

Annexe 2. 3. Risk related observed statements that are used to construct risk attitudes

Latent variable	How likely are you ready to take the following risks of shocks, worries or uncertainties when it occurs (choices)?	1	2	3	4	5
Natural hazard	Fear of the occurrence of flooding, earthquake, droughts or landslides					
	Crop failure due to lately begin or early end of rainfall (unpredictable and erratic rains)					
	Animal death from the incidence of animal diseases and pests					
	Loss of harvests due to the prevalence of frosts, hails, rust, pests, epidemic and diseases					
	Fear of losses and wastages, especially perishable items, due to the absence of storage facilities					
	Lack of water and forages for animals					
Technology risk	Fear of losses and wastages due to lack of information or knowledge on climatic and agricultural conditions including marketing					
	I do not like to take risks in attempting improved farming practices that are not used yet in the village (strongly disagree – strongly agree)					
	Difficulty to meet and get technical support and relevant information from extension workers in the village or district					
	Problems due to lack of veterinary and health clinics including drugs and manpower					
	Fear of injury or damage during implementing improved farming practices and technological innovations					
Market Volatility	Exceptionally declining the price or value of animals in the local markets					
	Fear of increasing cost of living or inflation					
	Lack of market for crops, vegetables, fruits and other produce					
Human security	Migration of family members (children) elsewhere, especially to Arab countries and Sudan					
	Facing shortage of labours to execute farming activities					
	Outbreak or prevalence of human diseases and illness, such as waterborne diseases					
	Fear of eating low-quality foods (not preferred and uncommon) due to food shortage					
	Fear of conflict with neighbours and local governments					
Financial shock	Problem due to lack of access to credits					
	Shortage of cash on hands or saving money					
	The problem of selling a permanent asset for debt services (arrears)					

Annexe 3. 1. The correlation coefficient of some target (latent) explanatory variables

Variables	perceived usefulness	perceived compatibility	perceived easiness	media influence	technical training	extension service	Relational capital	group pressure	personal efficacy
perceived compatibility	0.01								
perceived easiness	0.03	-0.06							
media influence	0.02	0.04	-0.01						
technical training	-0.01	-0.01	0.11**	-0.02					
extension service	0.03	0.00	0.03	-0.04	0.03				
Relational capital	-0.06*	0.02	0.02	-0.03	-0.02	0.00			
group membership	-0.03	0.02	0.02	-0.01	-0.01	0.03	-0.02		
personal efficacy	0.00	-0.04	0.02	0.03	-0.01	0.02	0.03	-0.02	
perceived resource	0.00	-0.14***	0.04	0.04	0.04	-0.01	0.02	0.03	-0.01

Notes: *, ** and *** shows statistically significant at 10%, 5% and 1% levels, respectively. Group pressure=group membership

Annexe 3. 2. Smallholder farmers' attitude and intentions across some target socio-psychological variables: one-way variance analysis

Variables	Intentions		Attitudes	
	F (2, 347)	$P(\chi^2)$	F (2, 347)	$P(\chi^2)$
Normative issue	12.1	0.00***	1.69	0.18
Perceived control	1.39	0.25	0.35	0.71
Perceived usefulness	1.76	0.17	1.97	0.14
Perceived compatibility	1.12	0.33	0.12	0.89
Perceived easiness	2.99	0.05**	2.64	0.07*
Media influence	0.76	0.47	1.15	0.32
Technical training	8.69	0.00***	3.97	0.04**
Extension service	0.86	0.42	0.75	0.48
Relational capital	3.07	0.04**	1.89	0.15
Personal efficacy	4.89	0.01**	30.4	0.00***
Perceived resource	0.04	0.96	0.34	0.71
Group membership	4.09	0.02**	3.52	0.04**

Notes: *, ** and *** shows statistically significant at 10%, 5% and 1% levels, respectively

Annexe 3. 3. Coefficients of explanatory variables for conservation agriculture: minimum tillage system (3SLS models)

Endogenous variables	Explanatory variables	Coefficient	Standard errors	Predictive power
Intention	Attitude	0.144	0.019***	R^2=0.68 $P(\chi^2)$=0.007
	Normative issues	0.659	0.428*	
	Perceived control	0.381	0.323	
	Perceived easiness	-0.120	0.066*	
	Technical training	0.281	0.064***	
	Relational capital	0.148	0.081*	
Attitude	Perceived usefulness	0.034	0.010**	R^2=0.61 $P(\chi^2)$=0.025
	Perceived compatibility	-0.602	0.094***	
	Perceived easiness	-0.068	0.040*	
Normative issue	Media influence	0.043	0.056	R^2=0.77 $P(\chi^2)$=0.013
	Technical training	0.056	0.016***	
	Extension service	-0.055	0.046	
	Relational capital	0.044	0.022**	
	Group membership	0.082	0.039**	
Perceived control	Personal efficacy	0.107	0.031***	R^2=0.83
	Perceived resource	-0.179	0.080**	$P(\chi^2)$=0.001

Notes: *, ** and *** shows statistically significant at 10%, 5% and 1% levels, respectively

Annexe 4. 1. Previous involvement of smallholder farmers in self-perceived risky activities

Engaged in self-perceived risky activities	Frequency	Percent
Rarely engaged in risk factors	19	6
Sometimes engaged in risk factors	124	35
Usually engaged in risk factors	165	47
More often engaged in risk factors	42	12

Annexe 4. 2. Brant and oparallel tests of the parallel regression assumption

Variables	Probability of Chi-square test	Variables	Probability of Chi-square test	Overall test
Gender	0.742	Soil fertility	0.634	Wolfe Gould $P(\chi^2)$= 0.607
Log(age)	0.457	Agroecology	0.061	
Religion	0.162	Attitude	0.467	
Occupation	0.257	Personal efficacy	0.797	Brant test $P(\chi^2)$=0.596
Education	0.481	Perceived resource	0.253	
Family size	0.467	Technical training	0.109	
Livestock	0.636	Media influence	0.733	Likelihood ratio $P(\chi^2)$=0.325
Farmland	0.246	Extension service	0.918	
Special skills	0.087	Group membership	0.145	Score test
Flat slopes	0.380	Relational capital	0.717	$P(\chi^2)$= 0.375
Credit access	0.463			Wald=0.363

Annexe 5. 1. Parameter estimates of the explanatory variables: Coefficients and marginal effects of the ordered logit model

Explanatory variables	Coefficient	P(Y=0|X)	P(Y=1|X)	P(Y=2|X)	P(Y=3|X)
Education	0.47(0.21)**	-0.05**	-0.07**	0.06**	0.06**
Labour supply	0.04(0.02)**	-0.04**	-0.01	0.05*	0.05**
Relational capital	0.04(0.02)**	0.04	0.06***	0.05***	0.05**
Group membership	0.22(0.12)*	-0.07**	0.04*	0.06***	0.06**
Technical training	0.04(0.12)	0.03	-0.01	0.05***	0.05***
Media influence	0.09(0.12)	-0.01	-0.01	0.03	0.03
Attitude	0.08(0.03)**	-0.07***	-0.11***	0.10**	0.10**
Extension service	-0.09(0.05)*	0.01	-0.01*	0.03	0.03**
Risk attitude	0.34(0.17)**	-0.03**	-0.05*	0.05**	0.05**
Perceived resource	-0.03(0.04)	0.01	-0.03	-0.02	-0.02
Gender (male)	-0.07(0.22)	0.01	0.01	-0.01	-0.01
Religion	0.11(0.31)	-0.02	-0.02	0.01	0.01
Special skills	0.33(0.32)	-0.03	-0.05	0.04	0.04
Occupation	-0.57(0.22)**	-0.05**	-0.09**	0.06**	0.06**
Experience (log)	0.14(0.19)	-0.01	-0.02	0.02	0.02
Livestock	-0.02(0.03)	-0.02	0.01	-0.06*	-0.07**
Farmland	0.53(0.63)	-0.05	-0.08	0.07	0.07
Flat slopes	-0.57(0.23)**	0.05**	0.08**	-0.06**	-0.06**
Fertile soils	-0.62(0.26)**	0.06**	0.09**	-0.07**	-0.07*
Agroecology	0.23(0.26)	-0.02	-0.03	0.03	0.03
Credit access	-0.35(0.29)	0.03	0.05	-0.04	-0.04

Observed and predicted probabilities

	Y_i=0	Y_i=1	Y_i=2	Y_i=3
Observed	0.12	0.31	0.41	0.16
Predicted	0.10	0.30	0.41	0.16

