Behavioural mechanisms and adaptation to climate change

Evidence from lab-in-the-field experiments in the upper Blue-Nile basin

Yalemzewd Molla Nigussie

Thesis committee

Promotor

Prof. Dr E.C. van Ierland
Professor of Environmental Economics and Natural Resources
Wageningen University

Co-promotors

Dr X. Zhu
Associate Professor, Environmental Economics and Natural Resources Group,
Wageningen University

Dr B. Kebede
Associate Professor, School of International Development and Centre for Behavioural and Experimental Social Science (CBESS), University of East Anglia, United Kingdom

Other Members

Prof. Dr G. Antonides, Wageningen University

Prof. Dr H. B. J. Leemans, Wageningen University

Dr M.J.J. Handgraaf, Wageningen University

Dr Consuelo Varela Ortega, Universidad Politécnica de Madrid, Spain

This research was conducted under the auspices of SENSE Graduate School.

Behavioural mechanisms and adaptation to climate change

Evidence from lab-in-the-field experiments in the upper Blue-Nile basin

Yalemzewd Molla Nigussie

Thesis
submitted in fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. Dr A.P.J. Mol,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Wednesday 18 January 2017
at 13:30 pm in the Aula.

Yalemzewd Molla Nigussie

Behavioural mechanisms and adaptation to climate change: Evidence from lab-in-the-field experiments in the upper Blue-Nile basin
143 pages.

PhD Thesis, Wageningen University, Wageningen, NL (2017)
With references, with summary in English

ISBN 978-94-6343-042-5
DOI: http://dx.doi.org/10.18174/400431

To my wife and sons.

Contents

Chapter 1

Introduction

1.1 Climate change adaptation decisions and smallholder farmers

In Sub-Saharan Africa, climate change has a significant negative impact on the agricultural sector causing severe problems for smallholder farmers. Many smallholder farmers in developing countries depend on traditional farming systems which have little resilience to unprecedented shock events caused by climate change. To overcome the welfare losses that may result from climate change, smallholder farmers need to identify the challenges and adjust their farming practices to cope with and adapt to climate change. According to Alston (2013), there are limits and barriers to adaptation to climate change; however, adaptation to climate change is possible with the right technology and adequate funding. According to IPCC (2001), autonomous adaptation is limited by absence of transformation in economic, political, and institutional structures in developing countries. Adaptive capacity is also limited by lack of education, information and training, and the limited options available to smallholder farmers. Planned adaptation is hence considered as an appropriate strategy in tackling climate change impacts. Planned adaptation involves the introduction of institutional arrangements and adaptation measures against climate change impacts for smallholder farmers. The economic literature has so far identified barriers and opportunities to adaptation to climate change. "Barriers are defined as obstacles that can be overcome with concerted effort, creative management, change of thinking, prioritization, and related shifts in resources, land uses, institutions, ..." (Moser and Ekstrom 2010:2). Opportunities for adaptation to climate change, on the other hand, can be facilitated through sustainable economic development practices (Klein et al. 2014). Through sustainable economic development, the barriers to adaptation to climate change can be reduced. Hence, adaptation measures such as the use of improved crop varieties, soil and water conservation, and irrigation technologies are appropriate measures in African countries (Deressa et al. 2011; Juana et al. 2013). Several socioeconomic, environmental and institutional factors are also identified as key drivers influencing farmers' choice of specific adaptation methods (Kabubo-Mariara 2008; Bryan et al. 2009; Deressa et al. 2009). Particularly decision behaviour is identified as a key factor limiting farmers' adaptation to climate change, because it is argued that farmers often have a high time preference or other reasons, such as a lack of information, to postpone adaptation.

Decision behaviour related to adaptation to climate change involves the identification of climate related threats, acquiring information and evaluation of adaptation options, and finally decisions on how to allocate time and resources. Decision behaviour in the economics literature is often explained by rational choice theory (Gary 1976; Sen 2008). Rational choice theory allows preferences (social and individual preferences) to be represented by real-valued utility functions. Optimal decisions are identified by solving a problem of maximizing utility (Axelrod 1984). Furthermore, rational choice assumes that decision makers have complete information of the consequences of actions or, if not, they can attach probabilities to each possible consequence (Watkins 1957; Coleman 1990; Arrow 1994). This theory has faced criticism by pioneer behavioural economists like Simon (1950). Empirical questions about the fundamental assumptions of rational choice theory have been raised for example by Allais (1953), Ellsberg (1961), Kahneman and Tversky (1979), and numerous other behavioural economists. Scepticism towards rational choice theory has triggered the idea of bounded rationality to model economic decision making closer to reality. According to Simon (1957:198), “rationality of individuals’ in decision-making is limited by the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make a decision”. The bounded rationality model attempts to understand decision behaviour under limited information, time and cognitive capacity of the decision maker. It has originally been tested in laboratory experiments using student subjects, and later also in lab-in-the-field, framed, and natural experiments by recruiting subjects actually involved in the matters of interest.

1.2 Individuals’ and social preferences in decisions related to adaptation to climate change

Modelling micro and macro-economic decision behaviour needs an understanding of individual and social preferences (Arrow 1958). In the literature, social preferences have been understood, for instance in terms of altruism and reciprocity, in which both own and others’ materials payoffs carry value for individuals’ utility (e.g. Becker 1974; Smith et al. 1995). The values and norms embedded in commonly accepted rules can also contribute to the sustainability of household level decisions as well as the provisions of public and common goods. In the standard economics of choice one can understand the trade-offs between own and others’ material payoffs. The approach towards understanding social preferences, however, poses a serious aggregation challenge, because social preferences can be individual characteristics or social constructs (Carpenter 2005; Carpenter and Seki 2005). Individual preferences, on the other hand, are determined only by taste factors (Arrow 1958). Other factors like price, income, and availability of goods have no role in individual preferences. Problems related to the public good provision, market mechanism and the environment are mostly addressed through a detailed analysis of both social and individual preferences.

Individual and social preferences constitute a major part in the design of environmental policy. Though the conventional method to address environmental problems is welfare economic analysis, recently the behavioural economics approach is receiving increasing attention (Brekke and Johansson-Stenman 2008). “Contrary to conventional economic theory, behavioural economics highlights that we act in a social context, and that issues such as social approval and status are central motivators of human behaviour” (Brekke and Johansson-Stenman 2008:6). Choices involving time preferences and problems which consider risk preferences can best be explained using behavioural economics. Climate change adaptation involves choices which involve both time and risk preferences and thus can be explained using behavioural economics approaches, because behavioural economics can provide better predictions of human behaviour than traditional approaches (Brekke and Johansson-Stenman 2008). Moreover, identifying an appropriate discount rate is central in understanding the economics of climate change. It is also evident that shocks and circumstances can shape individuals' and social preferences (Reynaud and Couture 2012; Liu 2013). Environmental problems are concrete natural phenomena and can be reflected in social choices. Adaptation to climate change can be considered to take place in a circumstance in which people are adjusting themselves (and perhaps their preferences) at times of shocks and uncertainties. Different people have different views, perspectives, preferences, and attitudes towards risk and time. Some people enjoy a risky situation and others do not; and some have high rates of time preference while others are patient.

In the conventional expected utility theory, utility functions are characterized in three dimensions: reflecting preferences over goods, time and uncertainty (Broome 1991; Andersen et al. 2008). The concept of risk preference has mainly developed based on the von Neumann-Morgenstern axioms (von Neumann-Morgenstern 1944). Expected Utility Theory (EUT), based on these axioms, suggests to use the probability weighted average of all possible levels of utility to select the best action. The criticism brought forward by Allais (1953), Ellsberg (1961) and others triggered the development of Prospect theory (Kahneman and Tversky 1979). Prospect theory identifies loss aversion as one of the drivers why people make decisions deviating from expected utility maximization (Kahneman and Tversky 1979).

Another important topic in utility theory is the time preference of individuals. Frederick et al. (2002) make a distinction between time preference and time discounting that dates back to Böhm-Bawerk (1889) (see Weikard and Zhu 2005). Time preference refers to "the preference for immediate utility over delayed utility, while time discounting is a broad term that encompasses any reason to care less about the future which might be affected by risk and uncertainty" (Frederick 2002:352). The time preference of an individual is determined by his/her personal preferences. Time preferences of individuals' may take into account the utility gained from the decisions and opportunity costs (see Dastjerdi 2009). A discount function is used in economic models to model the different weights placed on rewards accrued at different points in time. Intertemporal choices are most commonly used to derive time preference parameters of discounting functions which capture trade-offs between consumption today and consumption in the future. Hence, we are interested in risk and time preferences driving the behaviour of individuals and we want to see their implications on decisions related to adaptation to climate change.

Decisions are not only influenced by individuals' risk and time preference behaviour. Social preferences embedded in commonly accepted norms and rules can also play an important role in decisions related to cooperative common pool resources (CPRs) management. Cooperative behaviour in the management and use of CPRs depends on social preferences such as altruism, reciprocity, and social norms. Cooperation is central to human beings for the different social interactions like personal relationships, issues related to environmental conservation, political participation, international relations, and the market interactions (Schulman 1978). In addition, it also depends on the presence or absence of common interests between individuals. Absence or presence of common interest in the interaction of individuals can be explained by reciprocity theory of Schulman (1978). Reciprocity theory argues that individuals help other non-related individuals in the hope that they will reciprocate. CPRs are characterized by exhaustion and non excludability. Understanding cooperative behaviour and individuals' interactions are central in the theory of CPRs management.

A useful approach to study the interactions between individuals and their choices of behaviour is game theory (Lynch 1994). In some standard game theory models of social conflict, cooperation is costly from the perspective of an individual and the model predicts that individuals would not cooperate (see Doebeli and Hauert 2005). However, this prediction hinges on the setting. In repeated games cooperation is possible through reciprocity. Following this line of argument, we hypothesize that cooperation is possible in repeated game settings where subjects have equal material incentives and symmetric information. This will be the setting in the CPR game that we study. Lack of cooperation in the management of common pool natural resources is a serious problem in developing countries both for food security and climate change adaptation and mitigations. Though there is an established literature on adaptation to climate change, the possibility of climate mitigation through carbon sinks in common agricultural and forested lands is however over looked in developing countries. Due to high population density, deforestation and land use land cover changes are significantly increasing causing higher greenhouse gas emissions in developing countries. Hence, we need to improve our understanding of the possibility of carbon sequestration and carbon sinks through managing common agricultural and forested lands.

Social networks, groups' interactions and experience sharing depend on social preferences. Through an approach that combines the methods of neuroscience and economics, it is possible to study the brain processes on how human social interaction are made (Fehr and Camerer 2005). According to Fehr and Camerer (2005), the neuroeconomic approach is built on the hope that it will unify mechanistic, mathematical and behavioral measures and constructs. "There is now a large body of experimental evidence indicating that many people exhibit social preferences, that is, their preferred choices are based on a positive or negative concern for the welfare of others, and on what other players believe about them" (Fehr and Camerer 2005:419). Learning from social groups and networks is important for decisions related to adaptation to climate change. Learning from groups (e.g. group of homophilic adopters), and other social networks is a social interaction phenomenon that is embedded in either positive or negative concern for the welfare of others. For instance, people can learn from their social groups and networks either for a negative concern related to envy or a positive concern related to environmental conservation.

1.3 Agroecosystems and climate change adaptation

Climate change requires adaptation of agro-ecosystems in order to deal with the changes in precipitation patterns and temperature. The concept of agroecosystem based adaptation planning is important, because it is believed that extreme climatic events can severely impact smallholder farmers who depend on natural resources and traditional farming. Previous studies and the available data only give us a gross approximation regarding the heterogeneity of small scale agriculture. According to Altieri and Toledo (2005), such an approach, however, has ignored the different strategies that thousands of traditional farmers have used and still use to deal with climatic variability. Design of agricultural related technologies failed to consider agroecosystem characteristics. Scientists have now realized that many smallholder farmers cope with and even prepare for climate change, minimizing crop failure through a series of agro-ecological practices (Altieri and Nicholls 2013). According to Altieri and Nicholls (2013:1), "to rescue traditional management systems, it should be combined with the use of agro-ecosystem based management strategies which may represent the only viable and robust path to increase the productivity, sustainability and resilience of peasant-based agricultural production under predicted climate scenarios". Engaging stakeholders in an inclusive and coordinated manner would also help to come up with an appropriate priority list of adaptation options, looking through the lens of agro-ecosystems.

By bringing different actors together through a broader and participatory approach, it is possible to prioritize possible adaptation options (Few et al. 2006). Stakeholders remain the sources of diverse views and ideas in creating an enabling atmosphere for social planning. The process of analysing stakeholders' decision behaviour follows an approach to determine overall preferences among alternative options (UNFCC 2008). Analysing stakeholders' decision behaviour starts with the selection of an alternative (choice) from sets, followed by prioritization which considers resource scarcity, feasibility and many other criteria, and finally ranking. Previous interventions in the upper Blue-Nile basin either failed to incorporate stakeholders' opinion in planning and implementation or simply followed a blanket approach disregarding agro-ecosystem characteristics and the natural resources base. We put stakeholders' preferences into perspective and rank agricultural and water related adaptation options using relevant and context specific evaluation criteria. Specifically, we want to give due emphasis to the performance of adaptation options under the criterion "agro-ecosystem relevance". Stakeholders' dialogue and opinions would also give us a concluding remark to the findings under behavioural and micro level studies.

Individuals' and social preferences are constructs of the social and environmental systems. Risk and time preferences can, for instance, be influenced by agro-ecosystem characteristics like soil and natural resources bases. Traditional agriculture practices in parts of the developing world are place specific; over time the particular habitat and culture that they are living in can shape farmer's behaviour (Altieri and Nicholls 2013). This in turn would affect one's risk and time preferences. Effects of climate change on agro-ecosystems have received considerable research attention (see Rosenzweig and Hillel 2008; Simane et al.

2012). Rosenzweig and Hillel (2008) underline that maintaining agro-ecosystem balance under climatic stresses can help to achieve sustainable agricultural production; while Simane et al. (2012) stress the importance of agroecosystem based adaptation strategies and propose to scrutinize adaptation strategies from an agro-ecosystem point of view.

1.4 Research objective and research questions

In the context of the development of behavioural economics, this thesis contributes to the economic decision making literature by using experimental approaches to understand smallholder farmers' adaptation decisions to climate change in developing countries, specifically by a case study in Ethiopia. The thesis presents and analyses field experimental data to elicit social and individual preferences in decisions related to adaptation to climate change. The thesis further deals with psychological factors like personality traits. There are many definitions of personality traits available in the literature. The most commonly used is the definition by Johnson (1997:74). According to Johnson (1997:74) "personality traits are defined as consistent patterns of thoughts, feelings, or actions that distinguish people from one another". Learning behaviour through social networks and groups are also examined in conjunction with personality traits. It is evident that one's personality has the potential to determine the tendency for social interaction.

The scope of the thesis is further extended to understand social preferences, and commonly accepted norms and values in the management and use of common pool natural resources. Common pool natural resources, such as forests, water bodies and common agricultural lands are essential in adaptation to climate change for smallholder farmers in developing countries. Finally, the thesis gives a priority rank for a list of adaptation options based on stakeholders' survey and evaluations. Our approach makes the climate adaptation analysis comprehensive and inclusive, because it includes individual, social and stakeholders preferences on decisions related to adaptation to climate change by combining experimental approaches and surveys.

The overall objective of this thesis is to investigate the behavioural mechanisms that are important in smallholder farmers' adaptation decisions to climate change, and to explore the possibility of cooperative management of common pool resources in the context of adaptation to climate change. To this end, the following sets of research questions are addressed:

1. What behavioural factors determine decisions related to adoption of climate innovations in a smallholder economy?
   There is a hypothesis that decisions related to adaptation to climate change are influenced by both risk and time preferences of individuals (Brekke and Johansen-Stenman 2008; Jin et al. 2015). To address this hypothesis, we elicit risk and time preferences of farmers using lab-in-the-field experiments and see their influence on the adoption of climate innovations. There is a growing evience showing that preferences are evolving and changing over time. To test this hypothesis, we

try to understand how risk and time preferences are constructed through social systems and environmental factors like agro-ecosystems.

2. How do personality traits, learning from social networks and groups, and the recursive relationship of technologies determine adaptation to climate change?

   As part of this question, we are keen to study whether personality traits influence one's information acquisition process. We also hypothesise that farm related technologies are related recursively, i.e. the adoption of an option depends sequentially on the adoption of another option. To consider this hypothesis, we look into whether there is a recursive relationship between the adoptions of different farm related technologies. We further study how social interactions through social groups and networks, and occurrence of exogenous shocks contribute to learning behaviour and preferences.

3. Do social norms and ecological variables (favourable and non-favourable climate change) determine cooperative behaviour of smallholder farmers in the climate resilient management and use of common pool natural resources?

   In conjunction with this question, we look into the possibility of carbon sinks and sequestration in developing countries through managing common pool resources and using them as carbon sink. In this context, we also adhere to understand how social norms and social roles are associated.

4. What are the priority ranks of climate adaptation options in the upper Blue-Nile basin?

   As part of this question, we try to identify a set of evaluation criteria and study whether there is a consistent priority ranking by farmers and experts in the upper Blue-Nile basin for the various adaptation options considered.

The research questions are addressed in Chapters 2 to 5 of this thesis.

1.5 Methods

1.5.1 Lab-in-the-field experimental approach

"Economics as viewed by economists, and as viewed by professional methodologists was generally taken to be a non-experimental science" (Bardsley et al. 2010:1). The work of Friedman (1953) inspired behavioural economists on methodological self-perceptions in the last three decades. Friedman (1953:10) proposed that "we can seldom test particular predictions in the social sciences by experiments explicitly designed to eliminate what are judged to be the most important disturbing influences". Moreover, for environmental or natural resource issues (like air pollution or biodiversity protection), and for the use of open and common pool resources, markets are absent making the conventional economic methods problematic. As an alternative to the conventional economic approaches, experimental methods are largely applied in different social contexts.

Experimental data can be generated either in a lab, to test the behaviour of students, or in the field using subjects who are directly involved in the domain of interest. Lab based generated data has importance in terms of having higher response rate and reducing contaminations, however, there is a problem of external validity and drawing inferences. To bridge this gap, experimental economists are increasingly using field experiments (see Harrison and List 2004; Gerber and Green 2012). Field experiments can be classified in three broad categories (List 2014): (i) Artefactual field experiments also known as lab-in-the-field experiments which use participants from the domain of interest (e.g. Fehr and List 2004; Gneezy et al. 2009), (ii) Framed field experiments which are similar to artefactual field experiments except that they reflect the real contexts in the experiment (Harrison and List 2004); and (iii) Natural field experiments take place in the very environment where participants normally undertake a certain task, and subjects may be unaware that they are taking part in an experiment (e.g. Gneezy and List 2006). Field experiments are becoming popular because they help to study relationships that can hardly be gauged through observational data (Banerjee and Duflo 2008) and address many of the limitations in conventional economics. The assumptions in conventional economics have limitations, because it assumes that decision makers have perfect knowledge and mental model in all environmental and market mechanisms (Watkins 1957; Coleman 1990; Arrow 1994). In the thesis we apply lab-in-the-field experiments (Chapters 2 and 4) by drawing participants from smallholder farmers who are struggling with climate change impacts in their daily lives.

1.5.2 Econometric models

This thesis does not limit itself to experimental methods; it also makes use of a variety of econometric models. In Chapter 2 we use a multivariate probit model. The multivariate probit model (MVP) is used to explore whether risk and time preference behaviour and other socioeconomic, natural resources, and demographic characteristics have implications in decisions related to adoption of climate innovations. The multivariate probit model is a generalized probit model used to estimate several correlated binary outcomes jointly. We model three binary climate innovation decision problems: (i) Farm, (ii) Off-farm, and (iii) Institutional related climate innovations. Including variables such as risk and time preference parameters in the MVP regression could cause possible endogeneity, because behavioural variables could in turn depend on socioeconomic and demographic variables. To avoid possible endogeneity problem in the MVP regression, we further use an instrumental variable probit (IVProbit) regression after identifying plausible instrumental variables.

In Chapter 3 we use a trivariate probit model. A trivariate probit model is used to understand interrelated binary decision problems simultaneously by allowing a correlation between unobserved disturbances. Multivariate probit models have limitations to allow correlation among unobserved disturbance. The trivariate probit model is designed to exploit the limitations in multivariate probit models.

According to Terracol (2002), a multivariate normal distribution function can be expressed as the product of sequentially conditioned univariate normal distribution functions, which can be easily and accurately evaluated. The trivariate probit model procedure is written based on the GHK recursive simulator (after Geweke-Hajivassiliou-Keane). As a result, we employ a trivariate probit model procedure that was written by Terracol (2002) to understand whether adoption of high yield crop and livestock varieties (HYV) recursively depends on the adoption of soil and water conservation practices, and irrigation technologies, and to understand research question 2.

1.5.3 MCA

In Chapter 5, we want to come up with a prioritized list of adaptation options in the upper Blue-Nile basin. A stakeholder based multi criteria analysis (MCA) supported by the PROMETHEE II procedure is used to outrank and evaluate list of possible adaptation options. There are more than 40 or more approaches that can be distinguished in the literature (Nijkamp et al. 1990; Janssen and van Herwijnen 2006; Cinelli et al. 2014). The methods encompass from simple to complex rating systems. In common, the methods can give a broad framework for assessing the impact of making a choice, simplifying the decision into its constituent elements (Nijkamp et al. 1990; Nijkamp et al. 1990; Janssen and van Herwijnen 2006; Cinelli et al. 2014). All sorts of MCA methods requires first to develop a complete set of alternative, a tool to assess all relevant performance information for criteria, and a weight showing the relative significance of the criteria to resolve the problem.

1.6 Relevance of the thesis

In each chapter we address a research question that leads to novel contributions to the literature. The chapters are linked to each other in the following way: the empirical feasibility of policy options proposed in Chapter 2 have been tested and verified in Chapter 3. The limitations in Chapters 2 and 3 are addressed in Chapters 4 and 5. Chapters 2 and 3 are limited only to individuals' preferences; hence we extend to understand cooperative behaviour and stakeholders' opinion and evaluations in the process of adaptation to climate change in Chapters 4 and 5. The thesis can, thus, position itself in providing a comprehensive analysis to the adaptation decision to climate change, because it strives to understand micro level behavioural traits, cooperative behaviour (group context) and finally stakeholders' preferences, opinion, and evaluation.

Each chapter in turn contributes to the literature: Chapter 2 contributes to the debate on the relevance of behavioural economics in understanding smallholder farmers' adaptation decision to climate change in developing countries. It complements an understanding by drawing inferences from multiple price elicitation exercises of risk and time preference behaviour using lab-in-the-field experiments. It also opens an opportunity for further study by highlighting the possibility of eliciting risk and time preferences under different contexts including frameworks and heuristics of individuals. The effect of social and environmental constructs on subjects' preferences is also examined, and shows the possibility of climate adaptation through adjusting agro-ecosystem and institutional arrangements.

Chapter 3 contributes to the innovation adoption literature in two ways. First, it attempts to understand smallholder famers' personality using a short personality test, and its effect on information inquiry in the process of adaptation to climate change. Second, it shows the recursive relationship of the different farm related climate adaptation options. Future studies are hence possible to understand these relationships under different context and sample size.

Chapter 4 contributes to the literature by drawing a conclusion to the hypothesis that cooperation is possible in the management and use of commons under repeated game settings. We tried to understand subjects' behaviour under symmetric material incentives and information in a CPR game. It also brings the possibility of drawing subjects from smallholder farmers in the dynamic CPR games which have been confined to lab experiments using student subjects. Important insights are also gained regarding the environmental and social constructs of preferences and social norms. Above and more it shows the possibility of climate mitigation through commons management which is open for further inquiry under different climate scenario and settings.

Chapter 5 contributes to the literature in developing countries by presenting the outranking and prioritization preferences of farmers and experts for a list of climate change adaptation options. It also adds to the literature by highlighting agro-ecosystem relevance as an important criterion in the evaluation of adaptation options. The different adaptation options are compared and ranked. Key evaluation criteria are also identified that allow farmers and experts of developing countries to outrank and compare adaptation options. The insights obtained in the upper Blue-Nile basin are likely to be relevant to other parts of Ethiopia and may also be important to other developing countries.

1.7 Outline of the thesis

The research questions are addressed in Chapters 2 to 5. Chapter 2 looks into the implication of risk and time preference on climate innovation adoption by first generating data using lab-in-the-field experiment and estimating parameters using an EUT approach, and see their implication on decision related to adoption of climate innovations using a multivariate probit model. Chapter 3 considers the problem how personality traits, learning from social groups and networks, and information affect the adoption of farm related adaptation options. A trivariate probit model is used to understand how the different farm level technologies are recursively related, and to look into how learning and personality traits influence adoption of the different farm related technologies. Chapter 4 applies a CPR and a "route choice" experiment to understand how social norms and preferences, and ecological variables play a role in the sustainable management and use of common pool resources, and further facilitate climate change mitigation through a possible carbon sink. Chapter 5 applies an MCA using PROMETHEE II evaluation technique to outrank and prioritize possible adaptation options from agriculture, natural resource management and water related adaptation options. The thesis ends with a general discussion and synthesis of results and a summary of findings in Chapter 6.