Overall ordered logit model diagnosis

Wald chi-square test: $\chi^2(21)=41$; $P(\chi^2)=0.006$; Pseudo $R^2=0.45$; n=350

*, ** and *** represents statistically significant level at 10, 5 and 1%, respectively

Figure in the parenthesis are robust standard error for respective variables

Annexe 6.1. Summary statistics of explanatory variables across an alternative combination of agricultural practices (share or mean)

Variables	$C_NM_NR_N$	$C_YM_NR_N$	$C_NM_YR_N$	$C_YM_YR_N$	$C_YM_NR_Y$	$C_NM_YR_Y$	$C_YM_YR_Y$
Gender (male)	0.59	0.45	0.50	0.62	0.62	0.43	0.63
Age	53	53	51	50	46	52	48
Experience	25	25	29	25	21	26	21
Marriage	0.57	0.55	0.50	0.66	0.61	0.43	0.63
Special skills	0.56	0.55	0.35	0.37	0.37	0.35	0.25
Occupation	77	56	63	72	72	62	62
Labour supply	2.9	4.5	5.3	4.5	4.0	3.8	4.0
Education	0.43	0.36	0.25	0.46	0.44	0.49	0.52
Highest education	2.0	1.9	1.9	1.9	2.3	2.2	2.9
Farmland	0.58	0.58	0.55	0.55	0.54	0.57	0.57
Livestock	2.0	1.4	2.7	2.6	2.0	2.5	2.8
Flat slope	0.30	0.09	0.25	0.22	0.30	0.14	0.29
Gentile slope	0.30	0.36	0.38	0.43	0.43	0.43	0.46
Fertile soil	0.30	0.36	0.33	0.31	0.29	0.32	0.25
Medium soil	0.48	0.36	0.33	0.44	0.44	0.54	0.40
Depth soil	0.43	0.58	0.28	0.43	0.47	0.59	0.33
Credit access	0.48	0.47	0.50	0.43	0.47	0.59	0.43
Agroecology	0.80	0.73	0.88	0.77	0.84	0.89	0.81
Market proximity	0.22	0.36	0.38	0.48	0.46	0.49	0.48
Road accessibility	0.61	0.91	0.63	0.67	0.57	0.57	0.67
More risk aversion	0.40	0.38	0.33	0.32	0.34	0.30	0.22
Less risk aversion	0.30	0.38	0.38	0.45	0.48	0.51	0.54
Extension service	0.54	0.45	0.63	0.50	0.61	0.51	0.54
Confidence in extension agents	0.46	0.47	0.47	0.28	0.45	0.44	0.33
Drought	0.40	0.37	0.28	0.36	0.30	0.41	0.32
Stress	0.40	0.40	0.38	0.43	0.42	0.43	0.35
Government support	0.51	0.60	0.63	0.41	0.67	0.41	0.54
Farmer school	0.43	0.56	0.41	0.54	0.42	0.54	0.44
Media influence	0.09	0.00	0.25	0.13	0.09	0.14	0.16
Attitudes	3.44	3.28	3.16	3.15	3.17	3.30	3.17
Relational capital	0.63	0.73	0.70	0.76	0.73	0.78	0.81
Personal efficacy	3.16	3.11	3.23	3.26	3.21	3.30	3.23
Group membership	0.73	0.75	0.81	0.91	0.85	0.89	0.87
Technical training	0.39	0.33	0.32	0.38	0.50	0.38	0.42

Annexe 6. 2. Parameter coefficients of multinomial endogenous switching regression: the dependent variable log cereal yields (wheat and barley)

Variables	$C_NM_NR_N$	$C_YM_NR_N$	$C_NM_YR_N$	$C_YM_YR_N$	$C_YM_NR_Y$	$C_NM_YR_Y$	$C_YM_YR_Y$
Gender (male)	0.39(0.34)	0.46(0.16)♥	-0.60(0.21)♥	0.57(0.54)	0.34(0.16)*	-0.19(0.02)†	0.21(0.17)
Age(log)	-0.04(0.06)	-0.02(0.03)	-0.10(0.03)♥	0.80(0.36)♥	0.71(0.30)♥	-0.10(0.07)	-0.17(0.29)
Family size	-0.15(0.07)♥	-0.10(0.30)	0.57(0.31)	-0.12(0.06)♥	0.14(0.06)♥	-0.04(0.03)	0.01(0.11)
Education	-0.87(0.75)	0.19(0.47)	0.10(0.02)†	-0.47(0.40)	-0.27(0.56)	0.81(0.38)♥	0.69(0.23)†
Farmland	-0.97(0.23)†	-0.02(0.75)	-0.60(0.27)	-0.10(0.04)♥	-2.29(0.61)♥	-2.61(1.07)♥	-0.09(0.03)♥
Livestock	-0.02(0.55)	-0.07(0.10)	0.13(0.12)	-0.73(0.34)♥	-0.62(0.41)	-0.16(0.08)♥	0.26(0.70)
Special skills	0.84(0.88)	-0.62(0.86)	0.46(0.43)	-0.84(0.60)	-0.57(0.28)♥	0.15(0.13)	-0.46(0.41)
Credit access	-0.13(0.80)	-0.46(0.21)♥	0.28(0.11)♥	0.22(0.16)	0.13(0.24)	-0.41(0.42)	-0.57(0.44)
Occupation	-0.82(0.50)*	-0.65(0.29)♥	-0.34(0.07)†	-0.14(0.47)	-0.58(0.22)♥	-0.25(0.64)	0.09(0.06)
Drought	-0.77(0.54)	0.81(1.10)	1.64(2.08)	0.05(0.10)	-0.14(0.59)	-0.38(0.05)†	0.78(0.62)
Stress	0.31(0.30)	0.04(0.31)	0.21(0.07)♥	0.12(0.37)	0.18(0.19)	-0.33(0.24)	0.14(0.24)
Risk attitude	0.19(0.17)	0.37(0.63)	0.88(0.90)	-0.25(0.25)	-0.24(0.06)†	0.32(0.07)†	-0.63(0.12)†
Extension service	-0.01(0.88)	-0.52(0.44)	-0.11(0.59)	0.33(0.13)♥	0.03(0.32)	-0.17(0.54)	0.02(0.04)
Gov't support	0.09(0.04)*	-0.08(0.01)†	-0.24(0.52)	-0.06(0.59)	0.31(0.33)	0.45(0.41)	0.09(0.47)
Media influence	0.19(0.87)	1.06(0.95)	-0.13(0.55)	0.65(0.17)	0.28(0.30)	-0.32(0.57)	0.70(0.35)♥
Relational capital	0.17(0.09)*	1.28(1.17)	-0.23(0.11)♥	0.36 (0.34)	0.03(0.08)	0.44(0.92)	-0.02(0.95)
Group membership	-0.33(0.24)	0.16 (0.07)♥	-0.13(0.91)	1.42(1.40)	-0.74(0.60)	-0.70(0.20)†	0.64(0.83)
Technical training	0.43(0.42)	0.63(0.80)	0.09(0.93)	-0.72(0.66)	0.78(0.32)♥	0.60(1.28)	0.40(0.32)
Market proximity	-0.97(0.72)	0.18(0.58)	0.27(0.09)♥	-0.20(0.02)†	-0.62(0.25)♥	0.70(0.53)	0.07(0.02)♥
Road access	-0.08(0.87)	-0.19(0.05)†	0.26(0.37)	-0.15(0.16)	0.08(0.15)	-0.08(0.18)	0.10(0.02)†
Flat slopes	0.04(0.95)	-0.86(0.38)♥	-0.06(0.91)	0.56(0.37)	-0.33(0.11)♥	0.36(0.69)	-0.11(0.75)
Fertile soil	0.03(0.01)♥	0.23(0.81)	0.87(0.80)	-0.92(0.47) ♥	-0.80(0.39)*	0.02(0.03)	0.60(0.09)†
Shallow soil	-0.95(0.91)	0.20(0.81)	0.66(1.18)	0.89(0.31)♥	-0.21(0.32)	-0.78(0.65)	0.30(0.46)
Agroecology	0.03(0.01)†	-0.78(1.01)	0.93(0.64)	-0.23(0.32)	-0.24(0.31)	0.52(0.28)*	0.01(0.28)
Schooling year	0.11(0.05)♥	-0.04(0.03)	-0.14(0.20)	-0.07(0.05)	-0.03(0.05)	-0.07(0.07)	0.11(0.05)♥
Constant	14.9(4.00)†	12.0(15.32)	12.1(10.23)	9.0(2.75)†	8.3(5.82)	6.9(6.71)	5.8(2.69)♥
Overall model diagnosis							
Joint F-statistic	300♥	13.6♥	7.4♥	6.0†	11.2†	4.6†	4.8†
R-squared	0.97	0.88	0.91	0.68	0.78	0.82	0.57
Selection correction terms							
λ_0	0.08(0.17)	-0.06(0.27)	-0.26(0.05)†	0.22(0.20)	0.05(0.02)♥	-0.01(0.04)	-0.13(0.14)
λ_1	0.32(0.11)†	-0.08(0.04)♥	-0.36(0.80)	-0.19(0.21)	0.13(0.12)	-0.03(0.02)♥	-0.12(0.02)†
λ_2	-0.17(0.62)	0.15(0.05)♥	0.36(0.90)	-0.09(0.04)♥	-0.32(0.12)	0.12(0.05)♥	0.13 (0.19)
λ_3	-0.09(0.30)	0.15(0.21)	0.55(0.19)♥	-0.13(0.16)	-0.08(0.14)	0.26(0.11)♥	0.08(0.01)†
λ_4	0.56(0.19)♥	0.05(0.01)†	0.71(0.64)	-0.10(0.05)♥	-0.05(0.09)	0.10(0.11)	-0.05(0.12)
λ_5	0.14(0.36)	0.08(0.19)	0.61(0.28)♥	0.12(0.06)*	-0.06(0.03)♥	0.01 (0.11)	0.06(0.03)♥
λ_6	-0.12(0.41)	0.31(0.22)	0.09(0.05)*	0.16(0.07)♥	0.09(0.03)♥	-0.02(0.03)	-0.08(0.01)†