Chapter 2

Implications of smallholders' risk and time preferences for climate innovation adoption: Evidence from field experimental games[1]

Abstract: This chapter uses experimental lottery and time preference games combined with socio-economic survey to elicit subjects' decisions to adopt climate innovations in a smallholder economy in Ethiopia. Expected utility theory (EUT) with a constant relative risk aversion (CRRA) specification is used to derive risk aversion parameter and discount rate. The average risk aversion parameter and discount rate found in this chapter are *0.57* and *0.58* respectively. Multivariate Probit (MVP) and instrumental variable probit (ivprobit) models show that risk and time preference parameters significantly determine adoption decision of climate innovations. It is also observed that there is strong correlation between risk behaviour and different agro-ecosystems, and lower correlation between individual discount rate and willingness to invest in adaptation options. Institutional innovations are shown to be important for adaptation to climate change. We argue that credit, market access and expansion of learning systems should be in place to enhance uptake of climate innovations**.**

[1] This chapter is based on:
Nigussie YM, van Ierland EC, Zhu X, Kebede B, Klomp J (2016). Implications of smallholders' risk and time preferences for climate innovation adoption: evidence from field experimental games. *Working paper*

2.1 Introduction

As the threat of climate change is increasing, the concept of mitigation and adaptation to climate change through applying climate innovation and new technologies in low income societies needs more attention. Climate-innovation is "a transformative technology (non-fossil, non-nuclear product, system or service) that can have a significantly *positive effect* on climate change mitigation and adaptation if applied at a specific scale" (WWF 2011:23). The current practices of climate innovations are focused on clean energy technologies; however, climate innovations need not be limited to technological advancement: social and cultural innovations could also help to address the 21st century climate challenges (Suarez et al. 2011). Hence, there is a need to establish innovative technologies, energy systems, services, and institutions that could support communities in the generation of knowledge on mitigation and adaptation to climate change. Technical and institutional innovations addressing the livelihoods of smallholder farmers should be in place so that mitigation and adaptation to climate change would be possible (Chhetri et al. 2012). Simane et al. (2012) proposed community based innovation platforms (CBIPs) as an innovative approach to adapt to climate change in the upper Blue-Nile basin in Ethiopia. CBIPs are institutional arrangements designed to help smallholders realize a climate resilient economy through four integrated pillars: (i) innovation; (ii) natural resources management; (iii) market linkage, and (iv) stakeholders' involvement.

Farmers' behaviour towards adoption of new technology is shaped by socio-economic, physical and behavioural factors (Doerr et al. 2011). Pro-poor institutional arrangements and their working environment (Devereux 2000), market development and access (Schmidt and Tadesse 2014), and climatic factors (Deressa et al. 2008 and 2010) are relevant in shaping smallholders' behaviour. As summarized by Ihli et al. (2013), farmers' economic decisions such as crop selection (Price and Wetzstein 1999), technology adoption (Purvis et al. 1995), conservation (Worku and Friederich 2016), and crop insurance (Hill and Viceisza 2012) depend on many factors including their risk and time preferences. Understanding risk and time preference behaviour would help to devise a strategy that facilitates the adoption of climate innovations. Investment on mitigation and adaptation options involves costs and benefit at present and in the future. Such inter-temporal distribution of costs and benefits influences the investment decision on mitigation and adaptation options (Stern 2007), which in turn is affected by individual rates of time preferences (Butt et al. 2005).

Therefore, the objective of this chapter is to improve our understanding of how behavioural factors contribute to smallholder's decisions on adapting to climate change through adoption of climate innovations. We focus on farmers in the upper Blue-Nile basin in Ethiopia and derive individual level risk aversion parameters and discount rates using field experimental games. We, therefore, contribute to the literature by studying behavioural factors such as risk and time preferences in an experimental setting and analysing how behavioural, climatic, institutional and socio-economic factors affect smallholder's adaptation decisions through adoption of climate innovations.

The chapter is organized as follows. Section 2.2 presents the theoretical background. Section 2.3 covers the methods and the theoretical and empirical model. Section 2.4 presents the discussion on experimental and econometric results. Lastly, in Section 2.5 we present the conclusions.

2.2 Theoretical background

2.2.1 Risk attitudes and measurement

Starting with Binswanger (1980, 1981, 1982), many experimental studies were devoted to assess risk attitudes in developing countries (e.g. Barr 2003; Humphrey and Verschoor 2004; Harrison et al. 2010; Doerr et al. 2011; Ihli et al. 2013; Liebenehm and Waibel 2014). Risk is often measured through individual's risk perception. Recently, application of experimental studies introduced lottery choices which are either framed as a single choice among a set of predetermined prospects (Binswanger 1981; Eckel and Grossman 2008) or as an investment decision (Charness and Gneezy 2010). Alternatively, subjects might be asked to make multiple decisions between risky and non-risky pairs or sets of lotteries that reflect different risk structures (Holt and Laury 2002).

Previous studies which dealt with risk behaviour following individuals' risk perception include Holden et al. (1998), Cardenas and Carpenter (2008), Barr and Genicot (2008), Yesuf (2008), and Bezabih and Sarr (2012). Though, experimental elicitations of farmers' risk preferences in the context of developing countries were rare (Pennings and Smidts 2003; Reynaud and Couture 2012), currently there is a growing literature in the application of lottery games to elicit risk preferences (e.g. Kebede and Zizzo 2015; Doerr et al. 2011; Charness and Viceisza 2012; Ihli et al. 2013; Liebenehm and Waibel 2014).

Estimation of risk preferences is based on various procedures. The studies by Harless and Camerer (1994) and Hey and Orme (1994) applied econometric methods to estimate decision models from observed behaviour. Expected utility theory (EUT) (Von Neumann and Morgenstern 1944) is widely used to estimate risk parameter of individuals based on data generated in field experiments. EUT studies on risk preferences implicitly assume that risk aversion comes solely from the concavity of a subject's utility function (Binswanger 1980; Brick et al. 2012). This theory, however, has faced criticism from Kahneman and Tversky (1979 and 1992). According to Kahneman and Tversky decisions made by subjects are based on the potential value of losses and gains rather than the final outcome, i.e., subjects evaluate each choice independently of the other choice opportunities in an experiment. Recent studies by Cox et al. (2014) and Harrison and Swarthout (2014)[2], however, refuted this proposition. Cox et al. (2014: 29), argued that "if it were true that subjects isolate each individual decision in multiple decision experiments, then choice of payoff mechanism would be an unimportant detail". Empirically, Cox et al. (2014) found that there are large

[2] Harrison and Swarthout (2014) find that "preferences estimated with a model that assumes violations of the Independence axiom are significantly affected when one elicits choices with procedures that require the independence assumption, as compared to choices elicited with procedures that do not require the assumption".

differences across mechanisms in subjects' revealed risk preferences, showing a clear violation of isolation of each decision task i.e., a violation of the independence axiom proposed by Kahneman and Tversky (1979 and 1992).

2.2.2 Time preference and individual discount rate

In neoclassical economics, the rate of time preference (RTP) is usually taken as a parameter in an individual's utility function to capture the trade-off between consumption at present and in the future. It is also the underlying determinant of the real rate of interest (Laubach and Williams 2003). The rate of return on investment is generally seen as a return on capital, with the real rate of interest equal to the marginal product of capital at any point in time. Consumers, who are facing a choice between consumption and saving respond to the difference between the market interest rate and their own subjective rate of time preference; which is a reflection of subjective time preferences (Harrison et al. 2002). Studies on the rate of time preference have given much emphasis on investment and consumption theories; an association with climate change has rarely been addressed.

Studies on RTP use various methods: for instance, hypothetical questions (Holden et al.1998), field experiments (Coller and Williams 1999) and large scale elicitations (D'Exelle et al. 2012). Multiple price elicitation technique is the most recent approach where subjects are faced with choices involving different discount rates. Related studies following the multiple price elicitation technique include the work of Liu (2013), Frederick et al. (2002) and Harrison et al. (2002).

There is a growing literature on estimating risk and time preference jointly. Liebenehm and Waibel (2014) for small scale cattle farmers in West Africa; Andersen et al. (2006) for the general public in Denmark; Nielsen (2001) for a study on Madagascar ; and Tanaka et al. (2010) for Vietnamese villages. Joint elicitation helps to avoid over estimation due to the default assumption of risk neutrality. The discount rates defined in terms of temporally dated utility with constant relative risk aversion (CRRA) avoids this problem (Andersen et al. 2006). Parameterization often follows the classic estimation procedure of exponential discounting (with a constant discount rate) or hyperbolic discounting (with a discount rate decreasing with time) (Frederick et al. 2002).

2.2.3 Risk attitudes, time preference and climate change mitigation and adaptation

There is extensive literature that identifies the impact of climate change on agriculture (e.g., Mendelsohn et al. 1994; Deressa et al. 2008 and 2010). These studies classify adaptation options at the farm, off-farm and institutional levels (Bradshaw et al. 2004; Deressa et al. 2008; Simane et al. 2012). Uptake of innovations to deal with climate change impacts is limited by many factors including economic interests, social, ecological values and norms, awareness, and self-perception (Grothmann and Patt 2005). Deprived farmers either lack money to invest in new technologies, or may have already suffered economic difficulties before any climate catastrophe (McLeman et al. 2008). Since climate change poses uncertainty on the outcomes of innovations, risk behaviour is an important determinant of adoption. Climate mitigation and adaptation investment costs can also be explained through individuals' rate of time preference (Harrison et al. 2002; Brekke and Johansson-Stenman 2008) as it involves an investment today and a return sometime in the future. The discount rate employed in the benefit and cost calculations over time can be thought of as the opportunity cost of investment, but it can also be seen as the relative value of consumption over time (Anthoff et al. 2009). Therefore, an individual's discount rate is an important parameter for individual's decision to support a public good (Kovacs and Larson 2008). Although many empirical studies on time preferences and risk behaviour are available in the literature (e.g. Harrison et al. 2002 and 2004; Andersen et al. 2006; Yesuf 2008), detailed studies that link these issues to climate adaptation decisions are still lacking.

2.3 Methodology

We used a lottery game to estimate the risk attitude of individual farmers; and a time preference game to estimate individual discount rates. We played the games on a sample of 280 individuals in the upper Blue-Nile basin in Ethiopia from November 2013 to January 2014. Randomly selected subjects were invited to take part in the games. A socioeconomic survey was conducted after the game sessions. We estimated the risk aversion parameter and individual discount rate following a constant relative risk aversion (CRRA) utility specification. We further study how these behavioural factors influence climate innovation adoption using a multivariate Probit (MVP), and instrumental variable Probit (*ivprobit*) model. An *ivprobit* model is estimated for a possible endogeneity and to identify whether MVP model is more suitable than single equation *ivprobit* model.

2.3.1 The lottery game

2.3.1.1 Experimental design and procedure

We used stratified random sampling following Simane et al. (2012) agro-ecosystem classification taking an agro-ecosystem as the largest first strata. However, without compromising the stratification, we selected two agro-ecosystems based on innovation uptake and future climate mitigation and adaptation potentials following the recommendations of Simane et al. (2012). The second stratum was the random selection of two districts from each agro-ecosystem followed by random selection of two *Kebeles*[3] from each district. Caution was taken to avoid communication and experience sharing through common market places among sampled *Kebeles*. Accordingly, a total of eight *Kebeles* from each district and 35 subjects from each *Kebele* were selected.

3 Kebele is the smallest administrative unit in Ethiopia.

The games were conducted in a nearby farmers' training centre. Before conducting the games, subjects were informed through development agents for a possible 2.0-2.5-hour experimental session and the expected prizes and participation fee for showing up, in line with the literature on incentive effects (Holt and Laury 2002; Ihli et al. 2013). Based on Ihli et al. (2013) we also modified the lottery task by changing the monetary values and probabilities to different colours of balls (see Appendix 2.1). Before playing the game, an experimental protocol (see Appendix 2.3) was read to participants and demonstrations were shown. Finally, subjects played one of the choices for real by randomly drawing a rolled paper (written 1-10) from a basket and received the prize based on their choice of A or B. In each game session, a maximum of 8 subjects and four assistant experimenters took part. After the gaming session, they were guided to leave in different directions to avoid possible communication. We made an appointment with selected individuals to conduct a further focus group discussion.

The experimental design follows the multiple price elicitation exercises of Holt and Laury (2002). Charness and Viceisza (2012) and Ihli et al. (2013) applied the method in Senegal and Uganda. The use of visual aids is recommended to make the lottery choice easier under the present lower literacy level of African smallholders. During the field experiment subjects were, therefore, supported with visual aids, and received real lottery payments.

In the succession of pairs of binary lotteries, each pair is composed of a less risky lottery (option A) and a riskier lottery (option B). Subjects are asked to pick one lottery in each row (see Appendix 2.1). In the first row, the expected value of lottery A (10.2) is higher than lottery B (3.3); however, as one proceeds down the rows, the expected value of lottery B increases more quickly than lottery A. Subjects who are very risk-averse may never switch from choosing lottery A, while subjects who are very risk-seeking, may never switch from choosing the risky lottery B. Risk neutral subjects, on the other hand, would switch when lottery B overtakes lottery A in terms of the expected value (sixth row).

In a lottery game, subjects would behave as risk averse, risk neutral, risk loving, or show inconsistent behaviour due to multiple switching. Including inconsistently behaving subjects in the estimation would be problematic. This can, however, be handled by introducing an "indifference" option during the choice task (Harrison et al. 2002; Andersen et al. 2008), or treated as indicative of confusion, in which case the data can be removed from the analysis. In our case, a small number of subjects (13%) switched more than once and we opted to drop these observations. Parameter estimation and inference require a unique switching point to rationalize under standard assumptions on preferences (Charness et al. 2013).

2.3. 1.2 Estimation procedure

We assumed that smallholder farmers behave in accordance with CRRA preferences. Following Anderson *et al.* (2006), we assumed that the utility of income from outcome $j \in \{1,2\}$ in lottery $k \in \{left(A), right(B)\}$ that individual $i \in \{1, \dots, n\}$ gets, denoted by $Y_i^{k,j}$ is defined as:

$$U(Y_i^{k,j}) = \frac{Y_i^{k,j^{(1-r^{EUT})}}}{1-r^{EUT}}, \text{ for } r^{EUT} \neq 1, \tag{2.1}$$

where $U(Y_i^{k,j})$ is the utility function of individual *i*, and $r^{EUT}$is the risk aversion parameter, with r^{EUT} = 0 for risk neutrality, r^{EUT}0 for risk aversion; and r_i^{EUT}< 0 for risk seeking behaviour. In our lottery game each lottery k in row m ($m \in (1,2, \dots 10)$) has two possible outcomes, each with probability p_m^j. For a binary lottery, farmers are assumed to obtain the following expected utility for each *m (*see Harrison et al. 2002 and Anderson et al. 2006):

$$EU_{i,m}^k = \sum_{j=1}^2 p_m^j * U(Y_i^{k,j}), \tag{2.2}$$

and to choose either option A or option B according to the value of the following latent index or choice rule:

$$\Delta EU_{i,m} = EU_{i,m}^L - EU_{i,m}^R + \mu_i, \tag{2.3}$$

where $\Delta EU_{i,m}$ is the difference between the expected utility of option A and option B, μ_i denotes the errors made by subject i due to noises in the process of calculating the expected utilities. It is assumed to be normally distributed and uncorrelated across decision rows,

$$\mu_i \sim N(0, \sigma_{\mu_i}^2). \tag{2.4}$$

In studies by Loomes (2005), Galarza (2009) and Wilcox (2011), it is indicated that different types of error specifications have profound implication on estimates of the risk aversion parameter. However, a recent study by Drichoutis and Lusk (2014) has compared the different types of errors in EUT and rank dependent utility (RDU) models and concluded that EUT is least affected by the selection of error specification. The estimation, thus, follows by transforming the latent index in equation (2.3) to a Probit function. The probability that an individual chooses lottery left (option A) over lottery right (option B) is estimated by the following Probit function:

$$\Pr(EU_{i,m}^L - EU_{i,m}^R + \mu_i > 0) = \text{pr}\left(\frac{\mu_i}{\sigma_{\mu_i}} > -\frac{EU_{i,m}^L - EU_{i,m}^R}{\sigma_{\mu_i}}\right)$$

$$= 1 - \Phi\left(-\frac{EU_{i,m}^L - EU_{i,m}^R}{\sigma_{\mu_i}}\right) = \Phi\left(\frac{EU_{i,m}^L - EU_{i,m}^R}{\sigma_{\mu_i}}\right), \tag{2.5}$$

where σ_{μ_i} is the standard error of the stochastic term μ_i, giving rise to the stochastic expected utility indicator:

$$\Delta SEU_{i,m} = \left(\frac{EU_{i,m}^{L} - EU_{i,m}^{R}}{\sigma_{\mu_i}}\right). \tag{2.6}$$

$\Phi(\Delta SEU_{i,m})$ denotes the probability of choosing lottery A, and $1 - \Phi(\Delta SEU_{i,m})$ represents the probability of choosing lottery B. Subject specific characteristics may change the average risk aversion parameter, and hence we include individual characteristics X_i (see Galarza 2009) in the analysis. Accordingly, the log likelihood function for individual *i* can be written as:

$$L_i^{EUT}\left(r^{EUT}, \sigma_{\mu_i}, I_i^m, X_i\right) = \prod_{m=1}^{10}\left[\Phi(\Delta SEU_{i,m})^{I_{i,m}}\right] * \Phi\left[-(\Delta SEU_{i,m})^{1-I_{i,m}}\right], \tag{2.7}$$

where I_i^m is an indicator variable of the choice made by individual i in row $m \in (1,2, \dots 10)$, which takes the value of 1 when lottery A is chosen in row m, and 0 otherwise. X_i is a vector of individual $i's$ characteristics.

Primarily, we assumed homogeneity among subjects and only include the wealth of individuals measured by the monetary value of fixed and variable assets. In later stages, we consider heterogeneity among subjects by including vector of households' characteristics (X_i). Subject specific risk aversion parameters ($\hat{r}_i$) can then be predicted as a linear function of the covariates of X_i (in our case, age, sex and education level) and the average risk aversion parameter (r^{EUT}) estimated under EUT. Accordingly, individual level risk aversion parameters ($\hat{r}_i$) can be derived following equation (2.8),

$$\hat{r}_i = r^{EUT} + \hat{r}_{age} * age_i + \hat{r}_{sex} * sex_i + \hat{r}_{edu} * education_i \quad , \tag{2.8}$$

where, $\hat{r}_{age}$, $\hat{r}_{sex}$, and $\hat{r}_{edu}$ are risk aversion parameters due to heterogeneity in age, sex and education level, respectively.

2.3.2 Time preference game

2.3.2.1 Experimental design and procedure

The experimental procedure for discount rates follows the procedures for risk games explained in Section 2.3.1. In the multiple elicitation approach, we present subjects with 15 choices having a payment of ETB 200 to be paid at the end of one month and a payment $ETB\ 200$ plus interest payments R ($ETB\ 200 + R$) at the end of month 7 (Appendix 2.1) (Anderson et al. 2008; Tanaka et al. 2010; Liebenehm and Waibel 2014).

2.3.2.2 Estimation procedure of the individual discount rate

A similar specification with the risk aversion parameter is employed (see Andersen et al. 2006). To estimate the discount rate, the curvature of the utility function is determined by the risk preference of individuals (r) and replacing the expected utility by the present value of the two outcomes (option A and option B). Including the risk preference (r) provides valuable information about the curvature of the utility function, otherwise, assuming risk neutrality results in an over estimation of the discounting factor (see Andersen et al. 2006). Thus, the present value of the utility of payments at the end of the first month (Y_t) at time t is

$$PV_A = U(Y_t), \tag{2.9}$$

and the present value of the utility of payments made at time $t + \tau$ ($Y_{t+\tau}$) is

$$PV_B = \frac{1}{(1+\delta)^{\tau}} * U(Y_{t+\tau}), \tag{2.10}$$

where the subscripts A and B refer to the options A and B in the choice tasks. The following equations show the parametric form for the utility function in (2.9) and (2.10), and the CRRA form is given in equation (2.11) and (2.12):

$$PV_A = Y_t^{1-r} /(1-r) \text{ and} \tag{2.11}$$

$$PV_B = \left[\frac{1}{(1+\delta)^{\tau}}\right] * [Y_{t+\tau}^{1-r} /(1-r)] \tag{2.12}$$

The index of the difference between these two present values conditional on the discount rate (δ) and r (the risk aversion parameter assuming a CRRA specification) can then be defined as:

$$\Delta PV = PV_A{}^{1/\nu} / (PV_B{}^{1/\nu} + PV_A^{1/\nu}), \tag{2.13}$$

where ν denotes the errors made by subject i due to noises in the choice of a discount rate which is implicit in the choice task. The conditional log-likelihood is conditional on the EUT, CRRA and exponential discounting specifications being true:

$$lnL^{IDR}(r, \delta, \nu;\ Z, \boldsymbol{X}) = \sum[\ (ln\,(\Delta PV)\ * Z_i = 1)\ +\ (ln\,(\Delta PV)\ * Z_i = 0)\ ]\ , \tag{2.14}$$

where $Z_i = 1$ denotes the choice of the right (option B) and $Z_i = 0$ the left (option A) in discount rate task i, and $\boldsymbol{X}$ is a vector of individual characteristics which would help us to derive individual level discount rates as shown in equation (2.8).

2.3.3 Climate innovation adoption model

2.3.3.1 Multivariate Probit model

Climate related innovations in this chapter include farm related climate innovations (*FARM*), off-farm climate innovations (*OFFFARM*) and institutional climate innovations (*INSTITUTION*). *FARM* includes technologies like water and soil conservation, improved varieties, fertilizer, and modern farming technologies (Simane *et al*., 2012). In the *OFFFARM*, we include bee hiving, bamboo works, cattle fattening through cooperatives, petty trading, fodder, agro-business, renting of some agricultural utilities and forestry programs[4]. *INSTITUTION,* on the other hand, includes memberships to innovation platforms introduced by government, non-government and private sectors which help smallholders adapt to climate change.

To understand how risk, individual rate of time preference and other socioeconomic and demographic factors influence innovation adoption decisions, we follow Greene (2000) and use a Multivariate Probit (MVP) model. The MVP approach can simultaneously model the influence of the set of explanatory variables on each of the different practices, while allowing for the potential correlation

[4] A subject is said to be an adopter of any given technology if at least he/she adopts one of the list.

between unobserved disturbances as well as the relationship between the adoptions of different practices (Belderbos *et al.* 2004). Hence, a farm household (*i*) is facing a decision on whether to adopt climate innovations (*j*), given subject's risk aversion parameters ($\hat{r}_i$), individual discount rate (δ_i), observed characteristics of households explained by (x'), and unobserved characteristics (ε_{ij}). The MVP econometric approach has *j* binary dependent variables Y_{ij} such that:

$$Y_{ij} = 1 \; if x'\beta_i + \varepsilon_{ij} > 0, i = 1, \ldots, n; \; j = 1, 2,3.$$
$$= 0, \; otherwise, \quad (2.15)$$

where x' is a vector of explanatory variables, $\beta_i' s$ are vectors of parameters, and ε_{ij} are random error terms. The error terms are assumed to be normally distributed with zero means, unitary variance and J×J contemporaneous correlation matrix *R*=ρ_{ij} (see Belderbos et al. 2004), with density function $\psi(\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon_{i3}, R)$. Thus, the likelihood that each observation contributes is the *J*-variant standard normal probability:

$$\Pr(y_{i1},\ldots, y_{ij} \mid x) = \int_{-\infty}^{(2y_{i1}-1)x'\beta_j} \ldots \times \int^{(2y_{ij}-1)x'\beta_j} \psi(\varepsilon_{i1},\ldots, \varepsilon_{ij} \mathbf{Z'}\,\mathbf{RZ}) d\varepsilon_{ij} \ldots d\varepsilon_{i1} \quad (2.16)$$

2.3.3.2 Instrumental Variable (IV) method

Endogeneity is considered as a problem in the estimation procedure when behavioural measures are included with adoption decision. It is possible that unobservable characteristics that affect adoption of a technology will also influence risk aversion and rate of time preference. The presence of such endogeneity would result in a misleading conclusion on the significance level and direction of relationships. The solution is to explicitly account for such endogeneity by using an instrumental regression technique that assumes a joint normal error distribution (Di Falco et al. 2011).

Accordingly, the instrumental variable estimation follows a first stage estimation of the OLS regression of individual risk aversion parameter ($\hat{r}_i$) and discount factor (δ_i) on a set instruments and explanatory variablesX_i. Hence,

$$\hat{r}_i = \beta \mathrm{X}_i + \mu_i$$
$$\delta_i = \alpha \mathrm{X}_i + \mathrm{V}_i, \quad (2.17)$$

where μ_i and $\mathrm{V_i}$ are random error terms in the first stage OLS regression of endogenous variables. The use of OLS regression guarantees the presence of consistent estimates that are uncorrelated with the residuals (Greene 2008). Combining different estimation methods in the first and second stages is difficult unless a theoretical foundation justifies their use (see Newey 1987). Accordingly, our outcome variable based on a Probit model can be explained as:

$$Y_{ij} = 1 \; if x'\beta_i + \gamma \hat{r}_i + \rho \delta_i + \varepsilon_{ij} > 0$$
$$= 0, \; otherwise, \quad (2.18)$$

where Y_{ij} is the observed variable indicating the adoption decision. The impact of $\hat{r}_i$ and δ_i on the outcome variable is measured by the estimates of the parameter in a two-stage instrumental probit (*ivprobit*) regression by the parameters γ and ρ. The *ivprobit* model for FARM, OFFFARM and INSTITUTION would also help us to test the hypothesis on whether decisions are made jointly using the MVP model.

The identification of instruments was a difficult task. However, to reduce the possible causal relationship, we tried to find variables that are much more collinear to risk and time preference than adoption decision variables. Variables to be a strong instrument should be collinear (instrument relevance) with risk and time preference but non-collinear (instrument exogeniety) to adoption decision. Accordingly, access to health services, access to school in a village, proximate to financial institution and loss of farm animals are considered as instruments. Health education and access has been identified as a tool that would reduce risky undertakings related to health (Jackson et al. 2012). Access to schools is also expected to affect behaviour in villages which are closer to schools and main roads who would have better behavioural make up than those who are in distant. Besides, farmers with access to financial institution, have a better attitude towards saving and borrowing. Since, behaviour can be shaped over time, and it is a cumulative effect of environment and society, the presence of financial institutions shapes risk and RTP over time more than adoption decision. Finally, animals are main assets for farmers, a loss of these vital assets could negatively affect farmers risk and time preference behaviour.

2.4 Findings and discussions

2.4.1 Risk estimation results

The risk parameter estimate of the sample assuming that choices are entirely explained by EUT and the assumption of CRRA preferences being true is r^{EUT}= 0.577, with a relatively small standard deviation of the random mistakes σ_{μ_i} =0.015 (see Appendix 2.2). Including selected individual characteristics as covariance of the structural model, we find that those households with access to credit have a coefficient of risk aversion parameter close to zero (at *p-values=0.014*), indicating that access to credit reduces risk aversion behaviour (see in Appendix 2.2). A summary of the estimated risk parameters is given in Figure 2.1 showing that majority of individuals (85%) are under the risk averse category.

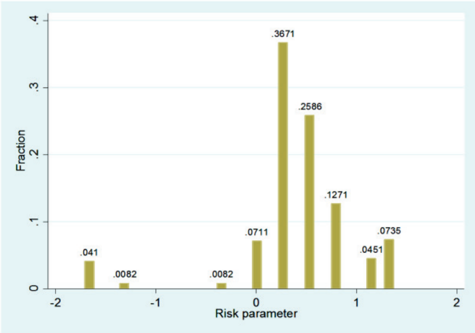


Figure 2.1. Distribution of risk aversion parameters

Source: own calculation.

We can derive subject specific risk parameters using equation (2.8). It is also possible to calculate individual level risk aversion parameter at the switching point during the lottery task. However, due to inclusion of the average risk aversion parameter (r^{EUT}) in equation (2.8), individual level risk aversion parameters differ from the ones calculated at the switching points (See Appendix 2.2). Thus, we opted to report the values based on switching, as they are showing actual choices between risk categories.

We also considered how shock experience (drought and flood experience) and location dummies (representing differences in agro-ecosystems) are correlated with risk behavior (see Appendix 2.2). The variation in correlation coefficient could have been from differences in endowment of natural resources, soil type, shock experience and accessibility to public infrastructure (Simane et al. 2012). The correlation coefficient between risk loving behavior and location dummy "Machakil" is strong *(0.317*) compared to others. This implies that farmers in Machakil may be more risk loving than other farmers in our study; the district has better access to markets and credit facilities compared to the other districts.

2.4.2 Individual discount rate estimation results

The maximum likelihood estimation result for the discount rate is *58% (δ=0.58)* and the risk aversion parameter in estimating the discount rate is 13.7% (r=0.137) (see Appendix 2.2). Andersen et al. (2006) have shown that it is necessary to estimate time preferences jointly with risk preferences as it provides valuable information about the curvature of the utility function in eliciting RTP. The standard error μ_i^{δ} is found to be ($\sigma_{\mu_i}^{\delta}$=*0.080*), showing that randomness in choices and the extent of noise is very small. From the follow up focus group discussion, we understand that subjects who preferred option A throughout the game have better awareness about alternative investment options like cash crops. On the other hand, those who preferred option B have taken training on saving and credit. In order to characterize elicited discounting behaviour, Figure 2.2 shows the distribution of individual discount rates (δ_i) estimated at the switching point. With the same reasoning as individual level risk aversion parameters, we preferred to derive individual discount rates at the switching point. The majority of subjects' (50%) have a discount rate (δ) above the median (22%). Under such high discount rates, it would be difficult to find climate innovation investment options that generate positive net present values.

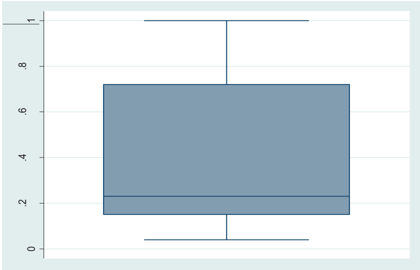


Figure 2.2. Box plot for the distribution of individual level discount rates in the case study

Source: own calculation.

To see how δ_i and the willingness to invest in some mitigation and adaptation practices, we derived the correlation coefficients between δ_i and selected adaptation measures (see Appendix 2.2). The result shows a weak correlation between individual level discount rate and willingness to invest in adaptation options. This is in line with the findings from focus group discussions and the study of Yesuf (2004) for Ethiopia.

2.4.3 Adoption decision, risk aversion parameter and individual discount rate

To understand the effect of risk behaviour, individual discount rate and other socioeconomic variables, we employed an MVP model. Table 1 presents the results of the MVP model. The descriptive statistics of the independent variables are reported in Appendix 2.2. Table 2.1 shows the estimated coefficients, the level of significance and the direction of influence of variables. The likelihood ratio test statistic ($x^2(3)$ =78.42, *Prob*> χ2 = 0.000), tells us that parametric coefficients are different from zero, i.e., rejecting the null hypothesis on the restricted model. The regression results of the MVP model are summarized below.

Table 2.1. Multivariate probit model estimation results with standard errors and coefficients

Variables	FARM		NONFARM		INSTITUTION	
	Coeff	SE	Coeff	SE	Coeff	SE
PRODUC	0.002	0.012	0.036	0.013*	0.033	0.012*
DISCRATE-DROUGHT	1.476	0.808***	-0.414	0.783	0.866	0.891
RISK-DROUGHT	2.117	0.635*	-1.28	0.609**	0.117	0.533
FAMSIZE	0.152	0.059*	0.086	0.054	0.084	0.057
FARMSIZE	-0.209	0.308	-0.312	0.338	0.797	0.340**
CREDI	0.033	0.235	0.506	0.243**	0.442	0.242***
EXTHYV	0.804	0.285*	0.552	0.348	0.034	0.269
EXTCH	-0.156	0.344	0.948	0.378*	-0.682	0.316**
EXTSOILC	0.184	0.407	-0.611	0.406	0.196	0.404
DROUGHT	1.249	0.670**	0.508	0.599	-0.728	0.586
FLOOD	1.055	0.672	-1.162	1.131	5.368	0.516*
TEMP	0.219	0.074*	-0.531	0.079*	0.008	0.071
RAIN	-0.039	0.014*	0.041	0.012*	-0.008	0.012
LIVSIZE	0.002	0.012	0.002	0.011***	-0.014	0.001
HSEX	0.402	0.317	-0.107	0.427	0.112	0.359
AGEH	-1.626	0.730**	-0.001	0.013	0.013	0.011
EDUH	2.123	0.615*	-0.189	0.262	0.297	0.218
DISINPUT	0.014	0.007**	0.022	0.009**	-0.003	0.006
MARKACESS	-0.006	0.005	0.004	0.004	0.015	0.004*
DISCOUNTRATE ($\widehat{\delta_i}$)	-1.675	0.744**	-0.017	0.725	-0.46	0.832
RISKAVERSION($\widehat{r_i}$)	-2.121	0.635*	1.299	0.610**	-0.081	0.534
_CONS	1.018	1.988	2.417	2.508	-8.48	2.339*
Likelihood ratio test χ2 (3)=78.42 *Prob*> χ2= 0.0000						
Sample size= 245	Wald χ2(63) =	1779.7		*Prob*> χ2= .0000		

Note: *,**,*** denotes p < 0.01, p <0.05, and p <0.10, respectively.
Source: own calculation.

Demographic and socioeconomic variables:

In this category of variables, sex of household head (*AGEH*), family size (*FAMSIZE)* and education level (*EDUH*) of head of the household are found to relate positively and significantly with adoption of farm related measures. This is consistent with the findings of Teklewold *et al*. (2006). On the other hand, we find that farm size (*FARMSIZE)* and adoption of institutional innovation is found to be positively related. Households with larger farm size might tend to participate in institutions which help them improve agricultural productivity.

Climate shocks and stresses:

Climate related shocks and stresses were measured by temperature, precipitation, and experience of drought and flooding. Change in temperature and precipitation at village level was approximated by taking averages for last ten years (2003-2012) at district level. As a result, we find that the change in temperature (*TEMP*) and change in precipitation patterns (*RAIN*) are found to relate negatively and positively respectively with the adoption of farm related and off-farm related climate innovations. Climate change related shock indicator variable (*DROUGHT*) measured by frequency of occurrence is found to influence adoption of farm related innovations positively. Flood (*FLOOD*) occurrence, on the other hand, is positively related to the adoption of institutional innovations. These findings are consistent with studies by Deressa et al. (2008 and 2010)

Social and physical variables:

Distance to input market (*DISINPUT*) and market access *(MARKACESS*) both measured by the time it takes to reach an input market and all product markets are among physical variables used. *DISINPUT* is found to be significant in determining adoption of farm and off-farm climate innovations. *MARKACESS* is significant in determining institutional innovations. Credit is another capital indicator variable measured by the amount borrowed (*CREDI*). It is found to influence off-farm and institutional innovations adoption positively and significantly. This suggests that rural infrastructure expansion is at the centre of climate adaptation programs. Access to markets and credit provide opportunities to farmers which enable them to acquire farm and off farm technologies. These findings are consistent with the studies by Teklewold et al. (2006), Deressa et al. (2008) and Yesuf (2010).

2.4.4 Risk behavior, individual discount rates and marginal effects

In the MVP model individual level risk aversion parameters ($\hat{r}_i$) found to relate negatively and significantly (*p=1%)* to the adoption of farm related innovations. The interaction term *(RISK-DROUGHT*) between drought occurrence and risk parameter is found to relate positively with the adoption of farm related innovations. In other words, those who are risk averse but have experienced drought have a higher probability of adopting farm related climate innovations. Furthermore, the risk aversion parameter is found to influence the adoption of off-farm innovations positively. Subjects who are more risk averse tend to invest in off-farm innovations and avoid risky farm investments. This is in line with the literature on this topic for developing countries (e.g. Liu 2013). With regard to individual discount rate, the MVP model show that individuals with a higher discount rate are reluctant to adopt climate innovations, which is evidenced by the negative relationship between the individual level discount rates and adoption of farm related innovations (*FARM*) (see Table 2.1). The high individual discount rate is consistent with Yesuf (2004) and Bezabih and Sarr (2012) for Ethiopian cases.

However, the estimated coefficients in the MVP are not interpreted directly; rather they show a change in the z-score due to a change in the independent variable. We are, therefore, interested to understand whether a change in risk aversion parameter, risk behavior and individual discount rate changes the probability of climate innovation adoption decision significantly. The marginal effects of risk aversion parameter, individual discount rate and risk attitudes are reported in Table 2.2. The risk aversion parameter is found significant (*p=5%)* in explaining the probability of innovation adoption. On average, a change in the risk aversion parameter by one unit changes the probability of innovation adoption negatively by 0.34; whereas a unit change of the individual level discount rate does not affect the probability of innovation adoption significantly. To understand a switch from one behavioral domain to the other, we measure the marginal effect of a shift from risk averse (used as the reference) to risk loving and risk neutral behavior. The marginal effect of a change in risk loving behavior changes the probability of innovation adoption by 4.9% indicating that a shift from other behavioral categories to risk loving behavior (from 0 to 1) significantly influences the probability of innovation adoption which is in line with most of the literature (see Ross et al. (2010) for an overview).

Table 2.2. Marginal effects of risk parameter, individual discount rate and risk attitude

Variable	dy/dx	Std. Err.	P>|z|
Parameters:			
DISCOUNT RATE	-0.414	0.455	0.363
RISKAVERSION	-0.340	0.164	0.038
Risk attitudes:			
RISKLOVER	4.911	0.106	0.000
RISKNEUTRAL	0.031	0.328	0.925

Source: own calculation.

2.4.5 Instrumental variable regression results (two step ivprobit)

In this section we present a two-step Probit regression with instrumental variables (see Table 3). We considered risk aversion and time preference parameters as endogenously determined by subject specific characteristics.

Table 2.3. Two-step Probit regression results with coefficients and standard errors

	FARCI		NONFARM		INSTITUTION	
VARIABLES	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
INDIVIDUAL DR	0.221	0.185	-0.411	0.150*	-0.0393	0.1662
RISKAVERSION	-2.886	0.484*	0.273	0.395	-1.0098	0.4198*
HSEX	-0.110	0.173	0.177	0.14	0.0122	0.1423
AGEH	-0.211	0.181	0.404	0.148*	0.0560	0.1636
EDUH	0.796	0.411**	-1.115	0.336*	0.1533	0.3676
LIVSIZE	-0.034	0.006*	0.016	0.005*	-0.0179	0.0057*
EXTHYV	0.954	0.130*	0.587	0.114*	0.0674	0.1049
EXTCH	-1.259	0.161*	1.283	0.119*	-1.0391	0.1310*
EXTSOILC	-0.816	0.125*	0.346	0.094*	-0.2424	0.1188*
DROUGHT	0.543	0.118*	-0.443	0.103*	-0.4845	0.0963*
FLOOD	-0.348	0.135*	-0.237	0.144*	0.2093	0.1064**
RAIN	-0.039	0.005*	0.033	0.005*	-0.0024	0.0046
TEMP	0.250	0.034*	-0.455	0.032*	0.0335	0.0283
CREDI	-0.147	0.293	1.186	0.237*	0.6275	0.2646**
MARKACESS	0.001	0.002	0.002	0.002	0.0146	0.0018*
DISINPUT	0.022	0.002*	0.019	0.002*	-0.0062	0.0022*
FARMSIZE	-0.558	0.145*	0.176	0.116	1.0004	0.1318*
FAMSIZE	0.327	0.032*	0.069	0.025*	0.1543	0.0265*
PRODUC	0.024	0.006*	0.042	0.006*	0.0475	0.0058*
CONS	0.001	1.025	2.283	0.868*	-4.9025	0.9181*
Wald chi2(19)	= 460.76		= 870.94		= 375.41	
Prob > chi2	= 0.0000		= 0.0000		= 0.0000	
INSTRUMENTED:	RISKAVERSIONPAR		INDIVIDUAL DR			
INSTRUMENTS:	HSEX, AGEH, EDUH, LIVSIZE, EXTHYV, EXTCH, EXTSOILC DROUGHT, CHANFLOOD, CHARAIN, CHTEMP, CREDI, MARKACESS, DISINPUT, FARMSIZE, FAMSIZE, PRODUC DISSCHOOL, DISHEALTH, DISFINANCEINS, LOSSANIMAL					

Note: *,**,*** denotes p < 0.01, p< 0.05, and p< 0.10, respectively.
Source: own calculation.

Steps in instrumental variable regression include the identification of valid and strong instruments. Though, we may not be prefect in identifying perfect instruments we tried to show how our instruments are strong. The instruments are access to school in a village (*DISSCHOOL*), access to health services (DISHEALTH), access to financial institution (ACCFINANCINS) and loss of animals (LOSSANIMAL). Accordingly, to test for correlation, an F-test was done after regressing a reduced form first stage regression and find that (F (21, 241))= 36.35, and (F (21, 3474)) = 14.97 for risk aversion and individual level discount rate respectively, indicating that the identified instruments are highly correlated with the endogenous variables (see Stock et al. 2002). The validity of our selected instruments was also tested by running an auxiliary first stage regression which reveals that socioeconomic and demographic variables significantly influence risk aversion parameter ($\hat{r}_i$) and individual discount rates (δ_i) (see Appendix 2.2). This shows that both risk and time preference are shaped by many factors including climatic factors, such as rainfall and change in temperature.

Initially, we were arguing that the decisions on adoption of the various types of climate innovations are simultaneously made. However, as we compare the two-step probit and MVP regression results, the different adoption decisions tend to be independent. The signs and directions of significance are different in most explanatory variables. For instance, individual discount rate (*DISCRATE*) at household level and market access (*MARKACCESS*) are insignificant in influencing farm related climate innovations in the case of ivprobit and significant in the case of MVP. Besides, the number of significant variables increased in the case of two-step Probit model. This is an indication that climate innovations adoption decisions are made independently of each other.

2.5 Conclusions

Primarily, the aim of this chapter was to improve our understanding of how behavioural factors like risk and time preferences influence decisions on climate innovation. We performed a field experiment in the upper blue-Nile basin in Ethiopia on risk attitudes and time preferences. The risk aversion parameter and individual discount rate were estimated following an EUT approach with CRRA specification. From the maximum likelihood estimation, we found that subjects are highly risk averse (r^{EUT}=0.577) and apply a high discount rate (*δ=0.584*). Risk and time preference behaviour have paramount importance in interventions related to rural development programs. Individual risk and time preferences are shaped by many factors including education, shock experience, and access to credit and markets. This is found true in our first stage regression of the ivprobit model where market access (*MARKACESS*), and drought and flood (*FLOOD* and *DROUGH*T) are significant in determining risk aversion and rate of time preference behaviour. Strategies to counter act against risk aversion and high discounting behaviour include institutions that support farmers through the market mechanism and these are important in the smallholder economy in the upper Blue-Nile basin. Enhancing education level, expansion of farmer extension services and pro-poor institutions are fundamental in changing the high discounting behaviour. As observed in the focus group discussion, on-going training and awareness helped famers to weigh the costs and benefits of the different investment options. It is therefore recommended to mainstream mitigation and adaptation policies in education and training programmes.

To see whether individual level risk aversion ($\hat{r}_i$) and discount rates (δ_i) are related to climate innovations adoption, we use an MVP model. We found that δ_i and ($\hat{r}_i$) are negatively and significantly related to adoption decision of farm related innovations; indicating that those who have a higher discount rate and that are more risk averse can be classified as non-adopters.

Climatic variables such as temperature (*TEMP*), drought (*DROUGHT*) and flooding (*FLOOD*) are found significant in determining climate innovation adoption decisions. Farm households that have experienced flooding and drought are inclined to adoption of new technologies.

Our sampled households are classified based on agro-ecosystems (see Simane et al. 2012). These agro-ecosystems have different climatic, natural resources, soil and ecology. The suitability of the agro-ecosystem for the farm and off-farm innovations basically has implication for adoption decisions. Agro-ecosystem 3, for instance, which is characterized by mid land plains and brown soil, and which is well-known for its excess cereal production, is found to have a negative correlation with risk loving behaviour.

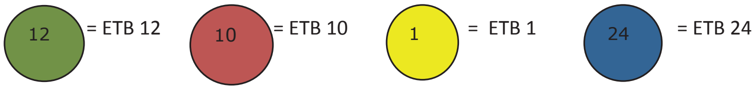
Distance to input markets and access to credit facilities positively influence the adoption of farm related climate innovations suggesting that rural development programs would bring a climate resilient economy if supported by access to markets and credit facilities.

Expecting endogeneity in the MVP model, we run a two-step *probit* (*ivprobit*) regression. The estimation results and tests suggest the presence of endogeneity. This is clearly shown in the differences in the significance level of some of the parameters between *MVP* and *ivprobit* regression. More variables are found significant in the case of *ivprobit*.

We conclude that behavioural factors like risk and time preference elicited following a field set up can best describe adoption decisions as explained in this chapter. Policy options including expansion of farmer training and experience sharing as observed from this chapter shows that training on saving and extension services have a positive impact on the decisions to adopt new innovations. Enabling access to credit, as it is evidenced from the empirical work, reduces risk aversion. Developing a strategy that would reduce high discounting would be favourable, since high discounting discourages investment in climate innovations. Access to input markets and to product markets would help to reduce the challenges and pressures through diversified livelihoods. Finally, we conclude that farm related institutional innovations, in particular community based experience sharing and learning platforms, cooperative groups based on agro-ecosystem and natural resources, and institutions for dissemination and introduction of agroecosystem relevant technologies are important for farmers in Ethiopia in the process of climate adaptation and mitigation.

Appendices

Appendix 2.1. Experimental aids and payoff matrices



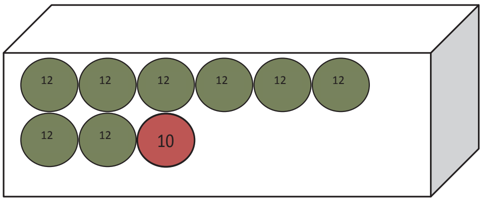
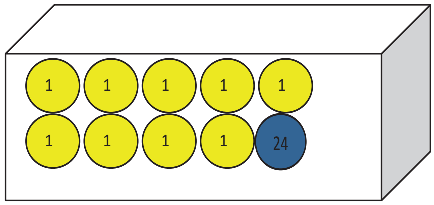
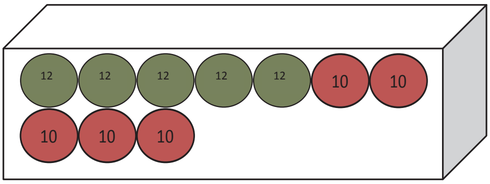
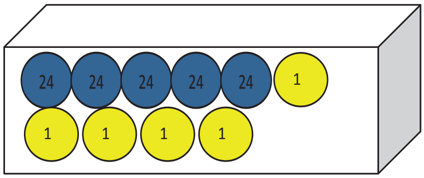
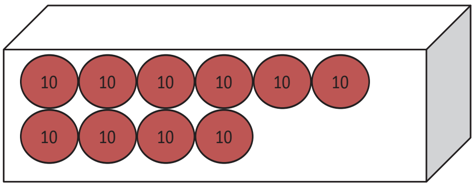
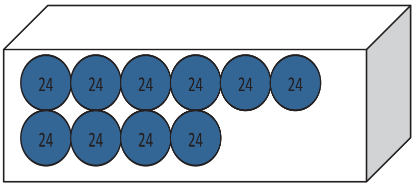
Choice No.	Box A	Box B	Choice A or B
1			
5			
10			

Figure A 1. Pictorial diagrams of lottery games (choice task 1, 5 and 10)

Table A1. Choice options (A, B) and related probabilities (p(x1), p(x2)) and pay-offs (x1, x2) for the lottery experiment

	Choice A				Choice B				Constant relative risk aversion intervals	Choice (A or B)
Choice	$p(x_1)$	x_1	$p(x_2)$	x_2	$p(x_1)$	x_1	$p(x_2)$	x_2		
1	0.1	12	0.9	10	0.1	24	0.9	1	-∞, -1.71	
2	0.2	12	0.8	10	0.2	24	0.8	1	-1.71, -0.95	
3	0.3	12	0.7	10	0.3	24	0.7	1	-0.95, -0.49	
4	0.4	12	0.6	10	0.4	24	0.6	1	-0.49, -0.15	
5	0.5	12	0.5	10	0.5	24	0.5	1	-0.14, 0.14	
6	0.6	12	0.4	10	0.6	24	0.4	1	0.15, 0.41	
7	0.7	12	0.3	10	0.7	24	0.3	1	0.41, 0.68	
8	0.8	12	0.2	10	0.8	24	0.2	1	0.68, 0.97	
9	0.9	12	0.1	10	0.9	24	0.1	1	0.97, 1.37	
10	1	12	0	10	1	24	0	1	1.37, ∞	

Table A2. Pay off table for time preference games

S.N	Option A (to be paid in one month)	Option B (to be paid at the end of month six)	Annual Interest rate (non-compounded applied to option B)	Choice (A or B)
1	ETB 200	ETB 204	4%	
2	ETB 200	ETB 205	5%	
3	ETB 200	ETB 206	6%	
4	ETB 200	ETB 207	7%	
5	ETB 200	ETB 210	10%	
6	ETB 200	ETB 212.5	12.5%	
7	ETB 200	ETB 215	15%	
8	ETB 200	ETB 217.5	17.5%	
9	ETB 200	ETB 220	20%	
10	ETB 200	ETB 222.5	22.5%	
11	ETB 200	ETB 227	27%	
12	ETB 200	ETB 237	37%	
13	ETB 200	ETB 252	52%	
14	ETB 200	ETB 272	72%	
15	ETB 200	ETB 300	100%	

Session__________ Date ___________ Seat__________

Appendix 2.2. Descriptive statistics and suplemental estimation results

Table A3. Definitions and summary statistics of variables used in the analysis

Variables	Description	Mean	Std. Dev.
AGEH	Age of head of the household	42.425	0.597
HSEX	1=if head of the household is male	0.905	0.019
MARH	1=if the head is married	0.941	0.005
CREDI	1=if access to credit is present	0.697	0.007
LIVSIZE	Livestock size	16.920	0.649
EDUH	1=if the head of the HH is educated	0.594	0.008
FAMSIZE	Family size	6.432	0.039
FARMSIZE	Farm size in Ha.	1.301	0.005
RISK-DROUGHT	Interaction term between risk par. and drought occurrence	0.316	0.025
DISCRATE-DROUGHT	Interaction term between IDR and drought occurrence	0.283	0.006
MARKACESS	Distance in minutes to reach in a nearby market	58.832	1.891
DISINPUT	Distance in minutes to input market	38.085	1.594
EXTHYV	1=if get extension service on HYV	0.922	0.018
EXTCH	1=if the farmer receives extension service on climate change related	0.743	0.029
TEMP	Change in temperature at village level	15.007	13.600
RAIN	Change in rainfall patterns at village level	1350.000	15.630
DROUGHT	1=if experienced drought for the last ten year	0.918	0.018
FLOOD	1=if experienced flooding for the last ten year	0.992	0.006
LOCELIA	1=if belonging to Debreelias district	0.269	0.007
LOBASO	1=if belonging to Basoliben district	0.246	0.007
LOCGOZ	1=if belonging to Gozamin district	0.285	0.007
LOCMACH	1=if belonging to Machakil district	0.203	0.007
DISSCHOOL	Time to the nearest school in a village (min)	26.9	0.348
DISTHEALTH	Time to the nearest health Centre (min).	54.78	0.55
DISTFINANCIST	Time to reach to the nearest fin. Inst. (min)	72.36	0.50
LOSSANIM	1=if lost animal due to unexpected shocks	0.68	0.01
$\hat{r}_i$	Individual level risk aversion parameter	0.412	0.594
δ_i	Individual level discount rate	0.415	0.351

Table A4. EUT estimates of CRRA coefficient with stochastic error (μ_i^{EUT}), homogenous agent case

Coefficient	Variable	Estimate	Std. Err.	P>|z|	[95% Conf. Interval]	
r^{EUT}						
	CONSTANT	0.5774	0.03472	0.00	0.5093	0.6456
μ_i^{EUT*}	CONSTANT					
		0.118	0.01481	0.00	0.0888	0.1471

*Note: r^{EUT} refers to the whole sample risk aversion parameter; and μ_i^{EUT} is the stochastic error term assuming a Fechner error story.