Notes: The level of statistically significant test († for $P<0.01$; ♥ for $P<0.05$ and * for $P<0.10$).

Values in parentheses show robust standard errors)

Annexe 6. 3. Parameter estimates of log per capita harvest: multinomial endogenous switching regression

Variables	CNMNRN	CYMNRN	CNMYRN	CYMYRN	CYMNRY	CNMYRY	CYMYRY
Gender (male)	0.10(0.14)	0.85(0.40)♥	-0.62(0.56)	0.35(0.30)	0.51(0.30)*	-0.02(0.26)	0.30(0.24)
Age(log)	-0.18(0.03)†	-0.07(0.12)	-0.42(0.31)	-0.29(0.04)†	0.54(0.35)	-0.11(0.05)♥	0.16(0.12)
Family size	-0.13(0.51)	-0.25(0.04)†	0.07(0.10)	-0.26(0.04)†	-0.29(0.03)†	-0.30(0.04)†	-0.25(0.04)†
Education	0.23(0.32)	-1.04(0.48)♥	0.09(0.36)	-0.28(0.09)♥	-0.78(0.40)♥	0.20(0.13)	0.14(0.03)†
Farmland	0.40(0.20)♥	-0.06(0.09)	-0.44(0.14)†	0.46(0.41)	-0.12(0.44)	0.28(0.05)†	-0.46(0.35)
Livestock	0.85(0.58)	-0.08(0.04)*	0.02(0.03)	0.36(0.12)	-0.44(0.17)♥	0.31(0.29)	-0.08(0.06)
Special skills	-0.39(0.91)	-0.57(0.31)*	0.12(0.15)	-0.20(0.14)	-0.24(0.19)	0.03(0.27)	-0.09(0.03)♥
Credit access	0.03(0.48)	-0.11(0.23)	0.13(0.02)†	0.11(0.09)	0.10(0.14)	0.14(0.24)	-0.36(0.28)
Occupation	-0.95(0.16)†	-0.40(0.30)	-0.92(0.68)	-0.22(0.05)†	-0.50(0.20)♥	-0.24(0.33)	-0.55(0.29)*
Drought	-0.78(0.40)	-0.81(0.60)	0.90(0.58)	0.15(0.50)	-0.06(0.35)	0.71(0.33)♥	0.06(0.39)
Stress	0.06(0.09)	-0.30(0.13)♥	0.18(0.59)	-0.05(0.18)	0.08(0.12)	0.50(0.16)♥	-0.02(0.17)
Risk attitude	0.15(0.04)†	0.89(0.46)*	0.07(0.03)♥	-0.07(0.13)	-0.15(0.17)	0.14(0.21)	0.21(0.18)
Extension service	-0.08(0.91)	-0.50(0.18)♥	-0.04(0.01)†	0.13(0.02)†	0.05(0.04)	-0.05(0.16)	-0.05(0.20)
Gov’t support	0.20(0.75)	0.31(0.34)	-0.63(1.25)	0.03(0.34)	0.13(0.19)	0.17(0.05)†	031(0.30)
Media influence	-0.29(0.12)♥	-0.40(0.90)	-0.03(0.01)†	0.02(0.09)	0.54(0.23)♥	-0.57(0.39)	-0.52(0.22)♥
Relational capital	-0.03(1.72)	1.28(0.45)♥	-1.65(3.20)	0.14(0.19)	0.14(0.53)	0.04(0.52)	0.23(0.65)
Group membership	-1.55(1.20)	-0.73(0.33)♥	0.15(1.61)	0.72(0.65)	-0.46(0.42)	-0.89(0.62)	-0.12(0.56)
Technical training	0.75(0.30)♥	0.24(0.28)	0.66(0.09)†	0.15(0.02)†	-0.39(0.42)	0.56(0.58)	0.41(0.27)
Market proximity	0.21(0.02)†	0.66(0.47)	0.73(0.26)♥	-0.96(0.69)	-0.09(0.01)†	0.63(0.34)*	0.55(0.08)†
Road access	-0.09(0.41)	0.06(0.19)	0.01(0.10)	-0.08(0.02)†	-0.03(0.09)	-0.01(0.09)	-0.04(0.09)
Flat slopes	0.16(0.94)	-0.09(0.49)	-0.42(0.32)	0.21(0.05)♥	-0.13(0.25)	0.21(0.36)	-0.28(0.04)♥
Fertile soil	0.63(0.44)	0.33(0.68)	0.12(0.02)	-0.41(0.36)	-0.34(0.13)♥	0.17(0.16)	-0.45(0.17)♥
Shallow soil	-0.45(0.53)	-0.36(0.21)	0.13(0.95)	0.44(0.31)	-0.12(0.17)	-0.49(0.44)	0.04(0.31)
Agroecology	-0.30(0.39)	0.66(0.48)	0.92(0.45)†	0.08(0.17)	0.07(0.17)	0.10(0.14)	0.06(0.18)
Schooling year	-0.10(0.08)	0.03(0.01)♥	-0.02(0.16)	-0.05(0.03)	-0.06(0.03)♥	-0.02(0.04)	0.02(0.03)
Constant	-0.61(12.88)	5.24(2.30)	-6.15(4.26)	0.54(0.35)	7.66(1.33)†	7.62(1.77)†	5.17 (3.36)
Overall model diagnosis							
Joint F-statistic	211.7†	97.5†	17.2†	27.6†	32.9†	31.8†	21.4†
R-squared	0.94	0.98	0.96	0.90	0.93	0.95	0.86
Selection correction terms							
λ_0	-0.06(0.08)	-0.08(0.06)	-0.15(0.04)†	0.02(0.01)	0.05(0.01)†	-0.06(0.12)	-0.03(0.02)
λ_1	-0.14(0.51)	-0.07(0.10)	-0.77(0.52)	0.10(0.09)	0.07(0.03)♥	-0.03(0.01)†	-0.09(0.04)♥
λ_2	0.24(0.30)	0.23(0.11)♥	0.77(0.24)♥	-0.05(0.04)	-0.09(0.07)	0.04(0.03)	0.05(0.02)♥
λ_3	0.09(0.01)†	0.17(0.08)♥	0.23(0.17)	-0.03(0.04)	-0.02(0.03)	0.10(0.15)	0.16(0.04)†
λ_4	0.05(0.33)	-0.15(0.18)	0.37(0.15)♥	-0.06(0.02)♥	-0.05(0.02)♥	0.03(0.02)	-0.06(0.02)♥
λ_5	0.26(0.08)†	0.05(0.04)	0.36(0.08)†	-0.04(0.01)†	-0.07(0.05)	0.04(0.02)*	0.05(0.02)♥
λ_6	-0.16(0.20)	0.10(0.06)*	-0.23(0.17)	0.05(0.02)♥	0.05(0.01)†	-0.02(0.06)	-0.05(0.04)

Notes: The level of statistically significant test († for $P<0.01$; ♥ for $P<0.05$ and * for $P<0.10$).