Table A5. EUT estimates of CRRA coefficient with stochastic error (μ_i^{EUT}), heterogeneous agent case

Coefficient	Variable	Estimate	Std. Err.	P>|z|	[95% Conf. Interval]	
r^{EUT}						
	HSEX	0.0468	0.051	0.358	-0.0531	0.1469
	AGEH	-0.0009	0.0068	0.8883	-0.0143	0.0125
	EDUH	-0.0279	0.0212	0.1881	-0.0695	0.0136
	CREDIT	0.1431	0.0581	0.0142	0.0291	0.2571
	CONS	0.5778	0.2799	0.0392	0.0291	1.1264
μ_i^{EUT}						
	CONS	0.1019	0.0145	0.000	0.0734	0.1304

Table A6. Comparison of predicted and switching point values of risk and discount rate parameters

Variable	Mean	Std. Dv.	Min	Max.
RISK_PREDICTED	0.570	0.0210	0.4960	0.6090
DR_PREDICTED	0.433	0.0895	0.2090	0.7190
RISK_SWITCH	0.4121	0.5940	-1.7100	1.3700
DR_SWITCH	0.415	0.3510	0.040	1.000

Table A7. Tetrachoric correlation matrix between location dummies, climatic shock and risk behavior

Covariant	Risk behavior type		
	Risk averse	Risk lover	Risk neutral
Location/Agroecosystem:			
DEBRE-ELIAS	0.347*	-0.537**	-0.119**
BASOLIBEN	-0.076**	0.136***	0.052**
GOZAMIN	0.002	-0.073***	0.111***
MACHAKIL	-0.184***	0.317**	0.013
Shock type:			
DROUGHT	-0.259**	0.381**	0.111***
FLOOD	0.075*	-0.045	0.529

Note:*, **,*** denotes p <0.01, p <0.05, and p<0.10, respectively.

Table A8. Estimates of individual time preferences assuming CRRA utility function

Coefficient	Variable	Estimate	Std. Err.	P>|z|	[95% Conf. Interval]	
r	Constant	0.1374	0.0177	0	0.026	0.1721
ν	Constant	0.6755	0.0802	0	0.5183	0.8327
LNdelta*	Constant	-0.538	0.2394	0.03	-1.008	-0.0688
	δ	0.5839	0.1398	0	0.3099	0.8579

* Note: r is the risk aversion parameter, υ the error term in the decision choice and LNdelta -the natural logarithm of delta (discount factor) which can be transformed through the syntax: delta= exp([LNdelta]

Table A9. Correlation matrix between individual discount rate and adaptation practices

	δ_i	Soil conservation	Tree planting	Water harvesting
δ_i	1			
Soil conservation	0.079	1		
Tree planting	0.177**	0.707**	1	
Water harvesting	0.194**	0.377**	0.579	1

Note: ** indicates p<0.05 significant level.

Table A10. First stage OLS regression results of endogenous variables

VARIABLES	risk aversion parameter			individual discount rate		
	Coef.	Std. Err.	P>t	Coef.	Std. Err.	P>t
HESEX	-0.146	0.034	0	0.355	0.050	0
AGEH	0.004	0.001	0	0.981	0.002	0
EDUH	-0.014	0.021	0.517	-2.259	0.031	0
LIVSIZE	-0.010	0.001	0	-0.008	0.001	0
EXTHYV	0.050	0.026	0.052	0.246	0.038	0
EXTCH	-0.098	0.028	0.001	0.510	0.042	0
EXTSOILC	0.051	0.027	0.06	0.362	0.041	0
DROUGHT	-0.100	0.024	0	-0.116	0.036	0
FLOOD	0.006	0.026	0.83	0.336	0.039	0
RAIN	0.007	0.001	0	-0.013	0.002	0
TEMP	0.031	0.006	0	0.118	0.009	0
CREDI	-0.001	0.024	0.977	1.565	0.036	0
MARKACESS	0.001	0.000	0.001	-0.002	0.001	0.001
DISINPUT	0.001	0.000	0.006	0.001	0.001	0.074
FARMSIZE	-0.075	0.032	0.019	0.355	0.047	0
FAMSIZE	0.053	0.005	0	0.008	0.007	0.243
PRODUC	0.008	0.001	0	0.015	0.002	0
DISTSCHOOL	-0.004	0.001	0	0.005	0.001	0
DISHEALTH	-0.002	0.000	0	-0.005	0.001	0
DISFINANCEINS	0.003	0.000	0	-0.002	0.001	0.005
LOSSOFANIMAL	-0.027	0.022	0.217	-0.243	0.032	0
CONS	-1.291	0.200	0	2.457	0.297	0
	F(21, 474)=	36.35		F(21, 3474) = 14.97		
	Prob > F=	0		Prob > F = 0.0000		

Appendix 2.3. Instructions for the experimental game sessions

Preparation:

- *Arrange participants in farmers training centres meeting so that there is enough space among the different groups. Besides, the facilitator can move easily.*

Record names on Participant List.

- *Put a sticker with participant ID on each participant on his/her chest and back. Since, they are informed to come at different time, recording their name and checking who else is absent. Considering that some subjects would be absent, some reserve lists have been made ahead of time*
- *When people come in give them the informed consent sheet and talk them through it.*
- *Change the instructions in to local language*

What we will do today

Dear participants I would like to thank for coming in this session. In the beginning of each experiment, you will receive a personal number, which randomly determined your seat that is your location throughout the session. Today we are going to play a lottery and time preference game. We have about two rounds of games that each of you will undertake i.e., you will play the lottery games first and time preference second. After you finish playing each game, you will play randomly one of the choices of both games for real and get a real money award based on the outcome of the play. Finally, prior to the choice task of the first game, the experimenter will illustrate you the randomization devices in a trial experiment which utilized different colored balls as payoffs. We have four colored balls; red representing ETB 10, yellow ETB 1, green ETB 12 and Blue ETB 24. Accordingly, in the trial the assignee will be paid the outcome of the lottery based on the value written on the ball.

Trial questions for Lottery games (following IFPRI)

The experimenter handed out the sheet of paper for the HL game.

A. Subjects will first be asked about what they thought the pictures on the form represented (Boxes with different color balls representing different values).

B. After this mini brainstorming, the experimenter will explain the following steps:

i. The brainstorming has shown that the task today has to do with bags and the balls of different color.

ii. Specifically, suppose there are two types of boxes (A and B) that contain two different types of balls (A -less-risky and B risky). We are going to ask you which of these two boxes you prefer.

C. How are these two boxes different? Let's focus on the first row.

i. Balls in Box A

ii. The balls in Box A have 9 green balls representing ETB12 and one red ball representing ETB 10, while Box B have 9 yellow balls representing ETB 1 and one Blue ball representing ETB 24

A. Explain the payoff Box A

B. Explain the payoff Box B

D. What do we know about the chances?

1. As in real life, you are asked to play a lottery, having a chance of win/loss.

2. The number of balls represents the chance of having the value indicated on the balls

3. In the first row, BOX A, 1 green ball out of the ten balls will bring you ETB 12,the rest 9 red balls have ETB 10. We can see that the difference in amounts is very minimal. In BOX B, on the other hand, there is one blue ball having a relatively greater amount (ETB 24) and 9 yellow balls having only ETB 1. Therefore, you are asked to choose between these boxes.

E. Questions/quiz for understanding

i. How much you will get if you draw one green ball?

ii. How much you will get if you draw one yellow ball?

iii. How the outcome differs across the rows? Compare row one with row 5.

Trial Questions for Time preference games (second round)

The experimenter will hand out the sheet to subjects

A. Brain storming questions

1. Subjects will be asked about what they feel of on receiving money today and tomorrow.
2. Consider row 1, what is the advantage of choosing option A over B?
3. What is the difference between row 1 and row 10?

B. Trial exercises

1. Pick randomly one of the players and bring him to the front
2. ask him/her to choose between option 1 and option 2 on row 5 and 11

1. **Playing the lottery games:** Welcome again to this gaming session: While you are involving in this game, you will gain a real monetary equivalent to one of the randomly chosen choices (from the ten). Consider there is box having 10 balls, having red and green colours. These balls are assigned different values which are divided in to two choices, A and B (see the poster on the wall). In the first choice, for instance, in box A, there is 1 red ball which have a value of birr 10, and 9 green balls which have a value of birr 12. Whereas, in box B, there is 9 yellow balls which has a value of birr 1 and 9 blue balls which have a value of 24. Accordingly, you are asked to choose between these two boxes. Remember, if you chose box A, you will draw one of the balls and expect to win birr 12 or birr 10, and if chose box B, you will draw again randomly

one of the balls and gain birr 24 if you draw the blue ball (which is only one) and get birr 1 if you draw the yellow balls which are nine out of ten. As you can see from the demonstrations, there is a difference in the payoffs of each alternative. Therefore, you are asked to choose among the given alternatives.

3. Time preference games (Game-2)

In this session, you will play a game that involves the choice between two payments having different due date: the first choice involves a payment that will be due within one month and the second choice involves a payment that will due in less than seven months. There are about 15 choices which you are asked to choose. In choice A, you will get birr 200 throughout the choice, while in choice B, you will earn varying payments starting from birr 2002. As you can see across the row, there is a difference in the payoffs of each alternative. Finally, you will play randomly one of the choices for real and get paid based on the outcome. You will take the money from the farmers kebele administration of you prefer choice after 6 month or take within a month if you choose A. There are no additional costs to collect the money in the future. During the game you are asked to follow the following rules:

- There are research assistants here who will help you to clarify about the choices and write the choices you made if you cannot read and write.
- There is a sheet on your table and consider it for your choice elicitation.
- The game involves the choice between getting the money in less than a month and in less than seven months, but choice B has always higher payments
- You are not allowed to talk to anybody until you are told to do so
- You have to keep your sit until instructed so.

Ok, understand? Let then now start playing the lottery game/ time preference games go! Start!

The facilitator

- *Check whether the sampled household attends or not. If he/she doesn't, follow the sampling procedure and appoint for another session*
- *Look at the player ID and record the outcome of the game*
- *Write down the payoff for each round.*
- *Then write the ID number of the participants.*
- *Keep track of time by stating when each minute has passed*.
- *At the end of each stated time announce the game period is over.*
- Before the game session, ask participants and fill the personality measure and take a socio-economic survey.

For the experimenter and assistant experimenters (the next game session)

- *Follow the above steps*
- *Record all payments on a record sheet*
- *MAKE SURE PARTICIPANTS SIGN THE RECORD SHEET.*

Chapter 3

How do personality traits and learning determine adaptation to climate change? A study on smallholder farmers in the upper Blue Nile basin[5]

Abstract: It is essential to understand how psychological and behavioural factors explain farmers' adaptation decision to climate change. In this chapter, we study how decisions on adaptation to climate change through adoption of high yield crop and livestock varieties can be explained by learning through past experience of shock events, learning from social groups and networks, by individual's personality traits, and adoption of related technologies. A regression analysis using a trivariate probit model revealed that learning, personality trait variables and other socioeconomic variables are statistically significant in determining adoption decisions. Moreover, the results show that individuals' personality traits and the information acquisition process are significantly correlated. We also find evidence that agricultural related climate change adaptation options are recursively related to each other. This causes possible endogeneity, i.e. adaptation decision of high yield crop and livestock varieties are found to depend on the adoption of soil and water conservation and irrigation technologies. Interventions designed to address climate change, therefore, should consider behavioural and personality factors, and it is important to understand how adoption of one technology creates an enabling environment for the adoption of another technology.

[5]This chapter is based on:
Nigussie YM, van Ierland EC, X Zhu, B Kebede; J Klomp (2016). How do personality traits and learning determine adaptation to climate change? A study on smallholder farmers in the upper Blue Nile basin. *Under Review at Climate and Development.*

3.1 Introduction

3.1.1 Background

The literature has identified factors that inherently limit adoption of technologies in developing countries, such as mismatch between the farmers' interest and the innovation (Harper 2005); lack of understanding of existing farmers practice (indigenous knowledge) (Hildebrand 1981; Norman 1986; Fresco 1986; Jouve 1986); failure of innovation (Panne et al. 2003); failure in extension work (Srinivas 1988; Hagmann et al.1997; Belay 2003; FAO and GTZ 2006); high cost of innovation due to credit constraint (Feder et al.1985), and other social factors (Fujisaka 1993; Pannell 1999; Glendenning et al. 2010). Yet, there are some important dimensions that deserve more attention. These include personality traits, learning and information acquisition processes, and the inter-linkage between different farm level adaptation options. The role of learning and personality traits are not yet explicitly studied in the literature of adaptation decisions under climate change. Apart from the work of Heinström (2003) who tried to link personality with the information acquisition process of students in Finland; Conley and Udry (2010) who studied how learning from neighbours influence adoption; and Kebede and Zizzo (2015) who linked personality factors with agricultural innovations in Ethiopia, there is a lack of studies on the combined effect of learning and personality traits on farmers' decisions to adapt to climate change.

Adoption of farm related technologies are linked to each other. In this chapter, we argue that a strategy for improving food security and adapting to climate change in a smallholder economy would focus on a combination of investment in soil and water conservation (SWC), irrigation technologies and uptake of high yield crop and livestock varieties. The current theoretical and empirical literature recognizes that adoption behaviour is complex and it provides a blend of theoretical models (Upadhyay et al. 2003). It is indicated in the literature that all adoption decisions are preceded by an information acquisition period, also called an awareness or learning period (Saha-Love and Schwart 1994; Adegbola and Gardebroek 2007; Posthumus et al. 2010). Thus, the three sets of technologies that we consider in this chapter are assumed to be interlinked, because an investment in soil and water conservation (SWC) and irrigation technologies facilitates the introduction of high yield crop and livestock varieties. Investments in practices for soil and water conservation (SWC) cover a larger spectrum of measures which are linked to each other and act as a learning platform to enhance crop production, food security and household income (Narayana and Ram Babu 1985; Adgo et al. 2013). Irrigation, on the other hand, has long been seen as an option to improve and sustain rural livelihoods by increasing crop production. "It can reduce dependency on rain-fed agriculture in drought prone areas and increase cropping intensities in humid and tropical zones by 'extending' the wet season and introducing effective means of water control" (FAO 2001:1). Most high yield varieties and technologically modified crops and livestock require a specific farming system (FAO 2002) which can be created through SWC and irrigation technologies. Posthumus et al. (2010) found that a decision to participate in programs and projects influences the adoption of soil conservation in Peru. In a similar approach, Tzouvelekas et al. (2006) found that the information acquisition process influences adoption of organic farming recursively. In climate change studies, Deressa et al. (2011) modeled households' perceptions of climate change and decisions to adapt to climate change in a recursive approach.

Thus, the general objective of this chapter is to understand how farm level adaptation to climate change through adoptions of crop and livestock varieties, SWC and irrigation technologies are influenced by a set of behavioural and personality factors, learning from social groups and networks and from past shock experience. Furthermore, we study how the interaction between personality traits and the information acquisition process affect adoption of high yield crop and livestock varieties; and how the adoption of high yield crop and livestock varieties recursively depend on adoption of SWC and irrigation technologies.

The first specific objective is to understand how personality traits affect individuals' response to climate change. According to Johnson (1997: 74) "personality traits are defined as consistent patterns of thoughts, feelings, or actions that distinguish people from one another". The personality differences in perception, acting and responding to external treats like climate shock incidences can play a significant role in climate change adaptation decisions (Marra 2002; Suarez 2011).

The second specific objective of this chapter is to study how learning (i) based on past shock experience, (ii) through instruction and (iii) from social networks and groups affect farmers' decisions to adapt to climate change in the upper Blue Nile basin in Ethiopia. Learning through past shock experience is a common traditional learning platform built in the social system. Learning through instructions includes extension visits, participation in demonstrations and experimental fields (Hanna et al. 2014). Learning through social networks and groups assumes that farmers share and learn new ideas and innovations through their social networks (Munshi 1999). Lwin et al. (2015) indicated that documenting existing agricultural practices can enhance successful adaptation to climate-change impacts. Indigenous knowledge plays an important role in local-level decision makings (Warren 1991; Anaeto et al. 2013). Hence, we study learning[6] from past experiences and social networks and groups.

The third objective is to understand how the information acquisition process is related with personality trait. We assume that personality traits affect farmers' general information acquisition processes, which would then further induce a shift in the probability of adopting a new technology. Information gathering is expected to enhance resource allocation skills increases efficiency in adoption decisions. Hence, a correlation analysis is employed to understand how farmers' personality is related with information acquisition. This further motivates us to study the interaction effects of personality traits and information acquisition process on adoption of farm related adaptation options.

[6] Learning through instruction can be studied using gross margin differences between the old and new technology as indicated by Abadi-Ghadim (2000), Cameron (1999) and Abera (2008). However, our data are generated through cross sectional means and we cannot trace back panel evidences on adoption of a technology. We tried to get evidence based on recall, but failed to obtain sufficient information for modelling purposes.

Finally, we wanted to model adoption decision in a recursive approach. We assume that adoption of high yield crop and livestock varieties depends recursively on adoption of SWC and irrigation technologies. Because of the recursive character of the three decision problems (decision to adopt SWC, irrigation technologies and crop and livestock varieties), a trivariate probit analysis based on the Geweke-Hajivassiliou-Keane (GHK) simulated maximum likelihood (SML) estimator is used (Teracol 2002) because standard maximum likelihood methods are not appropriate (Greene 2003). Trivariate probit models have been applied in studies by Posthumus et al. (2010), Mokhtarian and Wei (2011), and a trivariate heckit approximation by Anders and Jacob (2013).

The chapter is organized as follows. Section 3.2 outlines a theoretical framework and presents a short literature overview. While Section 3.3 discusses the methodological approach and Section 3.4 presents the data and samples. We present results in Section 3.5; and conclude in Section 3.6.

3.2 Theoretical framework and literature overview

3.2.1 Personality traits and adaptation to climate change

Psychological factors, mainly personality traits can play an important role in decision makings. Gifford (2011) introduced the notion of psychological barriers. Psychological barriers can potentially impede individuals' choices in the process of mitigation and adaptation decisions. "Economists have tended to concentrate on decision-making and actions; while psychologists have often taken the view that decision-making involves deliberate choice, the formation of attitudes and beliefs may be beyond our conscious control, and therefore outside a discussion of rationality" (Wilkinson and Klaes 2012:9). Unlike the economic foundation of decision making, the psychological foundation has received little or no attention in innovation adoption studies except that it has been rarely addressed using proxy measures (e.g. Genius et al. 2013). The personality dimension of individual differences in perception, acting and responding to external treats plays a significant role in climate change adaptation decision (Marra 2002; Suarez 2011). Thus, identifying individuals' personality traits and mental models is important to understand climate change adaptation (Grothmann and Patt 2005).

Empirical models in economics literature have given little attention to personality traits (Greaves and Ellison 2011). An important contribution has been made by Rogers (1962 and 2003) who identified that individuals have personal characteristics that influence their adoption decisions fairly and consistently. Pannell et al. (2006:7), on the other hand, argued that "personality may potentially play a major part in the style of decision making used by farmers, although because of measurement complexity, it has rarely been studied". Shrapnel and Davie (2001), in a study on Australia, tried to understand farmers' tendency to introversion and discomfort within group situations. They found that many farmers prefer a one-on-one relationship over group settings which would influence the extent and nature of a farmer's personal networks. Personal networks influence individuals adoption decision behaviour and are increasingly important for government and public policy and strategy interventions. Personality traits, therefore, influence the extent and nature of farmer's personal networks (Shrapnel and Davie 2000; Pannell et al. 2006).

There is also a presupposition that personality traits and the information acquisition process are correlated. Information acquisition behaviour according to Wilson (1997) includes the need for information, inner processes and environmental factors affecting the individual's way of responding to the information need. Personality traits are, thus, expressed in learning styles; and learning styles in turn reflected in learning strategies and finally produce a certain learning outcome (De Raad and Schouwenburg 1996). Blickle (1996) has compared the Big Five Personality trait Model with learning strategies and learning outcome. We therefore also study how the information acquisition process in climate change adaptation is affected by personality traits.

3.2.2 Theoretical approaches to learning, information acquisition, and adaptation to climate change

There are different theoretical approaches to address learning and innovation adoption decision behaviour. The pioneering theoretical model is the Target-input model (see for e.g.Jovanovic and Nyarko 1994; Foster and Rosenzweig 1995; Wilson 1997). The Target-input model needs a panel of farmers to observe learning behaviour over time. This include observing individuals decision on input use, deriving their payoffs as function of a distance between actual input use and the target, and drawing an inference. Because of high cost consideration in generating panel data, it is rarely applied in developing countries. The second prominent learning theory is the Bayesian learning theory. It is based on the Bayesian School of statistics and has a different view of what it means to learn from data, in which probability is used to represent uncertainty. However, previous studies have found empirical evidence suggesting that individuals rely more on a variety of learning heuristics than a pure probabilistic approach (e.g. Camerer and George 2003; Gans et al. 2007). The other theory in the learning and innovation literature is the Transformative learning theory. Transformative learning theory primarily relies on psychological foundations (see Elias 1997; Mezirow 1994 and 1997). Transformative learning theory applied by Tarnoczi (2011) on adaptation practices of Prairie farmers in Canada, and found that transformative learning is rare. In an attempt to avoid the complexities of more sophisticated theoretical learning models, researchers usually use proxies to measure learning.

The use of proxies to measure information access and the characteristics of the inquiry process are getting attention in the literature. Lindner (1987) argued that firm level innovation adoption can be explained by proxies like costs of acquiring information, education level, distance to the nearest current adopter and availability of extension services. Another approach that is closely related to proxy measures of learning is the experiential learning approach. Experiential learning implies learning through reflection on doing (Kolb 1984). According to this approach, learning can be explained through sharing experience from neighbours and seeing the respective change in production.

Although application of learning in climate change adaptation is rare, there are some studies which applied learning in the climate change adaptation literature. Tschakert and Dietrich (2010) stated that learning is a prominent component in managing climate extremes and shocks and in efforts to bring resilience. Walker et al. (2002) also introduced the idea of resilience management to prevent social–ecological systems by incorporating learning, memory and creativity. The United Nations Climate Change Learning Program and the International Fund for Agricultural Development (IFAD) Adaptation for Smallholder Agriculture Programme (ASAP), considered learning as central in adaptation to climate change (IFAD 2013). CARE has introduced the Adaptation Learning Program (ALP) for Africa (see CARE 2012) to facilitate Community-Based Adaptation (CBA). As a result, learning to adapt is pivotal and can contribute to decisions and plans involving mitigation and adaptation to climate change.

Empirical evidence on learning and micro level decision making processes includes the work of Abadi-Ghadim and Pannell (1999), Abera (2008), and Genius et al. (2013). The work of Genius et al. (2013) addresses information and learning inquiry process using a model that includes social networks to understand the farmer's decision making process regarding new technology adoption such as drip irrigation, Conley and Udry (2010) tried to link how learning from neighbours influence adoption decision. Hence, one can study how learning through social networks and groups is related to climate change adaptation in a smallholder economy.

3.2.3 Climate change incidences, adaptation practices and determinants

According to UNFCCC (2007), societies can respond to climate change by adaptation and mitigation efforts through reducing greenhouse gases (UNFCCC 2007). Since the agricultural systems are more vulnerable to climate change impacts; efforts to improve the adaptive capacity of the agricultural systems should get more and more attention. Because, climate change impact on agriculture is already evident and the trends to increase in the future if emissions are not stabilized at their current level (World Bank 2006). The Ethiopian agricultural system is characterized by smallholding farming which is vulnerable to climate change impacts (Deressa et al. 2009). Climate change projections in Ethiopia show that there would be a great variation in precipitation and temperature patterns (Hellmuth et al. 2007).

Previous studies have focused on adaptation options. For instance, Nhemachena and Hassan (2008) used an econometric approach to understand farmers' choices of available climate adaptation options. It was found that awareness of climate change incidences facilitate uptake of adaptation measures. The influence of age of household head on adaptation has been studied by Wegayehu and Drake (2003); a study by Nyangena (2007) and Dolisca et al. (2006) also found a similar correlation between age and adaptation decision. However, different studies have different conclusion as how age affects adaptation decision. Previous experience in temperature and rainfall change increases the probability of uptake of adaptation measures to climate change (Maddison 2006; Nhemachena and Hassan 2008; Aymone 2009; Deressa et al. 2009; Lwin et al. 2015). Education level is also studied by Deressa et al. (2009) and found that education significantly increases the probability of adopting of soil conservation and changing planting dates as an adaptation method. Sex of head of household is also an important variable affecting adaptation decision at farm level (Nhemachena and Hassan 2008; Deressa et al. 2009). Physical capital, land and labor are also found to be important factors for coping with and adapting to climate change (Nhemachena and Hassan 2008; Aymone 2009). In general, it was concluded that the choice of adaptation measure depends on factors like age, education, experience, awareness level about climate change, family size, land area, income sources and capital resources. Yet, studies related to the combined effect of learning and personality traits are limited in climate change adaptation literature and adoption decision models.