Values in parentheses show robust standard errors)

Annexe 6. 4. Estimated coefficients of multinomial endogenous switching regression: log per capita income as the dependent variable

Variables	$C_NM_NR_N$	$C_YM_NR_N$	$C_NM_YR_N$	$C_YM_YR_N$	$C_YM_NR_Y$	$C_NM_YR_Y$	$C_YM_YR_Y$
Gender (male)	-0.13(0.20)	0.34(0.50)	-0.22(0.07)♥	0.24(0.35)	0.06(0.04)*	-0.28(0.04)†	-0.34(0.45)
Age(log)	0.21(0.16)	0.05(0.02)♥	-0.35(0.24)	-0.13(0.05)♥	0.40(0.06)†	-0.05(0.03)	0.07(0.13)
Family size	-0.50(0.18)♥	0.27(0.09)♥	-0.39(0.12)	-0.24(0.09)♥	-0.26(0.07)♥	0.26(0.17)	-0.32(0.04)†
Education	-0.58(0.66)	-0.38(0.28)	-0.99(0.44)♥	-0.44(0.13)†	0.14(0.04)♥	0.15(0.04)♥	0.17(0.04)†
Farmland	0.04(0.03)	0.29(0.11)♥	-0.14(0.07)♥	0.39(0.46)	-0.76(0.59)	0.08(0.03)♥	0.21(0.14)
Livestock	-0.02(0.05)	-0.11(0.09)	0.02(0.06)	-0.24(0.31)	-0.26(0.37)	0.45(0.04)†	0.28(0.21)
Special skills	0.47(0.82)	-0.34(0.76)	-0.85(1.22)	-0.15(0.02)†	-0.27(0.02)†	-0.04(0.32)	0.08(0.04)♥
Credit access	-0.08(0.97)	-0.34(0.42)	-0.45(0.62)	-0.07(0.14)	0.03(0.15)	-0.19(0.03)†	-0.39(0.29)
Occupation	0.06(0.25)	-0.24(0.21)	-0.91(1.11)	-0.02(0.31)	-0.79(0.40)*	-0.15(0.47)	0.42(0.27)
Drought	0.31(1.90)	0.66(0.09)†	0.19(0.05)†	-0.88(0.75)	-0.33(1.05)	0.46(0.67)	0.10(0.06)
Stress	0.09(0.03)♥	0.15(0.30)	0.56(0.41)	0.23(0.34)	0.19(0.25)	0.29(0.23)	0.01(0.26)
Risk attitude	-0.26(0.09)♥	-0.29(0.37)	-0.70(0.09)†	-0.12(0.17)	0.04(0.20)	0.04(0.30)	-0.17(0.03)†
Extension services	-0.26(0.82)	0.31(0.41)	0.20(0.07)♥	0.15(0.02)†	-0.15(0.24)	-0.03(0.25)	0.06(0.03)*
Gov't support	-0.77(0.11)†	-0.65(0.75)	-1.23(1.15)	0.44(0.49)	-0.27(0.65)	-0.07(0.03)♥	-0.59(0.45)
Media influence	0.60(0.70)	-0.19(0.94)	-1.28(1.53)	0.49(0.52)	-0.54(0.38)	-0.05(0.02)♥	0.74(0.50)
Relational capital	-0.27(0.19)	-0.70(1.26)	-1.622.65	0.38(1.92)	-0.54(0.38)	0.20(0.08)♥	0.29(0.07)†
Group membership	-2.83(2.10)	0.42(0.67)	0.05(0.89)	-1.09(1.21)	-1.32(1.11)	0.06(0.03)♥	0.44(0.81)
Technical training	-0.38 (0.63)	-0.20(0.17)	0.42(0.85)	-0.19(0.50)	0.34(0.06)♥	0.12(0.74)	0.19(0.10)*
Market proximity	-0.62(0.50)	0.36(0.15)♥	-0.40(6.43)	-0.10(0.84)	0.22(0.05)♥	0.13(0.10)	-0.17(0.02)†
Road access	0.35(0.84)	0.04(0.36)	-0.07(0.29)	0.12(0.08)	-0.13(0.01)†	-0.15(0.14)	-0.13(0.05)♥
Flat slopes	0.54(0.89)	-0.38(0.07)†	-0.36(0.79)	0.37(0.13)♥	-0.03(0.03)	-0.61(0.48)	0.42(0.57)
Fertile soils	-0.19(0.09)♥	-0.18(0.27)	-0.45(0.16)♥	-0.40(0.04)†	0.51(0.62)	-0.12(0.16)	0.31(0.16)*
Shallow soils	-1.09(0.94)	0.08(0.03)♥	-0.38(0.54)	-0.56(0.53)	-0.45(0.39)	-0.05(0.76)	0.66(0.43)
Agroecology	-1.03(0.67)	-0.12(1.25)	0.55(0.41)	0.01(0.26)	0.53(0.14)♥	-0.08(0.26)	0.17(0.20)
Schooling year	-0.15(0.14)	-0.03(0.05)	0.04 (0.11)	-0.01(0.05)	-0.07(0.08)	0.07(0.03)♥	-0.01(0.06)
Constant	16.54(25.88)	2.26(3.06)	16.48(25.08)	7.25(2.99)♥	4.24(2.92)	8.42(5.70)	7.17(4.86)
Overall model diagnosis							
Joint F-statistic	122†	15.9†	43.5†	4.6†	12.6†	26.6†	14.5†
R-squared	0.91	0.87	0.90	0.74	0.75	0.90	0.82
Selection correction terms							
λ_0	0.11(0.16)	0.08(0.03)♥	0.02(0.11)	0.05(0.16)	-0.09(0.02)†	-0.04(0.09)	0.04(0.03)
λ_1	0.32(0.26)	0.45(0.73)	-0.06(0.02)♥	0.05(0.02)*	0.03(0.01)♥	-0.05(0.01)†	0.05(0.01)†
λ_2	-0.37(0.60)	-0.58(0.96)	-0.07(0.01)†	-0.68(0.08)†	-0.08(0.01)†	0.03(0.05)	-0.03(0.01)♥
λ_3	-0.22(0.29)	-0.24(0.35)	0.18(0.17)	-0.03(0.02)♥	0.06(0.05)	-0.03(0.05)	-0.06(0.03)♥
λ_4	-0.03(0.67)	-0.40(0.21)*	-0.26(0.36)	-0.07(0.02)♥	-0.05(0.08)	-0.07(0.01)†	0.09(0.07)
λ_5	-0.27(0.04)†	-0.26(0.11)♥	0.11(0.21)	-0.23(0.04)†	0.05(0.02)♥	0.05(0.03)♥	-0.27(0.06)†
λ_6	0.28(0.40)	0.18(0.09)*	0.36(0.03)†	0.06(0.03)♥	0.03(0.01)♥	-0.02(0.06)	-0.03(0.02)♥

Notes: The level of statistically significant test († for $P<0.01$; ♥ for $P<0.05$ and * for $P<0.10$).

Values in parentheses show robust standard errors)

Annexe 6. 5. Parameter estimates of log per capita assets: multinomial endogenous switching regression

Variables	$C_NM_NR_N$	$C_YM_NR_N$	$C_NM_YR_N$	$C_YM_YR_N$	$C_YM_NR_Y$	$C_NM_YR_Y$	$C_YM_YR_Y$
Gender (male)	0.09 (0.06)	0.63(0.61)	0.42(0.72)	0.70(0.44)	0.34(0.44)	0.32(0.55)	0.18(0.16)
Age(log)	0.23(0.18)	0.02(0.01)	-2.63(0.68)†	-0.80(0.32)♥	0.18(0.07)♥	-0.04(0.01)†	-0.05(0.08)
Family size	-0.35(0.13)♥	-0.31(0.15)♥	-0.27(0.13)♥	-0.19(0.05)♥	0.20(0.07)♥	-0.35(0.05)†	-0.30(0.05)†
Education	-0.44(0.83)	-0.59(0.57)	-5.52(1.66)♥	-0.05(0.33)	0.19(0.04)†	0.43(0.50)	0.25(0.05)†
Farmland	0.25(0.17)	-0.24(0.27)	-1.06(0.76)	-0.38(0.16)♥	-0.80(0.61)	0.65(0.68)	0.40(0.11)♥
Livestock	-0.24(0.55)	-0.14(0.07)♥	0.27(0.18)	-0.28(0.36)	-0.21(0.04)†	0.09(0.04)♥	0.09(0.62)
Special skills	0.08(0.06)	-0.48(0.36)	1.18(1.44)	-0.02(0.20)	-0.19(0.15)	0.35(0.24)	-0.35(0.24)
Credit access	2.46 (2.39)	0.27(0.24)	0.40(0.56)	0.02(0.01)♥	0.02(0.16)	0.04(0.02)♥	0.07(0.28)
Occupation	-0.02(0.27)	-0.05(0.06)	1.93(0.45)♥	-0.81(0.30)♥	-0.28(0.31)	-0.16(0.35)	-0.22(0.39)
Drought	-0.41(1.09)	1.50(1.14)	-0.90(1.18)	-0.25(0.55)	0.37(0.08)†	-0.46(0.41)	0.40(0.71)
Stress	0.76(0.23)†	0.53(0.40)	-1.31(0.42)♥	-0.30(0.28)	0.20(0.22)	-0.03(0.19)	-0.23(0.27)
Risk attitude	0.23(0.16)	0.29(0.38)	-1.86(0.75)*	0.31(0.22)	0.08(0.19)	-0.08(0.03)♥	-0.06(0.03)*
Extension services	-0.09(0.62)	0.19(0.04)†	-3.74(1.00)♥	-0.21(0.22)	0.04(0.24)	3.10(1.03)♥	0.14(0.04)†
Gov't support	-0.64(0.80)	-0.93(0.89)	1.51(0.99)	0.14(0.40)	-0.31(0.05)†	0.13(0.29)	-0.14(0.47)
Media influence	0.07(0.02)†	0.45(1.07)	0.37(0.71)	-0.34(0.87)	-0.48(0.10)♥	0.21(0.04)†	0.66(0.25)♥
Relational capital	-2.66(2.04)	-1.39(1.55)	6.43(2.44)♥	3.44(1.62)♥	-0.26(0.94)	0.12(0.62)	-0.33(0.29)
Group membership	-0.14(1.30)	0.33(0.76)	5.77(1.30)†	1.59(0.87)*	-0.44(0.95)	-0.69(0.76)	0.18(0.15)
Technical training	-1.21(0.28)†	0.39(0.12)♥	0.59(0.20)♥	0.68(0.23)♥	0.07(0.03)♥	0.40(0.22)	0.37(0.20)
Market proximity	-0.53(0.37)	-0.02(0.26)	0.12(0.83)	0.35(0.30)	0.03(0.01)♥	-0.54(0.15)♥	2.24(1.02)♥
Road access	0.22(0.21)	-0.13(0.24)	3.23(1.30)	0.86(0.46)*	-0.05(0.11)	0.13(0.11))	0.15(0.16)
Flat slopes	1.23(0.46)♥	-0.05(0.01)†	-2.02(0.62)♥	-0.58(0.27)♥	-0.03(0.34)	0.30(0.40)	-0.50(0.20)♥
Fertile soils	-0.93(0.89)	-0.28(0.16)*	-3.28(1.07)†	0.67(0.52)	0.25(0.05)	-0.80(0.08)	-0.08(0.01)†
Shallow soils	0.31(0.57)	0.41(0.31)	0.59(0.28)♥	0.48(0.41)	0.08(0.36)	-0.19(0.57)	0.18(0.04)†
Agroecology	-1.19(0.37)♥	-0.75(1.27)	0.53(0.22)♥	0.28(0.25)	0.38(0.42)	-0.17(0.21)	0.23(0.26)
Schooling year	-0.01(0.09)	-0.03(0.04)	0.56(0.15)♥	-0.03(0.04)	0.03(0.08)	-0.07(0.04)	0.03(0.01)♥
Constant	12.48(37.28)	12.05(9.70)	7.77(5.13)	5.57(4.00)	7.76(2.54)♥	7.01(4.88)	10.26(6.87)
Overall model diagnosis							
Joint F-statistic	291.8†	17.5†	24.0†	21.3†	6.2†	31.7†	7.2†
R-squared	0.90	0.88	0.93	0.80	0.73	0.94	0.74
Selection correction terms							
λ_0	-0.02(0.24)	0.08(0.04)*	0.05(0.22)	-0.01(0.02)	-0.01(0.02)	0.04(0.03)	0.08(0.03)♥
λ_1	0.07(0.03)♥	0.15(0.17)	0.14(0.02)†	-0.09(0.03)♥	-0.10(0.04)♥	-0.03(0.02)	0.07(0.01)†
λ_2	-0.11(0.86)	-0.20(0.17)	0.04(1.36)	-0.05(0.01)†	-0.02(0.01)	0.10(0.02)†	0.04(0.03)
λ_3	0.05(0.42)	-0.26(0.11)	0.06(0.02)♥	0.09(0.14)	0.03(0.04)	0.04(0.01)†	-0.06(0.03)*
λ_4	-0.07(0.01)†	-0.29(0.13)♥	-0.42(0.20)♥	0.18(0.09)*	-0.07(0.03)♥	0.06(0.04)	-0.06(0.04)
λ_5	0.01(0.51)	-0.06(0.09)	0.34(0.09)♥	-0.15(0.06)♥	0.02(0.05)	0.06(0.02)♥	0.25(0.17)
λ_6	0.09(0.57)	0.07(0.01)†	0.71(0.15)†	0.04(0.06)	0.05(0.04)	-0.08(0.14)	-0.09(0.03)♥

Notes: The level of statistically significant test († for P<0.01; ♥ for P<0.05 and * for P<0.10).

Values in parentheses show robust standard errors)

Annexe 6. 6. Parameter coefficients of multinomial endogenous switching regression: log per capita expenditures as the dependent variable