3.3 Empirical modelling of personality traits, learning and adaptation to climate change

In this section we present the empirical models employed in this chapter. Firstly, we model personality traits following the standard Big Five Personality model based on the Ten Item Personality Inventory survey (Gosling et al. 2003; Herzberg and Brahler 2006). Secondly, we model learning from social networks and groups, and learning through past shock experience. We further model adaptation decision of smallholder farmers by means of a trivariate probit model following Terracol (2012).

3.3.1 Measuring personality

The Ten Item Personality Inventory (TIPI) (Gosling et al. 2003; Herzberg and Brahler 2006) is an instrument that has been developed to measure the Big Five personality dimensions i.e. extraversion, agreeableness, conscientiousness, neuroticism, and openness to new experiences. It is generally a short personality measure which is helpful in saving time and money and is capable to give an estimation that is still compatible with the big five personality traits derived through a comprehensive personality survey (Gosling et al. 2003). In Gosling et al. (2003) one can find the TIPI scale and scoring procedure in to the big five personality domains. The TIPI is presented in Apendix 3.2. The Big Five personality dimensions of individuals' are defined in Goldberg (1993).

3.3.2 Conceptualizing learning and information acquisition

We argue that a response to climatic shock events comes partly from learning and information acquisition. The first source of learning is participation in demonstrations and trialling a technology over years (see Panell et al. 1999; Abadi-Ghadim 2000; Abera 2008). The second source of learning and knowledge comes through experience sharing among social networks and groups. Social groups including neighbours and rural based farmers associations, traditional informal gatherings and homophilic groups can contribute to the process of technology diffusion. We measured learning through social networks and groups in two ways: (i) by the number of individuals having the same age and education level adopting a technology (i.e. the stock of homophilic adopters), and (ii) by the number of individuals adopting a technology at a given year (i.e. the stock of adopters (Roger 1995; Genius et al. 2012)). Learning through social networks and groups follows the communication channel principle of Rogers (2003). Diffusion of innovation and information according to Rogers (2003) is a very social process that involves interpersonal communication relationships. Gershon et al. (2004) found that social groups composed of trained farmers and untrained farmers enable the diffusion of knowledge. In this chapter, therefore, we consider social networks and groups as the main sources of information exchange and learning points. The third learning source is through past shock experience. One's past shock experiences can influence an approach towards future climate change and weather threats which can be direct or indirect: direct in the sense that it is acquired through one's own unmediated participation in the threat; whereas indirect when mediated by reading, viewing, or hearing (Demuth 2015). In Figure 3.1, therefore, we present a conceptual framework showing the relationship between learning sources and adaptive responses.

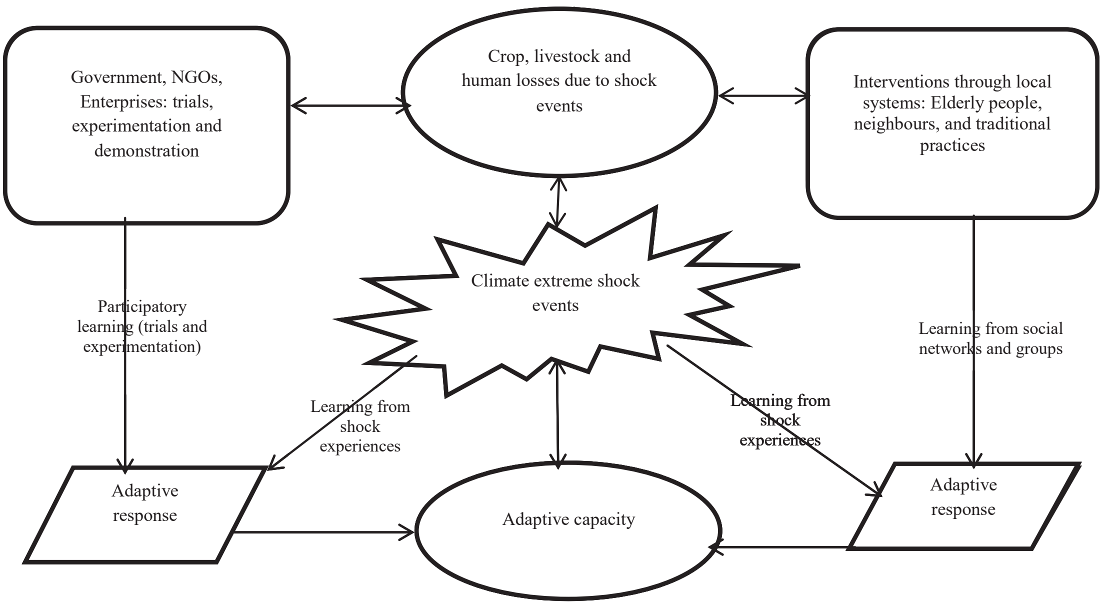


Figure 3.1. A framework showing farmers' learning process to adapt to climate extreme.

The model assumes that learning starts from occurrence of climate shock events which further stimulates interventions by different actors. Interventions that are deemed and prioritized by other agencies are referred to as external; whereas, internal sources are the learning process that an individual acquires through his/her own effort, either from own past experiences or learning from neighbours, social networks and groups.

Thus, modifying Genius et al. (2013) to determine whether the individuals under consideration have gained knowledge or skill from the social groups[7] in their reference group, we consider the following variables as proxy measures:

i) The stock of adopters in a year when the farmer considers an adaptation option. The stock of knowledge of technology *k* can be estimated by the number of adopters in the specific year:

$$K_{kjt} = \sum_{i=1}^{N}(h_{ikjt}) \tag{3.1}$$

where, K_{kjt} refers to the stock of knowledge of technology *k* accumulated in the network at time t is found by the sum of adopters h_i of technology *k* in village *j* at time t. Since our data included household level adoption decision of selected farm level technologies, we can obtain the relevant data for the application of Equation 1 from our data.

ii) The stock of *homophilic* adopters: these groups are those adopters in the same village but with similar age group and education level (within 6 years range according to Rogers (1995) and Genius et al. (2013)). Related to this variable, we collected data on individual's decision to adoption of high yield crop and livestock, SWC and irrigation, and then we derive stock of homophilic adopters based on the definition given.

iii) Finally, learning through past climatic and non-climatic shock experience is measured by developing an index for individuals' binary response to shock events for the past ten years. A list of such climatic and non-climatic shock experiences is given in Appenix 2.2.

3.3.3 Econometric model of adaptive response measures

To model adaptation decisions in a smallholder economy, it would be difficult to disentangle food security issues from climate change adaptation decision (FAO 2001). Accordingly, we select three farm level strategies that can jointly address food security and climate change adaptation. These are the application of irrigation systems, soil and water conservation technologies, and crop and livestock varieties.

3.3.3.1 Trivariate probit model

Since our model considers interrelated binary decisions that a farm household has made, a trivariate probit model is employed. A trivariate probit model enables the simultaneous estimation of the decisions on farm related climate adaptation options by allowing a correlation between unobserved disturbances. More importantly, it can be shown that parameter estimates in such a model are not affected by self-selection bias (Greene 2003), which may arise if unobserved determinants of adoption of SWC and irrigation technologies also affect adoption of high crop and livestock varieties. It is assumed that adoption of SWC

[7] Social networks and groups in this chapter are referred to as traditional gatherings in Mahiber (local traditional religious association), Debo (seasonal work group during harvest season), Idir (traditional insurance mechanism for funeral activities) and Iqub (traditional saving mechanism) that mostly do not depend on age and gender.

and irrigation technologies influence the expected utility of high yield crop and livestock varieties by changing awareness or attitude, or by providing incentives that are attractive to farm households (see Posthumus et al. (2010). Adoption of SWC, irrigation technologies, and high yield crop and livestock varieties are observed, so we can define variables y_j that equal one for positive decisions and zero otherwise. This leads to the following trivariate probit specification.

$$y_{CL} = \begin{cases} 1 \; if \; X_{CL}\beta_{CL} + y_{SWC}\gamma_1 + y_{IR}\gamma_2 + \varepsilon_1 > 0 \\ 0 \; otherwise \end{cases}$$

$$y_{SWC} = \begin{cases} 1 \; if \; X_{SWC}\beta_{SWC} + \varepsilon_2 > 0 \\ 0 \; otherwise \end{cases} \tag{3.2}$$

$$y_{IR} = \begin{cases} 1 \; if \; X_{IR}\beta_{IR} + \varepsilon_3 > 0 \\ 0 \; otherwise \end{cases},$$

$$\text{with} \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{pmatrix} \rightarrow N(0, \Sigma). \tag{3.3}$$

$$Cov\,(\varepsilon_1, \varepsilon_2) = \rho_{12}, \qquad Cov\,(\varepsilon_2, \varepsilon_3) = \rho_{23}, \qquad Cov\,(\varepsilon_1, \varepsilon_3) = \rho_{13}$$

where *X* refers to exogenous variables, β refers to covariates of parameters and the subscript *CL* refers to high yield crop and livestock varieties, *IR*-irrigation, and *SWC* refers to soil and water conservation. According to Wild (2000), such a system of three equations results in eight unique probabilities which enable estimation of three intercepts, two parameters from adoption of SWC and irrigation technologies and three correlation parameters ρ which make the model exactly identified. The equation for adoption of high yield crop and livestock varieties (y_{CL}) indicates that besides to X_{CL}, adoption of SWC and irrigation technologies are assumed to influence adoption of high yield crop and livestock varieties through γ_1 and γ_2 respectively. These variables, however, can potentially correlate with ε_1 which leads to a biased estimation. Unobserved disturbances influencing adoption of SWC (ε_2) and irrigation technologies (ε_3) may influence the residual of adoption of high yield crop and livestock varieties (ε_1). This might be due to selection bias (Green 1998, and 2003). To address such a limitation we employed a trivariate probit model procedure that was written by Terracol (2002), which is based on the GHK recursive simulator (after Geweke-Hajivassiliou-Keane). The GHK simulator has a number of desirable properties in the context of multivariate normal limited dependent variable models and has been shown to generally outperform other simulation methods (e.g. Hajivassiliou, McFadden and Ruud 1996). The model exploits the fact that a multivariate normal distribution function can be expressed as the product of sequentially conditioned univariate normal distribution functions, which can be easily and accurately evaluated (Terracol 2002).

3.4 Data and samples

Data for this chapter come from a socio-economic survey conducted from November to January, 2014 in four districts in Ethiopia. We surveyed 280 households that were randomly selected from two purposely selected agro-ecosystems. In the study area, there are six agro-ecosystems classified based on soil, natural resources base and ecology (Simane et al. 2012). We further randomly select two districts from each agro-ecosystem followed by random selection of two *kebele* from each district. Finally, we selected eight sample *kebeles* and from each *kebele*, 35 households were randomly selected. Before the final survey, training has been given to enumerators on how to administer the multi-purpose structured questionnaire. We used two sets of questionnaires: (i) a structured questionnaire designed to collect data on households' socioeconomic and demographic variables, climate adaptation behaviour and major adaptation practices, climate and non-climatic shock experience, and (ii) a TIPI survey to collect data on farmers' personality traits.

3.5 Results

3.5.1 Definition of variables and descriptive statistics

We summarized variables that are used in this chapter including socioeconomic and demographic, learning, personality traits, climatic and non-climatic shocks, and adaptation options in Appendix 3.1. The summary shows that the majority of the participants of the survey (91%) are male headed households. Learning measured by stock of homophilic adopters shows that there are about 3.79 individuals per each age and education group adopting crop and livestock varieties, 2.81 adopting SWC, and 6.68 adopting irrigation technologies in each sampled village. Regarding personality indicator variables, average extraversion score is (6.08) and conscientiousness has a score of (4.72). The proportion of climatic and non-climatic shocks experience of households' is shown in Appendix 3.1. Accordingly, 78% of the respondents have experienced flooding for the last ten years, and non-climatic shocks like animal disease (85%) and pests (75%).

3.5.2 Results of learning measures

3.5.2.1 Learning through social networks ad groups

Social networks and groups are considered as major source of farmers' learning. Figure 3.2 shows the stock of adopters in each technology group in the sampled population estimated using Equation 3.1. The stock of adopters in this group disregards age and education, rather considers adopters of a given technology in a given year living in the same village.

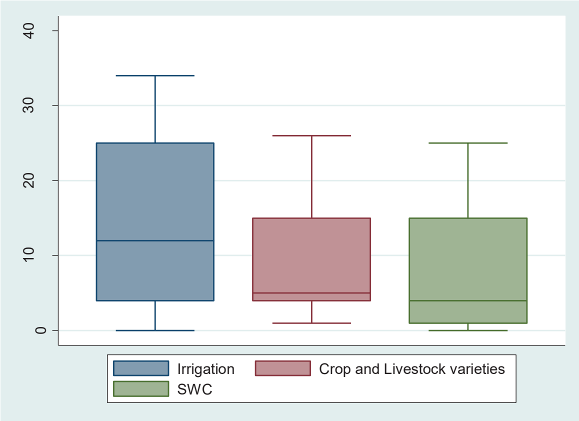


Figure 3.2. Learning measured by the stock of adopters of irrigation technology, SWC and high yield crop and livestock varieties living in the same village in a given year in Ethiopia

Hence, 50% of the stocks of irrigation adopters in a village have a group size of 12 (Figure 3.2). In the case of high yield crop and livestock varieties, 50% of the stocks of adopter have a group size of more than 4. Comparably, the group size is higher in the case of irrigation adopters.

3.5.2.2 Learning from homophilic groups

Table 3.1 presents the summary statistics of learning measured by homophilic adopters. The largest stock of homophilic adopters of irrigation technology (25) is found in village *Alias-Zuria*, while the smallest is in *Yewula*. With regard to SWC, the largest homophilic adopter group is in *Kerer* village, and the smallest in *Lemechim*. *Dendegeb* and *Lemechim* villages have also the largest stock of homophilic adopters of high yield crop and livestock varieties. In environments where there are informal institutional gatherings, learning and information diffusion is possible. Informal institutional arrangements like *Debo*, are common in the study area and are mostly made by peer groups. These gatherings only happen during the harvest seasons potentially facilitate experience sharing. Based on this view, we assume that social groups within these institutional arrangements would play a greater role in individual farmer's decision to adapt to climate change.

Table 3.1. Learning measured by the stock of homophilic adopters for high yield crop and livestock, SWC and irrigation by sampled villages in Ethiopia

Sampled villages	Stock of homophilic adopters		
	High yield crop and livestock varieties	SWC	Irrigation
AliasZ	2	2	25
Abesheb	5	2	7
Lemechim	6	0	2
Dendegeb	6	1	2
Enerata	3	2	5
Wonka	2	5	5
Kerer	3	8	2
Yewula	4	5	1
Total Average	4	3	6

Gershon et al. (2004) found that the presence of social groups composed of trained farmers and untrained farmers resulted in high rates of knowledge diffusion. Likewise, inclusion of the variable indicating "*stock of adopters*" and "*stock of homophilic adopters*" results in a significant positive impact on the adaptation decisions for the selected farm level adaptation options.

3.5.2.3 Information acquisition process and personality traits

To deal with the association between information acquisition processes and personality, we use a Pearson correlation analysis. The Pearson correlation analysis is shown in Table 3.2.

Table 3.2. Pearson correlation coefficients of information acquisition behaviour and personality traits, and t-values in brackets

Information acquisition behaviour	Personality traits				
	Extraversion	Agreeable-ness	Emotional stability	Conscientious-ness	Openness to experience
Training participation	0.019	0.127	0.026	0.212	-0.156
	(0.766)	(0.048**)	(0.694)	(0.0009***)	(0.0156**)
Experience sharing	0.042	0.003	0.053	0.037	-0.007
	(0.520)	(0.968)	(0.411)	(0.571)	(0.913)
Extension contact for high yield varieties	0.025	0.258	0.197	0.200	0.175
	(0.700)	(0.001***)	(0.002***)	(0.002***)	(0.007***)
Extension contact for SWC	0.03	-0.069	0.034	-0.165	-0.01
	(0.64)	(0.289)	(0.600)	(0.010***)	(0.873)
Extension contact for environmental protection	-0.03	0.187	0.038	0.127	-0.065
	(0.641)	(0.004***)	0.56	(0.050**)	(0.318)

, and * shows significant at 5% and 1% respectively.

The correlation analysis shows that willingness to participate in training is associated with the personality traits high agreeableness, high cconscientiousness, and low openness. Extension contact regarding high yield varieties is related to high agreeableness, high emotional stability, high cconscientiousness and high openness personality. Extension contact regarding SWC and environmental protection are related to low conscientiousness and high conscientiousness.

3.5.2.4 Findings of the trivariate probit model

The regression results of a trivariate probit estimator using the GHK recursive simulator (Terracol 2012) is presented in Table 3.3. In Table 3.3, we can see that the Wald test statistic (Wald chi2(51) = 150.90, Prob > chi2 = 0.0000) indicates that the null hypothesis that all slope parameters β_j are jointly equal to zero is rejected. In addition, the correlation coefficients of disturbance terms (RHO12, RH13) are insignificant showing that decisions related to adoption of high yield crop and livestock varieties are independent of adoption of SWC and irrigations technologies.

As we explained in section 3.3.1, inclusion of the three correlation terms (RHO12, RH13, and RH23) in the regression model guarantee identification of the model under the presence of endogenous dummy variables (Greene 2003). In addition, we included more exogenous variables that would help identify the dummy endogenous adoption decision variables (ADAP_SWC and ADAP_IRRI). Variables like extension service regarding SWC (EXTSOILC), stock of adopter of SWC (STOCKSOIL) and stock of homophilic adopters of SWC (SHOMO_SWC) are assumed to correlate with adoption of SWC; while membership in water groups (MEMBWATERG), stock of adopter of irrigation technologies (STOCKIRR), and stock of homophilic adopters of irrigation technology (SHOMO_IRR) are assumed to correlate with adoption of irrigation technologies. In the regression model, therefore, we can have four layers of independent variables (i.e. socioeconomic, learning, personality trait variables, adaptation decision variables, interaction variables and correlation coefficients). Interaction variables are derived from the five personality traits and information acquisition variables. The interaction gives rise to 25 interaction variables. Inclusion of all interaction terms in the model results in a serious of convergence problem. Hence, we run a naïve probit regression and considered only significant variables.

Table 3.3. Estimation results of the trivariate probit regression for ADAP_CL, ADAP_SWC and ADAP_IRRI, coefficients and standard errors (See Annex 1 for the full explanation of the variables and their names).

Y1 (ADOPTION OF HIGH YIELD CROP AND LIVESTOCK VARIETIES (ADAP_CL))	COEF.	STD.ERR
ADAP_SWC	5.306***	2.11
ADAP_IRRI	6.926***	2.024
HSEX	1.113	3.073
AGEH	0.035	0.039
EDUH	0.265	0.665
SHOMO_CL	0.033	0.066
STOCKCL	-0.089	0.074
EXTRAVERSION	0.147	0.201
AGREEABLENESS	0.048	0.101
EMOTIONALSTABILITY	-0.167	0.216
CONSCIENTIOUSNESS	-0.286	0.201
OPENNEXPERIENCE	-0.665*	0.303
AGREE_EXPSH	-0.131	0.139
EXTR_EXTENVI	0.174*	0.112
PRODC	0.014	0.018
EXPCLIM	-1.159**	0.528
EXPNCLIM	0.106	0.424
_CONS	0.548	3.861
Y2 (ADOPTION OF SWC (ADAP_SWC)		
HSEX	-0.301	0.384
AGEH	0.015	0.012
EDUH	0.079	0.227
SHOMO_SWC	0.025	0.019
STOCKSOIL	0.060***	0.025
EXTSOILC	0.439*	0.239
EXTRAVERSION	-0.095	0.079
AGREEABLENESS	-0.002	0.051
EMOTIONALSTABILITY	-0.033	0.091
CONSCIENTIOUSNESS	0.111*	0.063
EXTR_EXPS	0.058*	0.035
OPENNEXPERIENCE	0.069	0.079
PRODC	0.004	0.005
EXPCLIM	0.166	0.125
EXPNCLIM	0.698***	0.112
_CONS	-3.561***	1.08
Y3 (ADOPTION OF IRRIGATION TECHNOLOGIES (ADAP_IRRI))		
HSEX	-0.199	0.422
AGEH	0.033***	0.012
EDUH	0.457*	0.246
SHOMO_IRR	0.021	0.021

Table 4 continued Y3 (ADOPTION OF IRRIGATION TECHNOLOGIES (ADAP_IRRI))	COEF.	STD.ERR
STOCKIRR	0.036**	0.015
EXTRAVERSION	0.047	0.065
AGREEABLENESS	-0.037	0.086
EMOTIONALSTABILITY	-0.263**	0.127
CONSCIENTIOUSNESS	0.107	0.088
OPENNEXPERIENCE	0.117	0.081
PRODC	0.027***	0.007
EXPCLIM	0.464***	0.135
EXPNCLIM	0.636***	0.135
MEMBWATERG	-0.009	0.219
AGREE_EXTSOILC	0.136**	0.067
EMOTI_EXTENVI	0.378***	0.116
CONSC_EXTENVI	-0.262**	0.119
_CONS	-5.930***	1.183
RHO12=	0.218	0.176
RHO13=	-0.145	0.261
RHO23=	0.574	0.118

Wald chi2(51) = 150.90

Log likelihood = -205.2404 Prob > chi2 = 0.0000;

LR test of RHO12=RHO13=RHO23=0: chi2(3) = 17.429497 Prob > chi2 = .0005766

Note: *, ** and *** significant at 10%, 5% and 1% respectively,

Adoption of SWC (ADAP_SWC)

The results of the trivariate probit regression indicate learning and information acquisition variables like stock of SWC adopters (STOCKSOIL), learning from past non climatic shock experience (EXPNCLIM), and information acquisition from extension service related to SWC (EXTSOIL) significantly influence adoption of SWC. Personality trait variables like conscientious (CONSCIENTIOUSNESS) (+), an interaction term between extraversion and experience sharing (EXTR_EXPS) (+) significantly related to adoption of SWC technologies. The findings are in line with the hypothesis that personality trait and learning indicator variables are related to the adoption of farm related adaptation options. The presence of adopters in a social network (stock of SWC adopters) have an influence on non-adopters. People with high conscientious score i.e. those who are careful are also determined adoption of SWC technologies. People with high emotional stability i.e. having high energy and been participated in experience sharing are positive to adopt SWC practices. Previous models on adoption decision related to SWC identified variables like age, sex and education level as the main determinants. These variables, however, have no significant effect in our model.

Adoption of irrigation (ADAP_IRRI)

Adoption of irrigation technologies, on the other hand, are significantly related to socioeconomic variables like age of head of household (AGEH), and education level of head of household (EDUH). Learning indicator variables like stock of adopters of irrigation technology (STOCKIRR) and learning from past climatic and non-climatic shock experience (EXPCLIM) and (EXPNCLIM) respectively are significant in determining adoption of irrigation technology. Personality trait variables including emotional stability (EMOTIONALSTABILITY), and interaction terms between agreeableness and extension service related to SWC (AGREE_EXTSOILC), emotional stability and extension service on environmental conservation (EMOTI_EXTENVI), and conscientiousness and extension service on environmental conservation (CONSC_EXTENVI) significantly determine adoption of irrigation technologies. Income indicator variable (PRODUC) also determines adoption of irrigation technologies significantly. This is also in line with previous studies by Wegayehu and Drake (2003), Nyangena (2007), Dolisca et al. (2006) with regard to the influence of age and education on innovation adoption. The effect of learning and personality trait variables on adoption decision is in line with the hypothesis that personality and learning from social networks and groups influence adoption decision of farmers. Besides, the results related to the effect of learning from social networks and groups and adoption decision are in line with previous studies by Gershon et al. (2004) and Conley and Udry (2010) who found that learning from social groups and networks have a positive effect on adoption decisions.

Adoption of high yield crop and livestock varieties (ADAP_CL)

Variables like adoption of SWC and irrigation technologies are considered as main determinants in the adoption of high yield crop and livestock varieties. The regression results show that these variables significantly and positively determine adoption of high yield crop and livestock varieties. In other words, adoption of SWC, and irrigation technology are effective in inducing adoption of high yield crop and livestock varieties. A farming system that targets diffusion of high yield crop and livestock varieties then should first focus on adoption of SWC and irrigation technologies. High yield varieties developed for a specific agroecology and farming system will only successfully be introduced through enhancing SWC and irrigation technologies.

The influence of learning through social groups, i.e. the stock of adopters of high yield crop and livestock varieties (STOCKCL) and the stock homophilic adopters of crop and livestock varieties (SHOMO_CL), is not significant in the case of adoption of high yield crop and livestock varieties. This might be due to the fact that people already have the knowledge through previous exposures to SWC and irrigation technologies. The presence of such social groups at this stage has, therefore, nothing to do with adoption decisions of high yield crop and livestock varieties.