Variables	$C_NM_NR_N$	$C_YM_NR_N$	$C_NM_YR_N$	$C_YM_YR_N$	$C_YM_NR_Y$	$C_NM_YR_Y$	$C_YM_YR_Y$
Gender (male)	0.37(0.46)	-0.15(0.62)	-0.27(0.61)	-0.09(0.27)	-0.64(0.31)♥	0.07(0.20)	-0.10(22)
Age(log)	-0.04(0.37)	-0.02(0.31)	-0.87(0.39)♥	-0.18(0.24)	-0.14(0.21)	0.15(0.26)	0.27(0.20)
Family size	-0.34(0.08)†	0.31(0.07)♥	-0.11(0.12)	-0.27(0.04)†	-0.30(0.02)†	-0.29(0.04)†	0.28(0.03)†
Education	-0.65(0.55)	0.32(0.72)	-0.83(0.94)	0.36(0.41)	1.09(0.50)♥	0.32(0.38)	0.09(0.03)†
Farmland	0.29(0.10)	-0.09(0.57)	-0.19(0.77)	-0.26(0.04)†	-0.10(0.33)	-0.04(0.51)	0.07(0.27)
Livestock	0.16(0.10)	-0.09(0.07)	0.26(0.09)♥	-0.01(0.04)	-0.05(0.04)	-0.12(0.05)♥	-0.06(0.03)♥
Special skills	-0.17(0.25)	-0.07(0.34)	0.17(0.36)	0.02 (0.16)	0.14(0.19)	-0.06(0.16)	-0.01(0.11)
Credit access	-0.10(0.21)	0.08(0.03)♥	-0.49(0.39)	0.01(0.14)	-0.19(0.13)	0.06(0.17)	0.01(0.08)
Occupation	0.04(0.02)♥	0.03(0.20)	0.06(0.03)*	-0.03(0.20)	-0.52(0.14)†	-0.08(0.14)	-0.13(0.12)
Drought	0.58(0.71)	-0.43(0.69)	0.11(0.92)	-0.01(0.32)	-0.46(0.44)	-0.24(0.11)♥	0.04(0.01)†
Stress	-011(0.14)	0.69(0.24)	0.92(0.36)♥	0.05(0.15)	-0.15(0.11)	0.12(0.03)†	0.09(0.01)†
Risk attitude	0.40(0.50)	-0.15(0.65)	0.68(0.49)	-0.11(0.02)†	-0.56(0.44)	-0.27(0.52)	-0.14(0.29)
Extension services	0.02(0.63)	-0.14(0.46)	0.49(0.92)	0.01(0.46)	0.13(0.24)	0.15(0.47)	0.23(0.31)
Gov't support	-0.40(0.53)	0.15(0.05)♥	0.92(0.99)	0.11(0.26)	0.15(0.03)†	-0.07(0.22)	-0.06(0.18)
Media influence	0.48(0.37)	-0.59(0.62)	0.17(0.50)	0.20(0.49)	-0.35(0.30)	0.03(0.22)	-0.24(0.19)
Relational capital	-0.63(1.34)	0.39(0.74)	1.15(2.29)	0.56(0.96)	0.40(0.56)	0.05(0.01)†	0.14(0.07)♥
Group membership	0.32(0.07)†	-0.04(0.69)	1.91(0.76)♥	-0.27(0.55)	-0.51(0.50)	0.35(0.06)†	-0.26(0.43)
Technical training	0.05(0.18)	-0.09(0.15)	-0.07(0.16)	0.01(0.08)	0.07(0.08)	-0.05(0.14)	0.15(0.08)*
Market proximity	0.11(0.25)	-0.29(0.27)	-0.89(0.65)	0.31(0.14)♥	-0.23(0.14)*	-0.14(0.11)	0.07(0.02)†
Road access	-0.29(0.62)	0.29(0.50)	0.67(1.25)	0.10(0.32)	0.46(0.36)	0.01(0.27)	-0.29(0.25)
Flat slopes	-0.04(0.30)	0.12(0.02)♥	-1.00(0.44)♥	0.20(0.21)	-0.32(0.16)♥	0.20(0.16)	0.17(0.11)
Fertile soils	0.77(0.89)	-0.27(0.52)	-0.72(0.98)	-0.01(0.32)	-0.27(0.31)	0.09(0.32)	0.14(0.18)
Shallow soils	0.23(0.39)	0.02(0.42)	0.40(0.48)	-0.03(0.01)†	0.08(0.26)	-0.13(0.44)	0.06(0.22)
Agroecology	-0.07(0.23)	0.45(0.73)	0.89(0.30)†	-0.01(0.13)	0.52(0.21)♥	-0.32(0.11)♥	0.08(0.11)
Schooling year	0.09(0.04)♥	-0.01(0.03)	0.15(0.09)*	-0.02(0.03)	-0.04(0.03)	0.03(0.02)	-0.01(0.02)
Constant	4.27(2.24)*	3.98(3.09)	9.46 (6.31)	5.26(3.53)	6.16(1.21)†	2.38(1.65)	6.97(4.98)
Overall model diagnosis							
Joint F-statistic	191.3†	50.7†	126.7†	18.0†	30.5†	53.0†	21.2†
R-squared	0.89	0.93	0.91	86	90	0.95	0.92
Selection correction terms							
λ_0	-0.03(0.04)	-0.05(0.02)♥	-0.03(0.09)	0.02(0.01)♥	0.01(0.02)	0.01(0.03)	-0.03(0.02)♥
λ_1	0.02(0.01)	0.01(0.02)	0.09(0.03)♥	-0.03(0.01)♥	0.01(0.01)	-0.01(0.01)	0.02(0.01)♥
λ_2	0.02(0.05)	-0.07(0.09)	0.04(0.09)	-0.03(0.03)	0.08(0.04)♥	-0.11(0.03)†	-0.01(0.02)
λ_3	-0.14(0.14	0.09(0.15)	0.08(0.02)†	0.02(0.07)	0.12(0.10)	0.02(0.07)	0.01(0.06)
λ_4	0.05(0.01)†	-0.05(0.09)	-0.05(0.19)	-0.01(0.06)	-0.04(0.04)	0.02(0.01)♥	0.17(0.03)†
λ_5	-0.02(0.05)	-0.03(0.04)	-0.11(0.09)	0.04(0.01)†	0.02(0.02)	0.11(0.03)†	0.06(0.02)♥
λ_6	0.01(0.07)	-0.03(0.01)♥	0.16(0.08)♥	-0.01(0.05)	0.08(0.04)*	-0.04(0.07)	-0.07(0.04)*

Notes: The level of statistically significant test († for $P<0.01$; ♥ for $P<0.05$ and * for $P<0.10$).

Values in parentheses show robust standard errors)

Annexe 6. 7. Parameter coefficients of multinomial endogenous switching regression: the household food insecurity access scale (HFIAS) score as the dependent variable