Personality trait variables, like openness to experience (OPENNEXPERIENCE), and an interaction term between extraversion and extension service related to environmental conservation (EXTR_EXTENVI), significantly determine adoption of high yield crop and livestock varieties. The openness trait includes both being open to new experiences and open to new ideas. The result shows that individuals being conservative and cautious are responding positively to innovation adoption process. The result on the effect of the interaction term EXTR_EXTENVI indicates that those who have high score in extraversion and having access to extension work regarding environmental conservation are responding positively to adoption of high yield crop and livestock varieties.

Previous studies emphasized the role of socioeconomic and demographic variables in influencing adaptation decision to the impacts of climate change (see e.g. Nhemachena and Hassan 2008; Wegayehu and Drake 2003; Nyangena 2007; Dolisca et al. 2006; Maddison 2006; Aymone 2009; Deressa et al. 2009). There are, however, related works by Kebede and Zizzo (2015) which find that personality trait is related to agricultural innovation adoption in Ethiopia. Abera (2008) found that learning from past trailing and practicing significantly determines adoption of *teff* and wheat technologies in Ethiopia. Our study stresses the importance of personality traits, learning outcome variables and the recursive relationship between the different adaptation options. The importance of learning from social groups has been introduced in the literature mainly by and Conley and Udry (2010) and Genius et al. (2014). However, there is no adequate literature related to climate change adaptation. Furthermore, treating adoption processes in a recursive approach is very rare in previous studies, apart from Posthumus et al. (2010) who tried to see how participation decisions in programs further influence adoption of soil conservation, and Gershon et al. (2004) who tried to see how knowledge acquisition decision and diffusion on adoption of pest management are recursively related. In this regard, our results give a chance to understand how different adaptation decisions are interrelated.

3.6 Conclusions

This chapter follows an empirical model of learning and personality measures to see how climate adaptive response is influenced in the upper Blue-Nile basin, Ethiopia. Climate change is a real threat towards the livelihood of smallholder famers. As a response to this, different measures have been introduced, yet smallholders are facing climate related catastrophes and shocks. Based on this fact, we wanted to understand the behavioural factors that limit adaptation to climate change at the farm level. Accordingly, we collected data on socioeconomic, demographic, climate related and non-climate related shocks, and the different adaptation decisions made at farm household level. Besides, we applied a short personality test following the ten item personality inventory (TIPI) to come up with the Big Five personality traits. Learning indicator variables are also derived following two interrelated approaches (i) learning through social networks and groups (stock of adopters in a village and stock of homophilic adopters), and (ii) learning from past climate and non-climate shock experiences.

To address the overall objective of the paper i.e. the effect of learning and personality traits on adaptation decisions, we adopt a trivariate probit model. Because of potential endogeneity and recursive relationships between the adoption decision problems (i.e. decision to adopt SWC and irrigation technologies with high yield crop and livestock varieties) a trivariate probit model based on a recursive simulated maximum likelihood (SML) is appropriate. More importantly, it can be shown that parameter estimates in such a model are not affected by self-selection bias which may arise if unobserved determinants of adoption of SWC and irrigation technologies also affect adoption of crop and livestock varieties.

Having empirically derived learning measures and personality traits, we first see how the information acquisition process is related with one's personality traits. Future adaptation to climate change starts with learning and accumulation of knowledge through information acquisition. A correlation analysis of selected information acquisition process: *participation in farmer's training*, and *experience sharing*; *extension contact to trail and demonstrate HYV, SWC and environmental protection* with the Big Five personality traits shows that there is a significant correlation with personality traits. Secondly, the trivariate probit regression results show that there is a strong relationship between learning and personality trait variables and adaptive response. The stocks of adopters of SWC and irrigation technologies have positive influence on decisions related to adoption of SWC and irrigation technologies respectively. The stocks of homophilc adopters have no significant relationship with adoption decisions, indicating that the presence of such social groups have no influence on individuals decisions or there is an overlap between stock of adopter and homophilic adopters. This opens an opportunity to design further behavioural underpinnings like, household economic and social status, membership in development groups and other income sources (Suresh et al. 2012) that would affect information seeking behaviour of farmers. As part of the main findings of this chapter, we learned that adoption of irrigation technologies and SWC have a positive and significant effect on the adoption of high yield crops and livestock varieties. This indicates that there is a strong recursive relationship between adoptions of irrigation technologies and SWC, and adoption of high yield crops and livestock varieties. However, we find that correlation coefficients in the case of adoption of irrigation technologies and SWC (RHO23) is significantly different from zero. This shows that the two decisions are made jointly. This would result in high correlation between disturbance terms in the trivariate probit model. A further study using a heckit approximation (Holm and Arednt 2013) is recommended provided that the sample size is sufficiently large.

Policy recommendations are derived both from the conceptual framework and the empirical results. In the framework, we indicated the main sources of learning and possible response approaches to climate change by individual famers. The empirical results support the propositions implied in the framework shown in Figure 3.1. Policy makers in agriculture and climate change should address the limiting factors in the process of learning to adapt to climate change. With regard to this, we recommend the following:

- Strengthening the social fabrics to intervene in technology diffusions. Social networks can enhance learning and information exchange as evidenced by the strong relationship between learning through social groups (stock of adopters) of a technology with adaptation decision.
- Personality traits should be considered as they are limiting factors in climate change adaptive practices. Though personality traits are consistent pattern of thoughts which cannot be changed over time, a comprehensive psychological foundation of the adoption model is recommended.
- Learning outcomes as evidenced by information acquisition processes have higher degrees of correlation with personality traits. This implies that personality traits need to be considered, because they are influencing the search for and acquisition of information.
- The presence of a recursive relationship among the different adaptation decisions is evidenced in this chapter; therefore, failure in adoption of high yield varieties could have partially been rooted in a lack of a fertile ground from SWC and irrigation technologies. This stresses the need to further promote SWC and irrigation technologies not only for food security but also for successful adaptation to climate change in small holder economies.

Appendices

Appendix 3.1 Descriptive statistics

Table A1. Summary statistics of dependent and independent variables

Variable	Mean	Std. Dev.	Min	Max	description of variables
Socioeconomic variables					
HSEX	0.909	0.289	0	1	=1 if head of the Household is male
AGEH	42.548	9.042	22	72	Age of head of Household head
EDUH	0.593	0.492	0	1	=1 if head the Household is literate
Income indicator					
PRODC	37.336	1.566	8	146	Total grain harvest in quintal in most recent harvest period
Personality trait					
EXTRAVERSION	6.083	16.5	-10.5	1.83	
AGREEABLENESS	4.77	36	2.5	2.6	
EMOTIONAL STABILITY	5.39	8.5	2.5	1.29	
CONSCIENTIOUSNESS	4.72	8.5	-9	1.92	
OPENNESS TO EXPERIENCE	5.37	8	2.5	1.48	
Learning variables					
SHOMO_CL	3.79	2.34	0	10	Stock of homophilic crop and livestock variety adopters in a village
SHOMO_SWC	2.81	2.84	0	10	Stock of homophilic SWC adopters in a village
SHOMO_IRR	6.68	8.5	0	29	Stock of homophilic irrigation adopters in a village
STOCKIRR	13.075	11.439	0	34	Stock of irrigation adopters in a village
STOCKCL	9.946	9.009	1	26	Stock of high yield crops and livestock varieties adopters in a village
STOCKSWC	5.992	5.815	0	5	Stock of SWC adopters in a village
EXPCLIM	3.506	0.987	0	5	An index showing climate related shock experience
EXPNCLIM	2.282	1.012	0	4	An index showing non-climate related shock experience
TRAIN	0.68	0.467	0	1	=1 if participated in farm related training
EXPSHAR	0.66	0.471	0	1	=1 if participated in farm related experience sharing

Table A2. Proportions of households experiencing climatic and non-climatic shock experiences in the upper Blue Nile basin, Ethiopia

	Experience of climatic events					Experience of non-climatic events			
	TEMP. Var.	DROUGHT	EROSION	FLOOD	RAIN Fall VARIATION	LIVESTOCK LOSS	DEATH HH MEMB	ANIMAL DISEASE	CROP PEST
mean	0.95	0.69	0.94	0.78	0.31	0.04	0.01	0.85	0.75
Std.Dev	0.21	0.46	0.23	0.41	0.93	0.22	0.11	0.35	0.43

Appendix 3.2. Ten Item personality inventory questionnaires

Here are a number of personality traits that may or may not apply to you. Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.
1= Disagree strongly 2 = Disagree moderately 3 = Disagree a little 4 = Neither agree nor disagree 5 = Agree a little *6 = Agree moderately* 7 = Agree strongly **I see myself as**: 1. _____ Extraverted, enthusiastic. 2. _____ Critical, quarrelsome. 3. _____ Dependable, self-disciplined. 4. _____ Anxious, easily upset. 5. _____ Open to new experiences, complex. 6. _____ Reserved, quiet. 7. _____ Sympathetic, warm. 8. _____ Disorganized, careless. 9. _____ Calm, emotionally stable. 10. _____ Conventional, uncreative.

Chapter 4

Climate change and common pool resources management: A lab-in-the-field experimental approach[8]

Abstract: This chapter applies a common pool resources (CPR) game to understand the possibility of climate change mitigation through identifying the determinants of successful common pool resources governance in the Choke ecosystem, upper Blue Nile basin. We conducted two lab-in-the field experimental games with farmers: a "route choice" and a CPR experiment. The former is used to classify farmers as either "rule followers" or "rule breakers" in the CPR game. Our results reveal that groups of rule-followers preserve the resource indefinitely under sufficient regrowth of the resource due to favourable climate change. Furthermore, subjects with a rule following social norm tend to depend more on their social role and their role as an elderly person. Bringing together "rule followers" and "rule breakers" in a local institution would enhance the sustainable management and use of the commons thereby contributing to mitigation of climate change through increasing the carbon sink function of commons.

[8]This chapter is based on:
NigussieY M, E C van Ierland, B Kebede, H -P Weikard, X Zhu (2016). Climate change and common pool resources management: A lab-in-the-field experimental approach. *Working paper*

4.1 Introduction

Addressing climate change through mitigation strategies in developing countries is a fundamental challenge (Chandler et al. 2002). For many, emission reduction is not a viable option in the near term. Agricultural practices in developing countries have, however, the potential to degrade the environment through land reclamation from forests and wetlands (Niyibizi and Komakach 2013). The use of pesticides, chemicals and management of livestock are also considered as sources of greenhouse gases (GHGs) from the agricultural sector in developing countries (Houghton et al. 1996). In the smallholder economy, the mounting deforestation and land cover change is a major contributor to GHGs (Carr 2004; GOFC- GOLD 2009). The contribution of the agricultural sector to GHGs is predicted to rise by about 40 percent by 2030 largely due to the increasing demand for food from a growing population and the changing patterns of diets, including an increasing demand for ruminant meats (Smith et al. 2007).

Recently, some developing countries have introduced a green economic development initiative. For instance, Ethiopia's Green Economy Initiative is designed to achieve the economic ambitions of the country through clean development trajectories (FDRE 2011). The Ethiopian government has designed a climate resilient green economy (CRGE) initiatives consisting of four main strategies. These include exploiting the vast hydropower potential, large-scale promotion of advanced rural cooking technologies, efficiency improvements to the livestock value chain, and Reducing Emissions from Deforestation and Forest Degradation (REDD) (FDRE 2011).

Agricultural and forested lands are believed to be a major potential sink to carbon if trees are maintained and managed together with crops and/or animals (Albrecht and Kandji 2003). According to the Stern review, avoided deforestation could potentially reduce CO_2 emissions for under \$5/tCO_2 (Stern 2007). Mitigation options in the agricultural sector are related to improved agricultural systems and the reduction of deforestation or the restoration of degraded lands. These options require land-management alternatives in land-based activities related to agriculture and forestry (Smith et al. 2007; Golub et al. 2009).

Water bodies and forests are often characterized by non-excludability and rivalry. Such resources are called Common Pool Resources (CPR), for which any individual has rights to use but it is costly to exclude any user (Fuentes-Castro 2009). In his seminal paper, Hardin (1968) argued that unregulated CPR would be degraded. In more recent years Ostrom (1990) provided a broader view of the characteristics of CPR and discussed management options to prevent overuse and degradation of communal resources. Ostrom (1990 and 1994) argued that a cooperative self-governing institution can be created so that the resources can be used indefinitely.

Experimental game theoretic approaches have helped to understand the dynamics of cooperation in CPR management. Recent studies have identified the situational factors that accompany and reinforce cooperative behavior and the possibility of local institutions for the management of the commons (see for e.g. Pérez-Cirera 2001; Winter 2004; Cardenas et al. 2013; Reddy et al. 2014; Meinzen-Dick 2014;

Kimbrough and Vostroknutov 2015). Situational factors include defining property rights, acceptance of rules by the users and assignment of supervisors. However, few studies are available to address climate change mitigation through cooperative management of forests and agricultural lands.

Therefore, the objective of this chapter is to understand the factors that determine cooperative behavior of smallholder farmers to manage and sustainably use the common natural resources under high and low intrinsic growth rates of the resource due to favorable or unfavorable climate change scenarios respectively. We study this using a framed lab-in-the-field experiment. The CPR game is used to understand how climate change through its effect on intrinsic growth of resources, social norms (like "rule following" behavior), and social roles determine the sustainable use of commons. The CPR game is conducted in a setting where subjects have equal access to the commons and symmetric information. We follow the theoretical developments proposed by Kimbrough and Vostroknutov (2015), which in turn constitute important extensions of the contributions proposed by Ostrom et al. (1992 and 1994). They develop a theoretical model to capture cooperative behavior in a dynamic common pool resources game using student subjects in a lab.

The novelty of this chapter is twofold. Primarily, to understand social norms like rule following behavior, we introduce a repeated "route choice" experiment in a lab-in-the-field setting provided that it is relevant to the context. Subsequently we classify subjects as either "rule-followers" or "rule-breakers" based on the outcomes from the "route choice" experiment. We also introduce the importance of social roles in the literature of commons dilemma. Secondly, we introduce the possibility of climate change mitigation through management of commons. Climate mitigation involves restoration and reforestation of degraded forest and agricultural land; hence, we try to understand the degree at which rule followers and rule breakers cooperate in the restoration and reforestation of commons under favorable and unfavorable climate change prospects. In order to mimic climate change effects we set up a CPR problem with high and low growth rates of the resource representing favorable and unfavorable climate change, respectively. Under favorable climate change the resource might be sustained indefinitely. However, lack of cooperation can result in untimely depletion of the resource.

This chapter also contributes to the literature on the effect of behavioral, ecological and social roles in the overharvesting of shared common pool resources and its implication to climate change mitigation by using experimental data from smallholder farmers. Some important aspects covered in previous studies include the effects of

- economic and social heterogeneities (Taylor and Singleton 1993; Agrawal 1998; Varughese and Ostrom 1998; Kimbrough and Vostroknutov 2015),
- subjective satisfaction on the CPR games over standard measures of objective behavior of players (Becchetti et al. 2016),
- impatience and cooperation (Schlager and Heikkila 2009),

- asymmetry in field experiments on CPR problems (Fehr and Leibbrandt 2011; Cardenas et al. 2011; Janssen et al. 2011),
- the influence of different institutional arrangement on CPR extraction (Cardenas and Ostrom, 2004; Rodriguez-Sickert et al. 2008; Cardenas et al. 2011),
- culture and ecology on cooperation (Sebastian et al. 2011),
- social norms and ecological variables on cooperation and sustainable management of CPRs (Ostrom 2009; Lo 2013; Kimbrough and Vostroknutov 2015).

The chapter is organized as follows. Section 4.2 introduces the study site, the Choke ecosystem in Ethiopia. Section 4.3 reviews results from common pool resource games in the literature. Section 4.4 explains our experimental set-up. Section 4.5 presents the results based on the experiment and Section 4.6 discusses the implications of the results. We conclude in Section 4.7.

4.2 Climate change, and common pool natural resources in the Choke ecosystem

Land degradation and nutrient depletion is a major environmental and socio-economic problem in Ethiopian highlands. In the decades, problems related to land degradation and nutrient depletion have remained a critical challenge to the agricultural sector (Legesse 2003). The consequences of this made the country vulnerable to recurrent food shortages, in most cases it has claimed the lives of thousands and caused millions underfed. A strategy to counteract against land degradation, effective and efficient natural resource conservation strategies are needed (Legesse 2003). Mountain ecosystems are highly degraded and become vulnerable to changes in climate and population. Choke Mountain ecosystem is among those hotspots that attracted many researchers to identify options that help sustain natural resources. In the Choke ecosystem resources like water, irrigation systems, forests, watersheds, and soil have frequently been affected by excessive exploitation and climate change impacts, and frequently local institutional arrangement are malfunctioning (Simane 2011). In 2008, a local cooperative institution was organized under the Choke rehabilitation program (see Simane 2011). However, due to lack of binding agreement, ill-defined incentive structures, users' rights and appropriations (Epstein et al. 2014), the local institutions failed to bring tangible changes to the ecosystem as well as to communities.

The Choke ecosystem soil structure is in critical conditions (Temsegen et al. 2008; Teferi et al. 2010). Due to climate change and anthropogenic factors, extensive agricultural practices on marginal lands are increased by 206% from 1986 to 2011 in the Choke ecosystem. Shrubs, forest cover and grasslands were reduced by 79%, 40% and 17%, respectively in the same period (Fetene 2014). Investment in the common forest and agricultural land through afforestation, the construction of diversion ditches, ridge banking and destocking are essential to combat soil degradation (FAO 2011). This strategy would also help to mitigate climate change through carbon sinks in soil and forests.

The Choke Mountain ecosystem is also the origin of many rivers and streams which make up the tributaries of the upper-Blue Nile. Rivers are currently decreasing in volume and some are becoming seasonal. Teferi et al. (2010) indicated that there was a loss of 607 km^2 of seasonal wetland and 22.4 km^2 of open water in the Choke Mountain range from 1986 to 2005. Due to the reduction in volume and size of rivers and streams, there is frequent conflict over user rights for irrigation water (Getnet 2012). Water allocation rules are deemed important and hence the relevance of cooperative management (Biswas 2004; Davis 2007). Cooperative management and use of irrigation and ground water as a commons dilemma has been the focus of previous studies (e.g. Cardenas et al. 2013; Reddy et al. 2014; Meinzen-Dick 2014). Cooperative and compromising group interests are identified as playing a significant role in the management and use of the common water resources. Beyond food security objectives, water resources management has paramount importance for global climate change mitigation. According to Earth Institute (2009), water resources are major carbon sinks absorbing more than a quarter of the anthropogenic carbon dioxide emissions.

The forest cover in the Choke ecosystem is degraded due to high population pressure and climate change. Increasing poverty, long history of human settlement, overgrazing, cutting trees and bushes made the forest cover susceptible (Getnet 2012; Simane et al. 2012). Deforestation and loss of the ecosystem remain an important challenge. To come up with a socially optimal use of common forest resources and achieve the national target of Reducing Emissions from Deforestation and Forest Degradation (REDD) in the Choke Mountain, a strategy to realize cooperative local institutions should be devised.

Social and ecological factors have been considered as limiting factors in the literature (Ostrom 1990; Kimbrough and Vostroknutov 2015) to realize cooperative local institutions. However, the possibility of climate mitigation through cooperative management of commons has been largely overlooked. Recent studies by Cochran (2012) and Javier and Alejandro (2015), have tried to link the possibility of climate mitigation through cooperative commons management. Aliaga and Herrera (2015), based on climate scenarios, tried to understand the possibility of cooperative management of commons. Use of climate scenarios, however, requires the presence of sufficient and reliable forecasts. For instance, Calow et al. (2013) note that climate forecasts in Ethiopia are generally based on inaccurate and unreliable information. According to Calow et al. (2013), there are several gaps in the observations recorded in the Ethiopian climate forecasts mainly due to high variability in climate and topographic conditions. However, even in the absence of sound climate scenarios a stylized dynamic ecological model can shed light on management responses to climate change under favorable or unfavorable climatic conditions.

4.3 Common pool resources (CPR): management and experimental games

The theory of Common Pool Resources (CPR) describes collective action arrangements to devise institutions to cope with over exploitation of resources, and it addresses what types of rules would make such institutions successful. Ostrom (1990) provides evidence from long enduring, locally managed, common pool resource settings from around the world to show that the social dilemma, often dubbed "tragedy of the commons" can be overcome. After the seminal work of Ostrom, many others have tested and applied the possibility of overcoming the social dilemma in a variety of CPR settings around the world (see for e.g. National Research Council 1986; Ostrom, Gardner and Walker 1994; Baland and Platteau 1996; Kimbrough and Vostroknutov 2015). Consequently, the emergence of self-governing institutions and factors for sustainable CPR have become central issues in the debate. For example, Blomquist (1992) examined how social capital supports collective action in groundwater management in Southern California. The relationships between some of the key variables underlying CPR theory, such as the effects of group size on participation in collective choice activities, or the effects of economic and social heterogeneities on rule breaking and rule following have also been addressed (Taylor and Singleton 1993; Agrawal 1998; Varughese and Ostrom 2011; Kimbrough and Vostroknutov 2015). Schlager and Heikkila (2009) explore how collective choice processes that govern CPRs compare in resolving the conflicts that can emerge among CPR users over time. Fehr and Leibbrandt (2011) studied how impatience and cooperation in CPR management are related; Cardenas et al. (2011) and Janssen et al. (2011) draw conclusions from asymmetric field experiments on CPR problems; Cardenas and Ostrom (2004), Cardenas et al. (2011) and Rodriguez-Sickert et al. (2008) study how different institutional arrangements influence CPR extraction. The work of Kimbrough and Vostroknutov (2015) introduced how social norms and ecological variables affect cooperation and sustainable management of CPRs following Ostrom (2009). Recent developments in the application of CPR theory include the management problem of water resources like ground water management (Wang et al. 2003 and 2008; Dinar et al. 2013; Esteban and Dinar 2013); and fisheries (Fehr and Leibbrandt 2011; Carpenter and Seki 2005). In general, non-cooperative experimental approaches have contributed a profound literature in addressing the commons problems (see Brosig 2002).

Methodologically, CPR studies can be conducted either in a laboratory setting, often with students, or in a field set-up using subjects actually involved in resource management (see e.g. Camerer 2003; Harrison and List 2004; Cardenas and Carpenter 2005; Janssen et al. 2011 and 2014; Cardenas et al. 2013; Kimbrough and Vostroknutov 2015). Carpenter and Seki (2005) conducted public goods experiments with two groups of fishermen and students in Japan, and find that fishermen in general contribute more than students do. Janssen et al. (2011) conduct asymmetric-access irrigation games and found similar results when comparing students' and villagers' responses. Baggio and Janssen (2013) compare field data from irrigation games to agent-based models with a varying set of parameters including the degree of altruism, extraction, and investments in delivery infrastructure. In general CPR games using subjects who are directly involved in resources extraction offer a higher degree of external validity compared with laboratory experiments with students.

Ostrom's (2009) proposed that CPRs can be understood as "social-ecological systems" in which multiple interacting factors influence successful resource governance. Ecological characteristics of the resource system, like the speed of re-growth, and social and behavioral factors need to be incorporated in the analysis of the CPR problem. Ecological characteristics of commons can be affected by short term (e.g. extraction) and long-term climate change drivers. Climate change can potentially alter growth of resources and lead to the loss of species and ecological imbalance (Ecological Impacts of Climate Change Collection, 2013).

A comparison of different dynamic CPR games is made by Kimbrough and Vostroknutov (2015). Our CPR game structure follows the CPR framework developed by Kimbrough and Vostroknutov (2015). However, instead of students, our subjects are farmers who struggle with a real common pool resource problem in their daily life. Based on the evidence that climate change has direct effect on the ecology mainly through affecting growth rate of CPRs, we introduce unfavorable and favorable climate change (Ecological Impacts of Climate Change Collection 2013). Furthermore, our results will be discussed in the context of CPR management for climate change mitigation in Ethiopia.

4.4 Methods

4.4.1 Data Sources

Data for this chapter come from lab-in–the-field experiments conducted in 2015 in four villages in the Choke ecosystem, upper Blue-Nile basin. These particular villages are selected because of larger coverage of open access and common pool natural resources including forests, water bodies, and protected areas. A total of 192 farmers participated after being carefully selected with the help of development agents and Kebele administrators. Subjects received a formal call to participate in an experiment that would involve incentives and would take about 3-4 hours. The day selected for the field experiment is a "local holiday"[9]. There were three stages in the data collection process: the first was to conduct the "route choice" experiment which on average took one and a half hours. Results of this experiment were used for classifying rule-following and rule-breaking subjects. Then we conducted a CPR game that took about two hours. Finally, a short demographic and socio-economic survey was conducted. Each subject earned on average ETB 110 from all rounds of game play. Each group had a size of four subjects and we had 12 groups per village. Two groups were called in one session with two assistant experimenters for each group. Before each game session, the instruction for the games (the "route choice" and the CPR game) was read (see Appendix 4.3), and demonstrations were shown. The village's farmers training center and administration halls were used as field lab. The instruction was translated into local language, and posters and displays were used to facilitate understanding.

[9] Local holidays are those days in which people are not working in commemoration of angels and saints.

4.4.2 Experimental design

4.4.2.1 The "route choice" experiment

We developed a "route choice" experiment to understand subjects' rule following behavior. The objective of the rule-following game is to understand how social norms affect collective management of the CPR. Subjects were asked to choose between route types displayed in a big poster showing a zigzag and a shorter route (see Appendix 4.2 for the pictorial diagram). It was announced that, as a rule one is supposed to go over the zigzag road. To avoid biases from risk and time preferences of subjects, subjects were informed that there is no penalty or cost in choosing the route types. In addition, the return from choosing the shorter road, i.e. the rule breaking option, involved a successively higher return[10]. Accordingly, we avail subjects with a payoff (see Table 4.1) from choosing either route types. The stage at which players shift from the zigzag road (choice A) to the shorter road (choice B) is used as a measure of rule following: the later the stage of switch, the stronger the rule following behavior.[11] To understand how rule following behavior determines CPR management, we match subjects based on their switching point from choice A (rule following) to choice B (rule breaking). Accordingly, we allocate subjects to three groups, (i) only rule-followers, (ii) only rule-breakers and (iii) mixed groups.