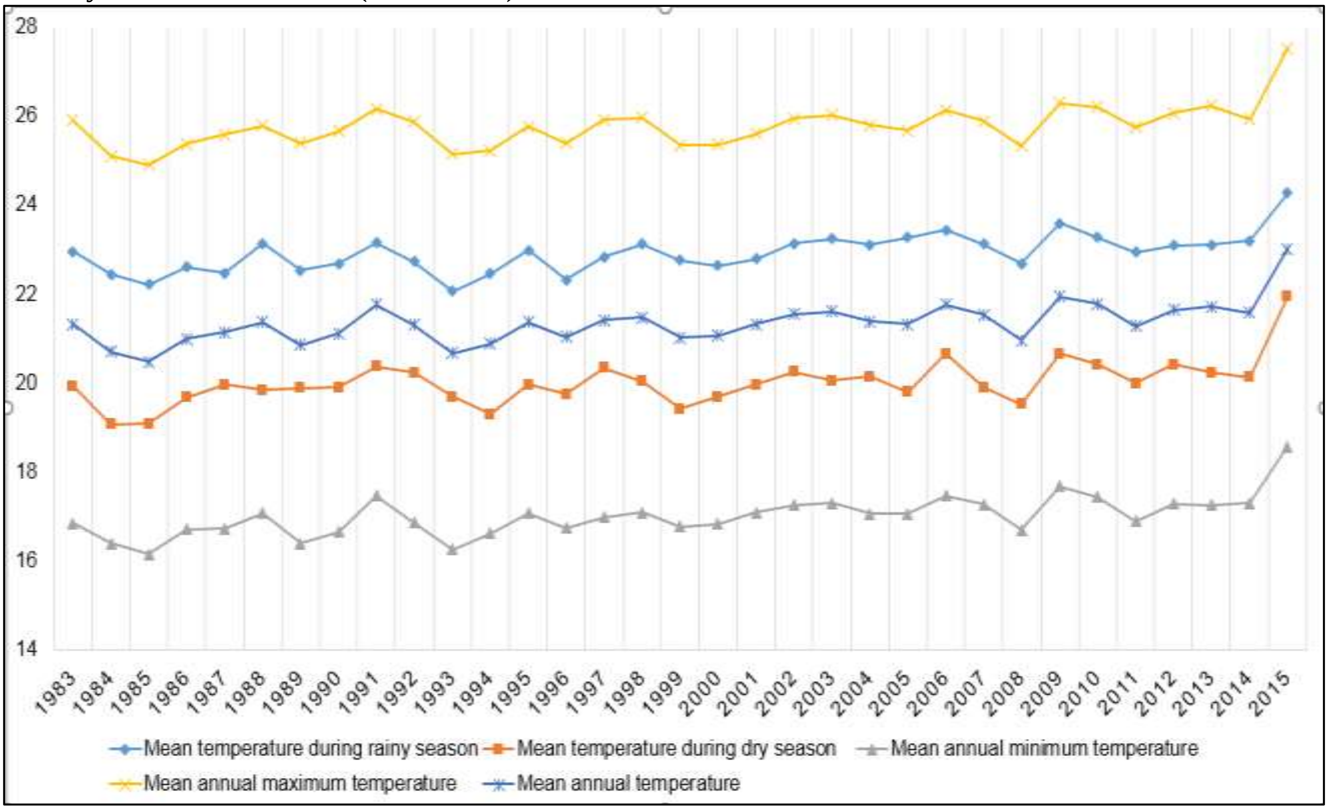
Variables	$C_NM_NR_N$	$C_YM_NR_N$	$C_NM_YR_N$	$C_YM_YR_N$	$C_YM_NR_Y$	$C_NM_YR_Y$	$C_YM_YR_Y$
Gender (male)	-0.02(9.68)	5.15(3.70)		-0.86(3.68)	2.30(5.24)	17.84(5.94)†	-3.40(5.39)
Age(log)	9.99(6.17)	3.90(1.87)♥		-2.77(4.97)	3.74(4.22)	-5.60(4.53)	-4.03(4.13)
Family size	1.52(1.44)	-2.22(0.46)†		0.17(0.08)♥	-0.12(0.43)	0.33(0.50)	0.31(0.47)
Education	-9.71(12.16)	-1.17(4.00)		5.02(6.50)	-3.09(8.66)	-35.23(9.11)†	0.47(0.05)†
Farmland	-3.93(14.16)	11.36(3.06)†		-0.06(8.70)	4.01(2.11)*	-33.08(13.45)♥	3.47(6.74)
Livestock	4.34(2.03)♥	0.01(0.44)		0.95(0.87)	0.43(0.81)	1.73(1.02)	-0.07(0.58)
Special skills	5.51(4.85)	-4.09(1.48)♥		-3.72(4.23)	0.60(3.14)	1.82(3.60)	-4.74(2.38)*
Credit access	-4.01(3.81)	2.67(1.34)♥		-2.39(2.59)	-0.13(2.77)	2.31(2.90)	0.46(0.08)†
Occupation	8.68(4.15)♥	-1.50(1.14)		-1.80(4.21)	2.19(2.73)	1.45(3.40)	-0.23(2.03)
Drought	7.37(15.13)	11.24(4.17)♥		-8.39(4.19)♥	-1.58(6.64)	19.76(6.06)†	-5.54(6.88)
Stress	7.55(2.51) †	8.64(1.33)†		3.53(3.10)	-0.21(0.10)♥	-5.29(3.28)	-2.60(2.58)
Risk attitude	6.98(10.28)	10.71(3.82)♥		-8.44(6.54)	-2.11(5.50)	30.54(9.60)†	-5.36(6.52)
Extension services	-8.37(1092)	11.47(2.34)†		11.12(9.97)	-1.03(4.61)	-26.58(8.84)†	1.22(5.54)
Gov't support	-1.08(10.56)	-14.93(2.91)†		3.79(4.12)	2.03(4.05)	2.73(4.00)	0.64(0.07)†
Media influence	-4.10(7.75)	15.05(4.12)†		-17.65(8.68)♥	1.84(3.89)	16.65(7.72♥	-1.47(4.13)
Relational capital	7.85(26.00)	-9.59(3.91)♥		-19.9(18.19)	5.32(8.42)	14.60(10.52)	-1.89(8.82)
Group membership	8.40(16.27)	-3.23(3.09)		-9.65(12.07)	0.97(0.33)†	39.43(14.1)♥	-5.23(8.65)
Technical training	1.35(3.53)	1.58(0.72)♥		3.04(1.65)*	-2.38(1.84)	3.43(2.78)	-3.70(1.80)♥
Market proximity	5.79(2.58)♥	-4.55(1.32)†		2.44(2.35)	-2.05(2.14)	4.76(2.52)	0.09(1.95)
Road access	7.60(12.53)	-15.96(3.24)†		-5.65(5.74)	3.75(5.67)	-0.43(5.31)	2.47(5.81)
Flat slopes	-0.15(5.75)	3.30(1.42)♥		4.81(3.92)	-0.42(2.37)	-7.12(3.36)♥	-2.80(0.57)†
Fertile soils	-1.92(17.84)	9.74(2.84)†		8.25(6.35)	-0.91(5.71)	-6.49(4.63)	0.10(4.28)
Shallow soils	-1.28(7.17)	6.99(2.25)†		-9.58(5.97)	-1.19(2.60)	21.12(6.58)†	-0.91(4.23)
Agroecology	3.65(5.08)	-19.22(4.82)†		4.76(2.7)*	-2.17(3.28)	4.23(3.15)	-5.00(2.37)♥
Schooling year	1.41(1.10)	-0.22(0.20)		-0.17(0.42)	0.91(0.73)	1.28(0.59)♥	0.28(0.51)
Constant	-159(38.9)†	23.99(16.12)		31.52(20.76)	-14.64(22.76)	-33.06(36.30)	7.57(21.41)
Overall model diagnosis							
Joint F-statistic	95.75†	67.06†		17.32♥	12.00♥	11.41†	22.32†
R-squared	0.26	0.44		0.46	0.29	0.33	0.19
Selection correction terms							
λ_0	-0.03(0.72)	0.20(0.13)		-0.42(0.40)	0.48(0.26)*	0.78(0.41)*	-0.15(0.27)
λ_1	-0.27(0.29)	0.65(0.12)†		-0.16(0.23)	0.11(0.15)	0.52(0.18)♥	-0.16(0.24)
λ_2	0.15(0.05)†	1.82(0.62)♥		0.12(0.04)†	-0.17(0.51)	1.05(0.54)*	-0.49(0.54)
λ_3	-1.40(3.08)	-2.09(0.88)♥		1.15(1.10)	0.39(1.37)	-4.28(1.54)♥	0.65(1.45)
λ_4	-1.78(2.62)	2.37(0.54)†		0.66(1.10)	-0.61(0.72)	-1.34(0.89)	-0.62(0.73)
λ_5	-1.26(0.74)*	0.51(0.21)♥		1.68(0.89)*	-0.01(0.37)	-1.93(0.73)♥	0.14(0.40)
λ_6	0.01(1.37)	0.19(0.44)		-1.09(1.17)	-0.12(0.05)♥	4.01(1.23)†	-0.75(0.86)

Notes: The level of statistically significant test († for $P<0.01$; ♥ for $P<0.05$ and * for $P<0.10$).
Values in parentheses show robust standard errors)

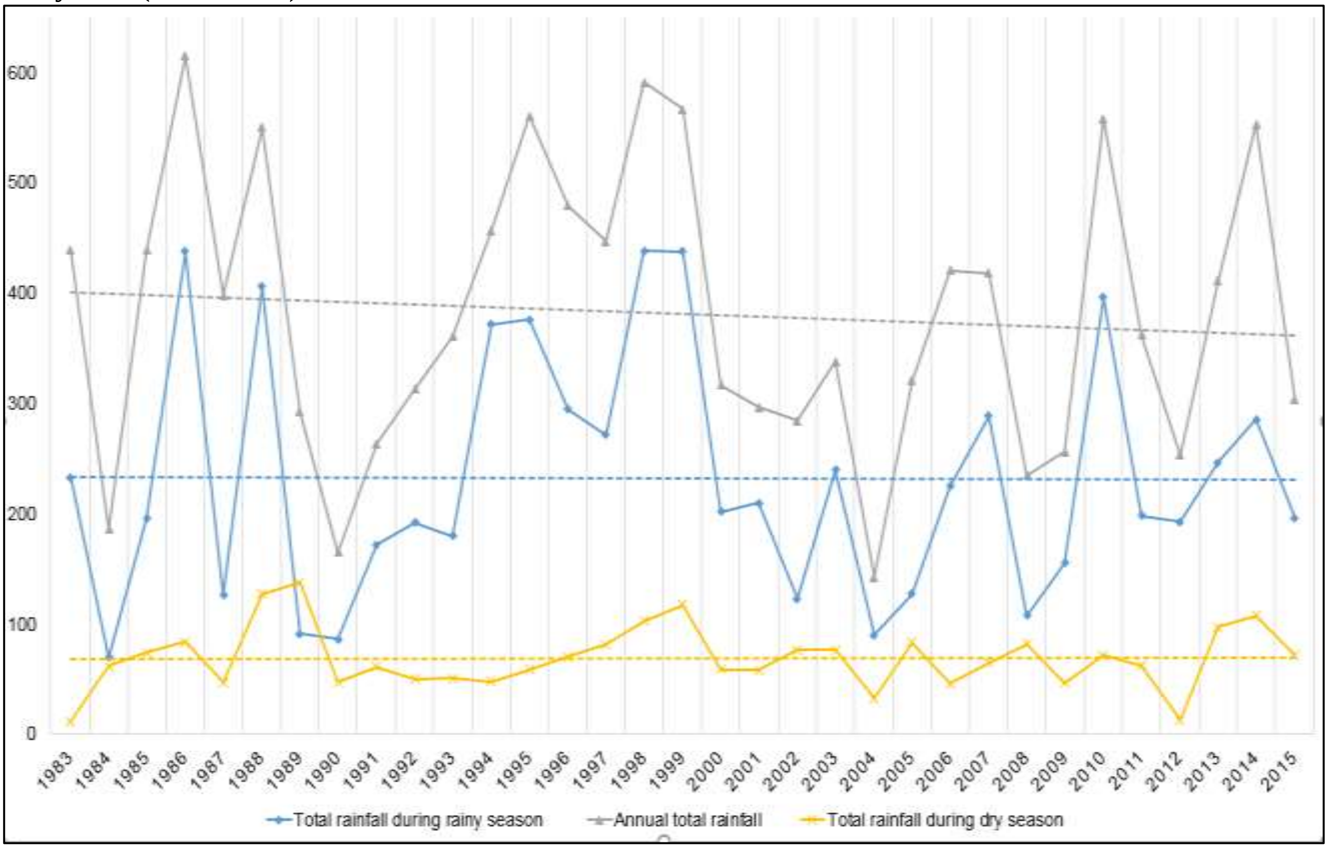
Annexe 7. 1. Types and number of climate change adaptation strategies adopted by smallholder farmers in the area (percent)

Types of adaptation strategies adopted	Freq.	%	Number of adaptation strategies adopted	Freq.	%
Diversifying farming production	231	66	None	83	24
Agroforestry systems	173	49	One strategy	0	0
Use of inorganic inputs	126	36	Two strategies	8	2
Use of organic fertilizers	199	57	Three strategies	22	6
Migration and looking supports	130	37	Four strategies	49	14
Expansion of irrigation and water harvesting schemes	175	50	Five strategies	85	24
			Six strategies	62	18
Soil and water conservation measures	214	61	Seven strategies	41	12
Diversification of livelihood portfolio	114	33	Eight strategies jointly	0	0

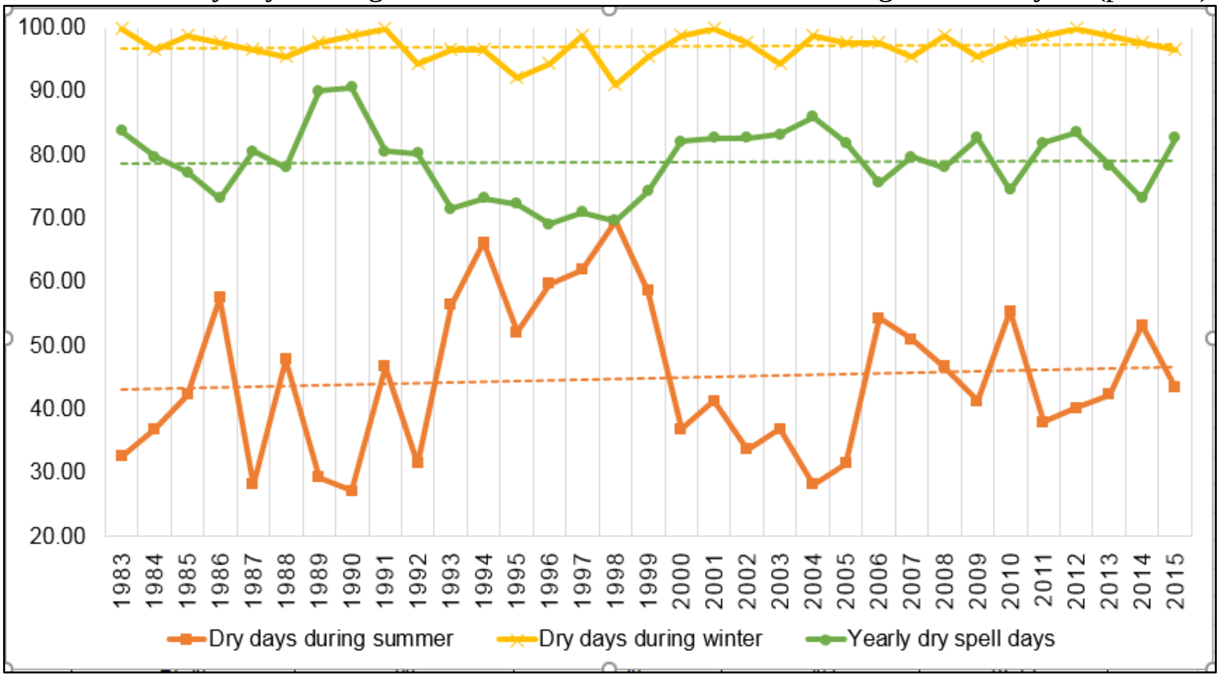
Annexe 7. 2. Trends of mean maximum and minimum temperatures (°C) during dry and wet or rainy seasons in the area (1983-2015)



Annexe 7. 3. Patterns of annual total rainfall (mm) during dry and wet or rainy seasons in the study area (1983-2015)



Annexe 7. 4. Dry days during winter and summer seasons, and during the whole year (percent)



Annexe 7. 5. Contingency coefficient of impacts of climate change across some variables

Impacts of climate change				Adaptation strategies		
Different impacts	Gender	Agroe-cology	Villages	Different strategies	Villages	Agroe cology
Crop failure	0.071 (0.181)	0.046 (0.393)	0.083 (0.791)	Crop-livestock diversification	0.123 (0.373)	0.019 (0.717)
Reduced water availability	0.082 (0.124)	0.051 (0.337)	0.156 (0.122)	Agroforestry systems	0.140 (0.224)	0.035 (0.513)
Animal death and destock	0.093 (0.081)*	0.039 (0.467)	0.272 (0.000)***	Use of inorganic inputs	0.170 (0.063)*	0.061 (0.254)
Students school withdrawal	0.117 (0.027)**	0.015 (0.777)	0.165 (0.081)*	Use of organic fertilizers	0.162 (0.094)*	0.069 (0.198)
Prevalence of human diseases	0.107 (0.045)**	0.044 (0.413)	0.090 (0.720)	Remittance and support	0.136 (0.249)	0.103 (0.053)*
Migration and looking support	0.042 (0.428)	0.016 (0.758)	0.171 (0.061)*	Expansion of irrigation	0.083 (0.788)	0.030 (0.580)
Biodiversity and resource loss	0.053 (0.320)	0.109 (0.039)**	0.122 (0.379)	Soil and water conservation	0.127 (0.332)	0.002 (0.970)
Lack of foods and money	0.062 (0.248)	0.033 (0.542)	0.103 (0.585)	Livelihood portfolio diversity	0.167 (0.075)*	0.050 (0.352)

Notes: values in parenthesis indicates P-value of chi-square test

*, ** and *** represents statistically significant level at 10, 5 and 1%, respectively

Annexe 7. 6. Estimated results of explanatory variables: Coefficients of climate change perception model and relative risk ratio of climate change adaptation model

variables	Perception	The coefficient of relative risk ratio for strategies					
	Coefficient	2	3	4	5	6	7
Gender (male)	-0.01(0.31)	2.13	0.99	0.97	0.91	0.65**	1.74
Experience/age	-0.38(0.28)	1.44	3.55	0.98	7.71**	3.91	10.2**
Family size	-0.04(0.07)	0.56	1.31**	0.99	0.97	0.94	0.97
Occupation	0.04(0.02)**	0.13*	0.46	1.59	0.94	0.71	0.88
Education	-0.11(0.03)***	0.53	0.42**	0.45*	0.77	2.09*	2.11**
Farmland	0.13(0.93)	5.64*	0.03*	0.44	0.96	0.65	2.15
Livestock	-0.05(0.02)**	0.88	1.02	0.85	0.95**	0.82	0.89**
Flat slopes		2.47***	0.85	1.23	1.23	1.35	1.09
Fertile soils		0.39	1.64	1.05**	0.95	2.72**	0.90
Agroecology	-0.02(0.38)	1.44***	0.86	2.04	0.77	1.20	1.04
Market proximity		0.62	0.93*	1.34	0.66***	0.84	0.95**
Road access	0.44(0.30)	8.83	0.82	0.95	1.16	0.43*	0.70***
Farmer school	0.08(0.03)**	1.10	1.81	0.46***	1.35	1.27***	1.60***
Extension service	0.13(0.02)***	0.72	1.06**	0.49	1.15***	0.74	1.20**
Extension confidence		4.73*	0.66	2.01**	0.74	0.58	0.79
Media influence	0.31(0.59)	4.82***	0.10	0.80	0.35	0.36	0.57
Relational capital	0.04(0.02)*	2.71***	0.63	0.67	1.29**	1.06*	1.35**
Group membership	0.04(0.01)***	1.74***	2.59	0.58	0.99	1.32**	1.09**
Technical training	0.07(0.03)**	2.75	2.12**	0.71	2.24*	1.10*	1.78
Attitudes	-0.02(0.14)	1.21	1.19	1.37**	1.08	1.25	0.78
Risk attitude		4.35	1.45	1.40	0.83**	0.96*	0.94**
Special skills		0.91	1.37	0.85	1.22	0.77	0.58
Stress	0.20(0.03)***	0.42	1.03	1.19	1.21	0.84	0.74
Perceived resource	0.32(0.29)	0.23	1.26***	0.76	1.27	1.36	1.16
Credit access		8.47	0.80	1.19***	0.99	0.60	1.14
Inverse Mills Ratio		4.37***	0.07	1.63***	0.07	0.02**	0.75**
Constant	2.52(1.69)	0.01	0.07	3.24	0.01**	0.04	0.04

Notes: ***, ** and * refers to level of significant at 1%, 5% and 10%.

Figures in the parenthesis are robust standard errors of respective variables

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