Table 4.1. Payoff table showing the "route choice" experiment

Game round	Payoff from zigzag route (A)	Payoff from shorter route (B)	Choice (A or B)
1	ETB10	ETB10	
2	ETB10	ETB 12	
3	ETB10	ETB 15	
4	ETB10	ETB 18	
5	ETB10	ETB 21	
6	ETB10	ETB 24	
7	ETB10	ETB 28	
8	ETB10	ETB 30	

4.4.2.2 The CPR dynamic game

Our CPR game protocol follows the framework developed by Kimbrough and Vostroknutov (2015). We adopted their design because it helps to understand the inter-temporal dynamics of common pool resources in developing countries. It also has features to capture the effect of history of harvests on state of resources stocks, and enables to introduce the effect of heterogeneity (like social norms) on sustainable commons management. More importantly it helps to apprehend the effect of climate change through its influence on the regrowth of the CPRs. Accordingly, the CPR model enables all beneficiaries to have equal access to the stock and material incentives which is termed as "common business" in the experiment. Parameterization follows a standard problem of harvests from a CPR by 4 subjects. We consider an initial

[10] see Botelho et al. (2014) and Cardenas (2011) on the effect of preferences over risk and time on the equilibrium solutions of commons.

[11] Switching at higher stages also indicates the effect of monetary incentive on subjects' behavior than a pure social norm. Incentive effects on social norms could also play a significant role. The scope this chapter, however, is limited to understanding the effect of social norms on rule following.

resource stock which at the same time reflects the carrying capacity of the system ($S_0 = 460$) which might be due to exogenous environmental or technical factors (Kimbrough and Vostroknutov 2015). At any time $t > 0$ the available stock depends on the stock in the previous period, extraction efforts e_{it} and the re-growth rate β. We assume $\beta = 0.5$ for favorable and $\beta = 0.125$ for unfavorable climate change.[12] We also assume a the critical stock $\bar{S} = 30$ of the resource below which it cannot replenish, i.e. β=0 if $\bar{S} < 30$. Furthermore in each round an individual's total effort endowment is $E_{it} = 40$. It can be allocated to extraction from the commons e_{it} with a productivity parameter $\alpha = 2$ causing higher GHGs. The remainder is allocated to private activities like farm or off-farm labor. Hence, the payoff function of individual *i* is given as,

$$\pi_t(e_{it} \,|S_t) = (E_{it} - e_{it}) + \alpha e_{it} \qquad (4.1)$$

where, $\pi(e_{it} \,|S_t)$ is the benefit of individual i at time t from the effort allocated (e_{it}) to extracting CPR given that the resource stock at time t is $S_t \geq \sum e_{it}$. According to payoff function (1), the payoffs from extraction and other private activities are (αe_{it}) and ($E_{it} - e_{it}$) respectively. We will assume that income from private activities boosts adaptive capacity to climate change ($E_{it} - e_{it}$) and is not constrained by scarcity like commons. Therefore, the maximization of individuals' benefit $\pi_t(e_{it} \,|S_t)$[13] at time t is constrained by the available resource stock after harvests made in period *t-1* and is explained in equation (2).

$$S_t = S_{t-1} + \beta(S_0 - S_{t-1}). \qquad (4.2)$$

Note that Equation (4.2) implies that if the remaining resource falls short of the threshold $S_0 - S_{t-1} < \bar{S} = 30$ growth ceases to regenerate and subjects share the remaining stock (S_t) following a simultaneous eating algorithm, i.e. proportional to demands. The game was designed in an infinite fashion, but we only play ten rounds ($T = 10$). Under low literacy level and cognitive capacity of farmers (to recall previous harvest decisions), playing 10 rounds can provide useful information.

To understand the effects of ecological variables on cooperative management and use of CPRs, subjects were divided to play a high growth rate treatment (due to favorable climate change) (82 subjects) or the low growth rate treatment (due to unfavorable climate change) (110 subjects). We understand that making games similar to real life contexts can be helpful in strengthening external validity. It has disadvantages, however, of focusing the minds of the players on local contexts that are largely unobservable to the researchers. For this reason, we present the CPR problem as an abstract public business called "*Yehibret sira*". In each round, subjects can collect a payment from allocation of effort endowment either from private business or *Yehibret sira* represented by two boxes (see Appendix 4.2). The payoff from each

[12] Kimbrough and Vostroknutov (2015) also used exponential, reverse high and low growth treatments (to see the effect of assortative matching on resources dynamics). However, we only stick to high and low growth treatments, because including more treatments become time demanding and make the task more complex in the farmers context.

[13] In the classical repeated game the stage game payoff is defined by $\pi_i = e - X_i + (X_i / \sum X_i) F(\sum X_i)$, where F is a strictly concave function with a maximum and X_i is the amount extracted by player i (see Ostrom et al. 1994, Velez et al. 2009) and mostly uses a one shot game making it less informative to capture the effect of ecological dynamics.

Yehibret sira and the private business are ETB 0.40 and ETB 0.20 respectively. For the details of the payoff structure see online Appendix 4.3.

The equilibrium outcome of the game depends on the ecological variable β (referring to high and low growth rate due to favorable and unfavorable climate change respectively), the minimum threshold level of the resource $\bar{S}$, and the initial resource stock (S_0). As shown by Kimbrough and Vostroknutov (2015) under the high growth rate of the CPR $\left(\beta \geq \frac{\bar{S}(n-1)}{(S_0-\bar{S})}\right)$ with *n*-players in an infinite game, the sub-game perfect Nash equilibrium (SPNE) outcome is when the resource stock converges to $\bar{S} + \beta(S_0 - \bar{S})$; while when the resource growth rate is low $\left(\beta \leq \frac{\bar{S}(n-1)}{(S_0-\bar{S})}\right)$, SPNE outcome is when the resource stock converges to zero. In our game we choose β to represent these two cases. One can also see the equilibrium outcome with norms using the social planners solutions.[14] In this chapter, however, we only stick to a model without norms.

4.4.3 Social roles

Roles are "standardized patterns of behaviour required of all persons playing a part in a given functional relationship regardless of personal wishes or interpersonal obligations irrelevant to the functional relationship"; while norms are “the general expectations of a demand character for all role incumbents of a system or subsystem" (Katz and Kahn 1978: 43). Hence, apart from understanding social norms through rule following games, we collected data on social roles to understand how social norms and roles are interdependent.

In a society or a social group one can find him/herself represented as a set of specific social positions (e.g., worker, scholar, schoolboy, husband, and soldier). According to the social role expectations, a person is obliged to obey the social demand associated with his social position. In meeting this social demand, a person chooses one of several possible variants for executing a social role (Neimann and Hughes 1951). Accordingly, in our study we define a social role to indicate an individual farmer’s status to play a role in a given a community. We took a farmer’s status as chairperson for *iddir*[15], team leader for development groups, and being an elder- “*shimagile*”[16] who often mediates local conflicts. Having a social role is expected to affect conservation and sustainable use of CPRs through its relationship with subjects’ social norm. In this chapter, we try to see how social norms (e.g. the rule following behavior) and social roles are related.

Social role indicator variables are derived from binary questions. We asked each participant whether they have a leadership role in development groups, work groups and traditional community associations like *Idir*. An elderly role, on the other hand, takes a value 1 if an individual’s age is above 48. It

[14] The social planners solution can be examined by introducing a model with norms in which there is an extra utility for adhering to the rule following social norm.
[15] Iddir is an informal local institution for community services like funeral, and other emergency needs in the community.
[16] Shimagile is a term used to locals who are known in mediating conflict and considered as role model in many respects.

is expected that having a social role and being an elder are highly associated with rule following behavior. Shared values and norms are key triggers of cooperation (Ostrom 1998 and 2000). Individuals' willingness to cooperate might also depend on a set of non-material incentives involved in the solution of these dilemmas (Ostrom 2000).

4.5 Results

4.5.1 Relationship between social norm and social role variables

Social norms like rule following behavior are expected to be related to social roles of individuals. Table 4.2 shows the association between the social role (i.e. the leadership role in different social groups) and being an elder (elderly role) with rule following behavior measured by the switching point in the "route choice" experiment.

Table 4.2. Measure of association between social role and the rule following behavior

					Switching point					
Social-role	1	2	3	4	5	6	7	8	9 (No switch)	Total
No social role	19	36	14	9	4	1	1	0	23	107
Social role	8	12	13	6	4	1	3	3	34	84
Total	27	48	27	15	8	2	4	3	57	191
Pearson chi2(8) = 20.7729 Pr = 0.008										
Elderly-role	1	2	3	4	5	6	7	8	9	Total
Not elderly	20	19	32	20	12	6	3	1	23	136
Elderly	7	16	7	3	2	1	1	1	34	72
Total	27	35	39	23	14	7	4	2	57	182
Pearson chi2(9) = 19.4656 Pr = 0.022										

The Pearson chi2 tests in Table 4.2 show the presence of high degree of association between rule-following behavior and role indicator variables. The numbers of rule breakers (defined as those who switch below stage 5) are larger in both non-elders and those having no role in the community. In order to conform this association, we further regress the switching point (Switch_at) in the "route choice" experiment on a set of socioeconomic and demographic variables (Table 4.3).

Table 4.3. OLS regression results of Route choice (Switch_at) on a set of socioeconomic and demographic variables

	Coef.	Std. Err.	P>t
Sex	0.1866	0.4780	0.697
Education status	1.9039	0.2418	0.00
Marital status	0.7971	0.4298	0.065
Social role	1.1746	0.3644	0.002
Elder role	0.0695	0.3861	0.857
Livestock size	-0.0159	0.0496	0.749
Farm size	2.9510	0.4921	0.00
Crop harvest in Ha	-0.0301	0.0135	0.027
Constant	-1.0792	0.8243	0.192
Prob > F = 0.0000			
R-squared = 0.5002			

In the regression, we find that having a social role influences significantly the rule following behavior. However, an elderly role is not significant though it is positive. Hence, social role are more robust in determining rule following behavior.

4.5.2 Results of the CPR game

4.5.2.1 State of optimal extraction under rule following behavior and climate change

As explained in the methods section, subjects were primarily divided into two groups playing the high or the low growth treatment. These groups were further divided into groups of three composed of only rule-followers, only rule-breakers or of mixed types. Out of those who played the high growth treatment (due to favorable climate change), 20 individuals (5 groups) form the rule followers' group, 28 individuals (7 groups) form rule breaking groups, and 36 individuals (9 groups) form mixed groups. One group dropped out due to incomplete information. Figure 4.1 shows the disaggregated outcome of the CPR game.

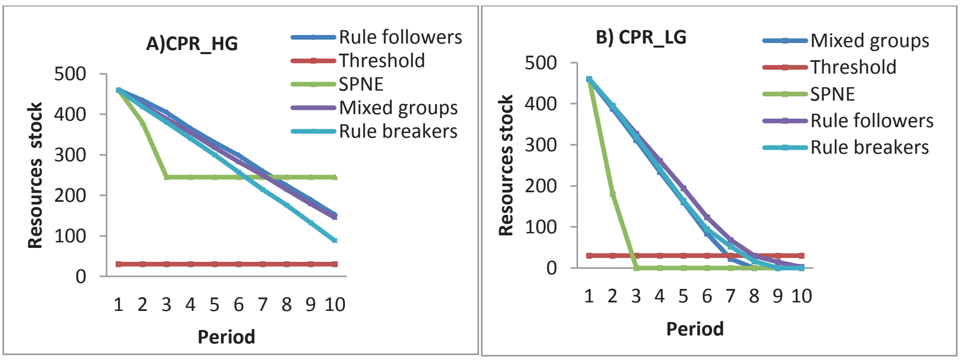


Figure 4.1. Resources stock over time by treatment (HG=high growth rate due to favorable climate change and LG=low growth rate due to unfavorable climate change)

We expect that groups of rule followers can preserve the resource indefinitely. The equilibrium outcome of the model under favorable climate change[17] (Figure 4.1A) is to use the resource indefinitely. Even though the players use the resource indefinitely under this treatment, the outcome of the experiment is different from the prediction of the model. Comparing average resource use across groups, we find that rule followers preserve the resources much better than other groups. The mixed groups are better than rule breakers in preserving the resource. Extrapolation of harvest rate under favorable climate change shows that rule breakers deplete the resource after the 11th period while rule followers use it indefinitely.

In Figure 4.1B, we show the state of optimal harvest by subjects under unfavorable climate change. The equilibrium outcome under this scenario is to deplete the resource after period 3. Unlike Kimbrough and Vostroknutov (2015), due to having high initial resources stocks and smaller effort endowments, there are three SPNE under low growth rate treatment.[18] The results of the experiment show that rule breakers and mixed groups deplete the resource after period 8 and period 7 respectively (Figure 4.1B).

4.5.2.2 Group-wise comparison of state of optimal extraction under unfavorable climate change treatment

Here we discuss how different groups of rule followers and breakers behave in the dynamic CPR game. This is presented in Figure 4.2 and Appendix 4.1.

[17] High growth and low growth treatments are synonymously used as favorable and un-favorable climate change respectively.
[18] The equilibrium path in this treatment is to exert maximum effort (E_{it}) provided that the available resource stock is higher than nE_{it}.

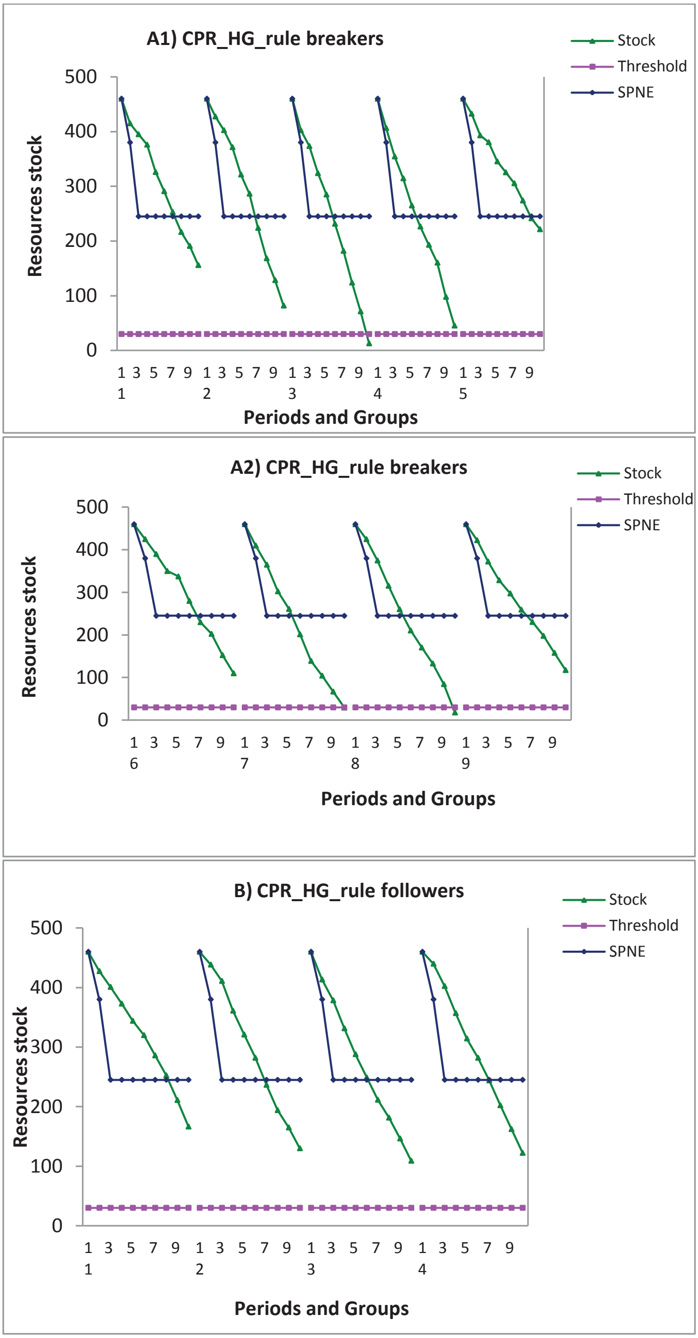


Figure 4.2. Group-wise comparison of resources stock over time under favorable climate change treatment
Note: HG=High growth rate due to favorable climate change

Under favorable climate change, all rule following groups sustain the resource indefinitely while four (of nine) rule breaking groups deplete the resources after 9th and 10th period. However, there are two rule breaking groups (groups 1 and 5 in the upper panel of Figure 4.2(A1 and A2)) that sustain the resources indefinitely. For the remaining three rule breaking groups (groups 2, 6 and 9 in A1 of Figure 4.2), extrapolation shows that they will deplete the resources after the 12th period.

Under the low growth treatment (see Appendix 4.1), we had 14 rule follower groups, and 6 rule breaker groups.[19] In the rule follower groups, only one group (group 1) sustains the resources after the tenth period, two groups (group 3 and 11) use the resources until the tenth period. The rest of the groups deplete the resource after the 7th and 8th period. Rule breakers, on the other hand, deplete the resource after the 7th period. There were no rule breaking groups that sustain the resources until the 10th period.

In addition to the CPR game results, we further need to conform how average extraction rate of individuals is influenced by a set of exogenous variables. This is shown in Table 4.4.

Table 4.4. OLS regression results of average extraction of individuals over a set of explanatory variables

	Coef.	Std. Err.	P>t
Demographic			
Sex	-0.656	0.790	0.408
Age	0.063	0.029	0.031
Literacy level	0.992	0.469	0.036
Farm size	0.604	0.868	0.487
Social role and norms			
Social role	-2.671	0.618	0.000
Elder role	-1.860	0.802	0.022
Rule following	-0.249	0.127	0.052
Village dummies			
Gedamayit	1.244	0.831	0.136
Yeted	0.636	0.868	0.465
Laychabi	-0.541	0.846	0.523
constant	17.729	1.468	0.000
Number of observation =	191		
F(10, 173) = 2.95			
Prob > F = 0.00			
R-squared = 0.14			

In Table 4.4, one can observe that average extraction of individuals' is significantly influenced by social role and norm variables. In addition, variables like literacy level and age of individuals influence extraction rate positively and significantly. The negative and significant relationship of social role, elderly role, and norm indicator variables support our argument that, sustainability of common pool resources depends on social role (leadership role), elderly role, and social norm (rule following) behavior of subjects. The result is in accordance with the experimental results.

4.5.2.3 Comparison of effort allocation

Recall that subjects played a game that requires allocation of effort endowment to either the extraction of CPRs or to other private activities. Exerting higher effort above the equilibrium level on the extraction of commons causes possible degradation and deforestation triggering higher emission of GHG, whereas an

[19] Mixed groups are not included here, we only wanted to compare only rule followers and only rule breakers.

effort allocated to private activity can enhance farmers' adaptive capacity through diversifying income sources. Accordingly, we compare extraction vs. adaptation effort levels of farmers disaggregated based on rule following and rule breaking behavior groups. The outcome is presented in Appendix 4.1. Comparing rule followers' adaptation vs. extraction efforts, one can see that average effort allocation to extraction is smaller than the average effort level allocated to adaptation strategy. However, this result varies across the different social norms and ecological treatments. For instance, rule followers under unfavorable climate change exert higher effort in adaptation strategies than rule breakers.

4.6 Discussion

Understanding the role of social norms and ecological variables in cooperative management of commons (Ostrom 1990) is the crucial first step in analyzing climate mitigation in forests and common pool agricultural lands. A need for integrated approaches to understand the possibility of establishing local institutions to manage CPR has been articulated both in the research community and among policy-makers. How and why various local institutions are established, as well as the effect of social norms, social roles, and climate change on cooperative management need to be addressed in an experimental set up that reflects real life practices.

In the first step, we tried to understand whether social norms and social roles are independent or not. This would help policy makers to understand how local level development groups should be organized. The results of a Pearson chi2 test show that there is a high degree of association between having a social role in the community with rule-following behavior. A possible inference can be drawn from this relationship. When individuals are having a social role, they develop a social norm to fulfill the general expectations of the system or subsystems (Katz and Kahn 1978). This is supported by the CPR game where rule followers preserve the resources better than rule breakers in both favorable and unfavorable climate change treatments.

In the CPR game under favorable climate change treatment (which enables high growth rate of the resource) ($\beta = 0.5$), the model predicts that the resource can be used indefinitely. However, under this treatment, the outcomes of our model and the SPNE are different despite the fact that rule followers use the resource indefinitely. Mixed groups, which are randomly matched, are better in preserving the resource than rule breakers. The high harvest rates by rule breakers might have been compensated by low harvest rates of rule followers in the mixed groups. Group type composition can partly explain observed heterogeneous resource dynamics (Kimbrough and Vostroknutov 2015).

It is also shown that the minimum resources threshold level ($\bar{S}$) and the initial stock size affect the speed of exhaustion. In our model, we have a relatively higher initial stock capacity and lower value of $\bar{S}$ as compared to subjects effort endowment, which later affect the rate of depletion and the number of SPNE in the low growth treatment. The use of higher initial stock size also helps to compare the results with the findings of Oses-Eraso and Viladrich-Grau (2007) which asserted that it would be impossible to sustain a CPR and establish cooperative institutions if users did not expose to the situation of scarcity.

Comparison of depletion rates between rule followers and rule breakers under favorable climate shows that rule breakers deplete the resource after the 11 period. Besides, the rate of harvest by rule breakers is higher than rule followers. This is consistent with the findings of Kimbrough and Vostroknutov (2015) in a lab experiment using students. Similar studies which found exhaustion of resources under different growth treatments include the Forestry Game by Cardenas et al. (2011), and Bru et al. (2003). Janson (2010), however, observed a different result. Communication of subjects according to Janson (2010) results in cooperative management of resources resulting a sustainable use of the resources. In addition, under severe climate change which would hamper growth of resources, realizing cooperative local institutions would be challenging.

We also tried to show how individual players allocate effort endowment to extraction vs. private activity. We assume that higher extraction effort results in degradation and deforestation of the commons contributing to GHG emissions. Disaggregated effort allocation indicates that there is an overall higher effort allocation to private activities (Adaptation_eff) than extraction effort (Extraction_eff). This is shown in the appendix 4.1. However, there might be other behavioral mechanisms like reciprocity and trust of individuals explain this outcome and hence deserve further study. In general, the results of lower effort allocation as compared to private activities highlights the possibility of mainstreaming mitigation strategies (restoration and rehabilitation of degraded land forests) into the smallholder farmers' economy together with existing adaptation efforts (see Golub et al. 2009; Smith et al. 2007). However, this does not mean that commons are sustainably managed at both high and low growth treatments. There is higher disparity among rule followers and rule breakers in the different ecological treatments and even complete depletion of the resource by some groups.

4.7 Conclusion and recommendation

Researchers and policy makers give little attention to climate change mitigation in developing countries since most of atmospheric GHG are emitted from developed countries. However, forecasts show that GHG emissions from land use and land cover change, deforestation and degradation will countervail adaptation and mitigation. Management of forests and agricultural land is a possible strategy to mitigate climate change in developing countries. It is believed that if trees are maintained or reintroduced and judiciously managed, together with crops and/or animals, then agricultural and forested lands can be a major sink for large quantities of carbon (Albrecht and Kandji 2003). However, addressing climate change mitigation in developing countries relies on the characteristics of the available mitigation options. Forests, infrastructure for soil and water conservation, and underground and irrigation water are mostly characterized by non-excludability and exhaustibility. They fundamentally have open access and common pool resource characteristics. Cooperative institutions are expected to play a major role in the management of such resources.

Therefore, the objective of this chapter is to understand the social and ecological factors that determine cooperative behavior of smallholder farmers to manage and sustainably use common natural resources. To understand famers' behavior, we conducted two separate games: the "route choice" experiment to understand social norms like rule following behavior, and a CPR game to understand extraction vs. conservation behavior. The "route choice" experiment helps to account for heterogeneity and understand how social norms play a role in sustainable management of commons. The games were conducted in a framed lab-in the field experiment. The players of the games are farmers having equal access to the commons with symmetric information and resource endowment.

Primarily, we wanted to see how social roles are associated with rule following (social norm) behavior. We find that social role and the rule following behavior are highly interdependent. There are interventions already designed by government and other agents to address climate change and food security in Ethiopia. These include development groups, work groups and water groups. Organizing development groups composed of elders and with those that have a social role would help sustain the management and sustainable use of commons. Primary screening of the who about of members in terms social role and social norm are encouraged to pay greater attention. This is evidenced in the CPR experimental results under high growth rate treatment where mixed groups sustain better than rule breaker groups. Secondly, the results of the CPR games reveal that rule followers preserve the resources much better than rule breakers and mixed groups both under unfavorable and favorable climate change treatments. Specifically, we find evidence that under a low growth rate of the resource, rule breakers and mixed groups deplete the resources after period 8 and 7 respectively showing that cooperation under climate change stressor is hard to obtain. This implies that sustainable management of commons can be possible under favorable climate change which could provide sufficient re-growth of the resource. Under unfavorable climate change, on the other hand, adaptation options to climate change can potentially reverse this trend by offsetting higher extraction efforts through enhancing regrowth.

Mitigation efforts can also boost cooperative behavior through enhancing re-growth of commons. To enhance the carbon sink functions of soils and forests through management of commons, we recommend a participatory development approach and inclusive planning. The presence of mixed groups (rule followers and breakers) and elders and youth in development groups can help to sustain the use of commons. Apart from the existing adaptation efforts, initiating climate mitigation strategies in a smallholder economy is recommended. However, it should also be noted that in the broader context of development CPR management cannot be confined to carbon sink objectives but has to take into account long-run food security of local populations.

Appendices

Appendix 4.1. Optimal harvest and effort allocation to diferent activities

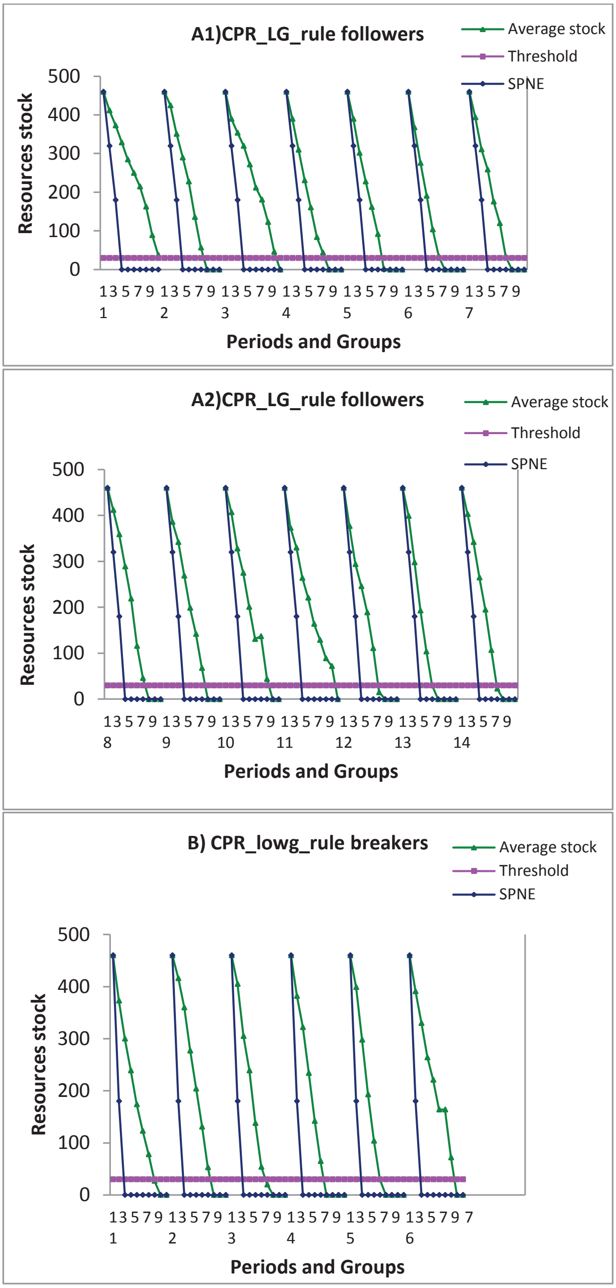


Figure A1 Group-wise comparison of resources stock dynamics under unfavourable climate change treatment

Note LG=low growth rate due to unfavourable climate change

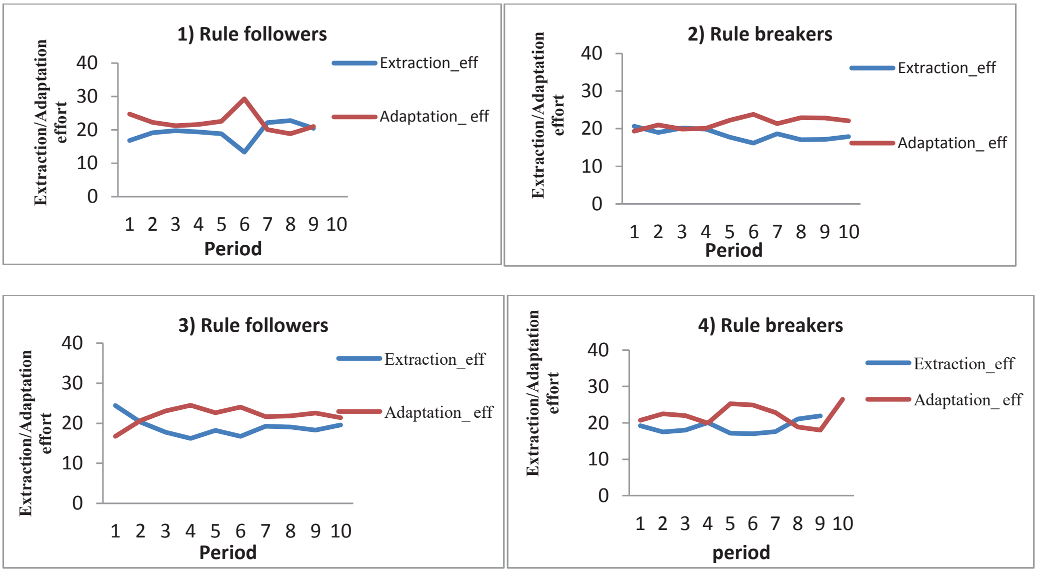
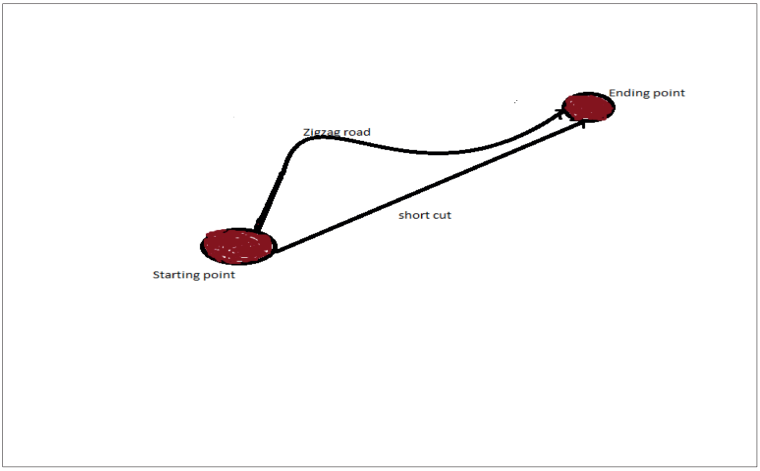


Figure A2 Extraction (Extraction_eff) vs. adaptation effort (Adaptation_eff) allocation of farmers under unfavourable (Figures 1 and 2),and favourable (Figures 3 and 4) climate change

Appendix 4.2. Experimental aid materials and payoff table



Figuere A 4 Pictorial diagram of the "route choice" experiment

Figure A6. Boxes representing the CPR problem (public business) and private business

Table A1. Payoff matrix for the CPR game

Player Card No ____________										
Round number (period)	1	2	3	4	5	6	7	8	9	10
Amount of coupons left in the common business										
My collection of coupons from private business										
My collection of coupons from common business										
My earnings from this round in ETB										
Total earning	=									

Appendix 4.3. Instructions for the experimental game session

Part I of the game

Welcome to this hall.

You are now participating in a decision-making experiment. During your stay, you will make subsequent decisions which involve a considerable amount of money depending on your decisions. Therefore, you are asked to follow the instructions carefully. Your earnings will be paid to you in CASH at the end of the experiment. This set of instructions is for your private use only. **During the experiment you are not allowed to communicate with anybody**. In case of questions, please raise your hand. Then we will come to your seat and answer your questions. Any violation of this rule excludes you immediately from the experiment and all payments.

Part I

In this experiment, assume that you want to go from the red spot to the green spot (assistant experimenter show the pictures). You have two choices to reach the green spot; **going either through the zigzag road** or **through the straight road**. During the experiment, you can choose either road by ticking a box on the experimental paper which is given to you. The rule in this game is to go through the zigzag road. Your earnings in this game are depended on your choice of road to reach to the green spot. Specifically, follow the demonstration below. After you finish all the 8 rounds one will be randomly selected and you will get the respective payoff.

Demonstration 1: You are told that the rule is to go through the zigzag road to reach to the circle spot. Now consider that you are in the second round of this game (assistant experimenter show the decision form to them), if you choose the zigzag road which is rule following you will get Birr 10, and Birr 12 if you choose the straight route. Now you can choose privately you route.

Demonstration 2: Now assume that you are in the third round, and if you choose the zigzag road you will get Birr 10, whereas, if you choose the straight road which is against the rule to reach the green spot you will get Birr 15. Now you can choose privately you route.

Now we almost done the two rounds; and then after, it is your turn to privately choose the alternative routes by seeing the poster in front of you.

This is the end of the instructions for this game. If you have any questions, please raise your hand and an experimenter will answer them privately. Otherwise, please wait quietly for the experiment to begin.

Part II

Instruction for the CPR game

This part of the experiment will consist of several decision making periods. In each period, you will collect **40 coupons from the two boxes**. Your task is to decide whether to take the 40 coupons from either private business (the box in the right corner of the hall) or from both of the boxes (a **private business box** and a **group** business box (*YEHIBRET SIRA*) (left corner of the hall)). From the private business box you are free to take any amount of coupon provided that it could not go beyond the maximum collection 40 coupons. Each coupon in the private box represents 0.20 ETB cents. Coupons in the public business represent ETB 0.40

cents. Thus, **each period you receive the sum of your earnings from your private business plus your earnings from the group business (a business owned by the members of the group)**.

There are 4 people, including yourself, participating in your group. You will be matched with the same people for all of this game. Other people in your group will make the same decisions as you. The private business has an unlimited number of coupons that you can take, so it will never run out of coupons. However, the group business initially contains a total of **460** coupons. This is the **capacity** of the group business. Whenever any person in your group takes a coupon from the group business, the number of coupon is reduced. However, each period, some of the coupon taken from the group business will **replenish**. Specifically, they will replenish according to the following rule: If there are **X** coupons remaining in the group business at the end of a period, the group business will replenish by **(460 - X)/8** coupons. Thus, at the beginning of the next period, there will be **X + (460 - X)/8** coupon in the group business (assistant experimenter show the coupons to subjects).
BUT if the total number of coupon in the group business ever falls to **fewer than 30** coupons, the group business will **not replenish**. Finally, if at any point, the group attempts to take more coupon from the group business than actually remain in the box, the remaining coupon will be divided across the people who chose to take from the group business based on the simultaneous eating algorithm.

Here are two examples to make this clear:

(1) Suppose that at the beginning of the period, there are **460** coupons in the group business box. Then, suppose the people in your group, including yourself, take a total of **160** coupons from the group business box. At the end of the period, there would be **460 - 160 = 300** coupon remaining in the group business box. The group business would then replenish before the next period. Specifically, **(460 - 300)/8= 20** coupon would be added back to the group business box.
So, at the beginning of the next period, there would be **300+ 20 = 320** coupons in the group business box.

(2) Now, suppose the next period begins with **320** coupons in the group business, and suppose that the people in your group take **140** coupons from the group business. At the end of the period, there would be **(320 - 140) = 180** coupon in the group business. The group business would then replenish before the next period. Specifically, **(320 - 180)/8= 17.5** coupon would be added back to the group business. Then at the beginning of the next period, there will be 180+17.5=197.5 coupons available in the group business.

In general, first, decide on the number of coupons to take from the private and the group business by picking a coupon from the boxes labeled as private and group business. Your collection must sum to 40. While you make your decision, the **3** other members in your group will also decide on how many coupons to take from the private and group business.
Second, after everyone has made a decision, your earnings for that decision period are the sum of your earnings from the private and group businesses.

As an example, suppose that you take a total of **30** coupons from the private business and **10** coupons from the group business. Your total earnings from that period would be **30*0.20 + 10*.40 = ETB 10**. Remember, the return from the group business is **ETB 0.40 cents** per coupon drawn and the return from the private business is **0.20 ETB cents** per coupon. While you are deciding how to allocate your coupons, everyone else in your group will be doing so as well. After each session, you will be informed how much is left in the group business. This is the end of the instructions. If you have any questions please raise your hand and an experimenter will come by to answer them.

Chapter 5

Evaluation of climate change adaptation alternatives for smallholder farmers in the upper Blue-Nile basin [20]

Abstract: Climate change is expected to have severe negative impacts on the livelihoods of smallholder farmers in developing countries. However, smallholder farmers and governments in these regions tend to be ill-prepared for changes such as more frequent seasonal droughts and periods of extreme temperatures or rainfall. Stakeholders' evaluation of adaptation options can improve awareness and policy decisions regarding climate change. Therefore, in this paper, we present the results of a stakeholder-based multi-criteria analysis (MCA) of climate change adaptation options for agriculture, natural resources and water management in the upper Blue-Nile basin in Ethiopia. We discussed current and potential adaptation practices and challenges, potential options, and evaluation criteria with representatives from different social groups in a stakeholder workshop. Subsequently, we conducted a survey asking farmers and experts to evaluate adaptation options based on a set of potentially conflicting criteria. The PROMETHEE II outranking method was then applied to our survey data in order to compare and rank climate adaptation options. The outranking results of agricultural adaptation options reveal that rankings based on importance, urgency, no regret, ancillary, and mitigation criteria conflict with the rankings on feasibility (applicability, affordability and agro-ecosystem relevance) criteria. The conflict in the order of rankings arises from the differences in preferences attached to the evaluation criteria by stakeholders. Overall, the top ranked agricultural adaptation options are improved soil and land management practices that are specific to a given agro-ecosystem. Hence we recommend policy makers in the upper Blue-Nile basin to pay greater attention to the criterion "agro-ecosystem relevance" when designing interventions related to adaptation to climate change.

---

20 This chapter is based on:
NigussieY M, E C van Ierland, Edwin van der Werf, X Zhu, B Simane (2016). Evaluation of climate change adaptation alternatives for smallholder farmers in the upper Blue-Nile basin. *Under review at Ecological Economics.*

5.1 Introduction

Since the risks to climate change are real and uncertain, society needs to develop adaptation strategies, especially for those who are highly vulnerable (Adger et al. 2003). The consequences of climate change for developing countries are more severe than for developed countries due to low adaptive capacity and high vulnerability (UNFCC 2006) in developing countries. For example, Ethiopia is heavily dependent on rain-fed agriculture, and its geographical location and topography in combination with low adaptive capacity imply a high vulnerability to adverse impacts of climate change. Historically, land degradation in the form of soil erosion has negatively affected agricultural production and economic transformation of Ethiopia (Balana et al. 2010; Pender and Gebremedhin 2007). Rainfall variability and high-temperature episodes are accompanied by recurrent seasonal drought and fluctuating run-off to the Nile tributaries (World Bank 2010; World Bank 2011). Several studies have proposed strategies, both at the micro and the macro level, to tackle problems related to natural resources degradation and climate change effects in Ethiopia (see e.g. Deressa et al. 2008; Salvatore et al. 2011; Tesso et al. 2012; Tesfaye and Brouwer 2012; Simane et al. 2012 and 2013; Nigussie et al. 2016).

Since policy interventions for climate change adaptation require participation of and dialogue with stakeholders, stakeholder analysis has become a focus of study in various countries (Chaudhury et al. 2016; Dilling and Berggren 2014). Since long-term effects of climate change in Ethiopia are expected to be enormous (Conway and Schipper 2011; Simane et al. 2014; World Bank 2010), previous adaptation options identified through empirical research and government policies and programs need to be evaluated and prioritized by stakeholders' comprised from different groups. However, there is a lack of stakeholder-level evaluation and stakeholder dialogue to identify prioritized adaptation options on the basis of well-defined evaluation criteria in the process of adaptation to climate change at different hotspots, such as the upper Blue-Nile basin in Ethiopia.[21]

We used a stakeholder workshop and a survey of farmers and experts to identify alternative adaptation options, select evaluation criteria and collect data. We subsequently analysed these data using the PROMETHEE II preference outranking method for multi-criteria analysis (MCA). MCA is a decision-support tool applicable to choice problems in different contexts under a number of different alternatives and possibly conflicting criteria (Hajkowicz et al. 2000). It is an evaluation method used to rank or score the performance of an alternative (policy options) against multiple criteria (Hajkowicz 2007). MCA studies can help identify alternative options, select criteria and score options, and then assign a weight to each criterion to provide a weighted sum that is used to rank options (Janssen and Van Herwijnen 2006). Previous studies in the upper Blue-Nile basin failed to evaluate adaptation options by sets of possibly conflicting criteria. Especially the agro-ecosystem relevance of an option has been overlooked. Due to a lack

[21] The Ethiopian National Adaptation Plan of Action (NAPA 2007) is a stakeholder level project evaluation framework developed on the basis of cost benefit analysis.

of resources and skilled labour in Ethiopia, adaptation interventions are designed without considering the specific characteristics of an agro-ecosystem (Nyamadzawo et al. 2013; Simane et al. 2012). This gap can be filled through an approach that enables stakeholders' engagement in the different stages of multi criteria analysis. Therefore, the objective of this paper is to rank and evaluate possible adaptation options for smallholder farmers in the upper Blue-Nile basin using a set of conflicting criteria. We explicitly study the agro-ecosystem relevance of each option.

The chapter is organized as follows. Section 5.2 presents materials and methods including identifcation and evaluation process of adaptation options by MCA. Section 5.3 presents the results of identified adataption options and their ranking based on MCA and discusion. We give concluding remarks in Section 5.4.

5.2 Materials and methods

5.2.1 Multi-Criteria Analysis

In the literature on prioritization of climate change adaptation options, there are two approaches used to arrive at a list of prioritized climate change adaptation options: the overall vulnerability assessment framework, and the adaptation assessment and evaluation framework (Champalle et al. 2015). Assessing vulnerability to climate change at the regional level is important to understand the risks posed by climate change and provides further information to identify measures for future adaptation to climate change impacts.

There are different methods to assess and prioritize alternative policy options in climate change adaptation (Zhu and van Ierland 2010). Cost benefit analysis (CBA) is a widely used evaluation technique in the literature. In CBA, the benefits and costs of adaptation are expressed in monetary terms, and the net benefits are calculated. However, applicability of CBA for many adaptation options is limited since it requires monetary measures for benefits and costs in order to assess whether the benefits exceed the costs (De Bruin et al. 2009). However, benefits of climate change adaptation do not always have a clear monetary value. Cost effectiveness analysis (CEA), also requires monetization of costs. These drawbacks of CBA and CEA forced researchers to choose MCA, which enables to arrive at a priority list of climate adaptation options by combining qualitative and quantitative approaches. It has recently been applied in climate change adaptation prioritizations to assess climate change policies (e.g. De Bruin et al. 2009; Pearce et al. 2012).

There are three approaches in multi criteria analysis (MCA). The first is rooted in multi-attribute utility theory. Multi-attribute utility theory requires the identification of utility functions and weights for each attribute that can then be assembled in a unique synthesizing criterion (Keeney and Raiffa 1993). The second approach in MCA refers to interactive methods. Interactive methods require preference information from the decision maker throughout the selection process and require progressive articulation of preferences (see for example Geoffrion et al. 1972). The third MCA approach is the outranking method. It focuses on building a relation called 'outranking relation', which represents the decision maker's preferences. Ranking of the alternatives has to be done on the basis of pair-wise comparisons of alternatives (choices). Examples of well-known outranking methods are PROMETHEE (Brans and Vincke 1985), ELECTRE (Roy 1973), and MACBETH (Bana e Costa and Vansnick 1997). Cenelli et al. (2014) provide an overview of MCA methods for sustainability assessments.

In this paper, we use the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), which is an outranking method for decision making that allows for ranking of alternatives based on a set of evaluation criteria, where each criterion has an assigned weight (Brans and Mareschal 2005). Examples of applications of PROMETHEE are Palma et al. (2007), who use it to evaluate the integrated performance of silvoarable agroforestry on hypothetical farms, and Jactel et al. (2012) who analysed the ranking of forest management alternatives in the context of forest damage risk from climate change.

5.2.2 Out ranking procedure of adaptation options

MCA outranking methods focus on pair-wise comparisons of alternatives where the starting point is a decision matrix describing the performance of the alternatives to be evaluated with respect to identified criteria (Belton and Stewart 2002). In this paper, the PROMETHEE II method (Brans and Vincke, 1985; Brans et al., 1986; Brans and Mareschal 1990, 2002) was used because it enables complete pre-order of alternatives, and facilitates the tracing of the final performance rank. The PROMETHEE algorithm starts with structuring the decision context (Bana e Costa and Vansnick 1997). This structuring enables the identification of a finite set $\mathrm{A} = \{\mathrm{A}_1, \dots, \mathrm{A}_\mathrm{i}, \dots \mathrm{A}_\mathrm{m}\}$ of alternatives to be evaluated and compared as well as the establishment of a set of relevant criteria $\mathrm{C} = \{\mathrm{C}_1, \dots, \mathrm{C}_\mathrm{k}, \dots \mathrm{C}_\mathrm{q}\}$ (Brans and Vincke 1985). Alternatives and criteria can then be expressed in an $m \times q$ evaluation matrix, in which each row describes an alternative and each column describes the performance of the alternatives under each criterion (Brans and Mareschal 2005). On the basis of the evaluation matrix, the alternatives are compared in pairs in order to determine how one option is to be ranked relative to the other. A general characteristic of PROMETHEE is that all m alternatives are compared in a pair-wise manner, separately for each criterion. Let $f_k(A_i)$ be the score of climate adaptation option A_i under criterion *k*. Then, the preference score of two alternatives A_i and A_j is calculated using the preference function $\mathrm{P}_\mathrm{k}\left(\mathrm{A}_\mathrm{i}, \mathrm{A}_\mathrm{j}\right), i \neq j$:

$$\mathrm{P}_\mathrm{k}\left(\mathrm{A}_\mathrm{i}, \mathrm{A}_\mathrm{j}\right) = \begin{cases} 0, \text{ if } \left(f_k(A_i) - f_k(A_j)\right) \leq \mathrm{q}_\mathrm{k} \\ 1, if \ \left(f_k(A_i) - f_k(A_j)\right) > \mathrm{p}_\mathrm{k} \\ \frac{\left(f_k(A_i) - f_k(A_j)\right) - \mathrm{q}_\mathrm{k}}{\mathrm{p}_\mathrm{k} - \mathrm{q}_\mathrm{k}} \quad , if \ \mathrm{q}_\mathrm{k} < \left(f_k(A_i) - f_k(A_j)\right) < \mathrm{p}_\mathrm{k} \end{cases} \tag{5.1}$$

where, q_k and q_k are respectively the indifference and preference thresholds assuming a linear interpolation. The unicriterion net flow Φ_k indicates the performance of alternative A_i against all other alternatives for criterion k and is calculated as follows:

$$\Phi_k = \frac{1}{m-1}\left(\sum_j P_k\left(A_i, A_j\right) - \sum_j P_k\left(A_j, A_i\right)\right), i \neq j \quad 5.2$$

The multicriteria preference degree for alternative A_i against alternative A_j is calculated as the weighted sum of the pairwise preferences over the two alternatives for all criteria:

$$\pi\left(A_i, A_j\right) = \sum_{k=1}^{q} w_k P_k\left(A_i,\ A_j\right), i \neq j \quad 5.3$$

where w_k represents the weight of criterion k, with $w_k \geq 0$ and $\sum_{k=1}^{q} w_k = 1$. In the presence of m adaptation options, the PROMETHEE II outranking method provides two preference flows. The first, $\Phi^{+}(A_i)$, reflects how strongly an alternative A_i dominates all the other alternatives A_j and the second, $\Phi^{-}(A_i)$, reflects how strongly A_i is dominated by all other alternatives:

$$\Phi^{+}(A_i) = \frac{1}{m-1}\sum_j \pi\left(A_i,\ A_j\right) \quad i \neq j, \quad (5.4)$$

$$\Phi^{-}(A_i) = \frac{1}{m-1}\sum_j \pi\left(A_j,\ A_i\right),\ i \neq j. \quad (5.5)$$

The net preference flow $\Phi(A_i)$ is calculated as follows:

$$\Phi(A_i) = \Phi^{+}(A_i) - \Phi^{-}(A_i). \quad (55)$$

Finally, alternatives can be ranked by their net preference flow $\Phi(A_i)$. We use the Visual PROMETHEE software for our analysis.

5.3 Identification of adaptation options

The study area is the Choke mountain ecosystem found in the upper Blue-Nile basin, Ethiopia, where the landscape is dominated by low-input mixed crop-livestock subsistence agriculture, with cultivation extending from the Blue Nile gorge up to nearly the mountain's summit. Climate change has already been perceived in extreme rainfall events and an upward trend of regional temperatures over the past 20 years (Simane et al. 2012). It is also observed that there is a strong tendency during July to September that rains are imposing a challenge on crops and animals in the Upper Blue-Nile basin (McSweeney et al. 2010; Ethiopian EPA 2011). At the national level, both the frequency and intensity of droughts have increased and inflicted severe damages on the livelihoods of millions of people (Simane et al. 2014).

We identified possible adaptation options through literature review and a stakeholders' workshop for the study area. The agricultural sector in Ethiopia has frequently been affected by climate variability and change (Tesso et al. 2012; World Bank 2010). In the highlands, soil degradation is very pervasive and almost all farmers perceived erosion problems which make many of them to believe in soil and water conservation measures as profitable measures (Teshome et al. 2014). Seasons are fluctuating over the past decades and are expected to remain the same in the next 25 years (Conway and Schipper 2011; World Bank 2010; EPA 2011). As a response to this, in the Upper Blue-Nile basin, agricultural adaptation options like change in crop calendar (Simane et al. 2014), conservation tillage (Temesgen et al. 2012), and a list of other adaptation options are suggested in Simane et al. (2012).

In addition to its impact on agriculture, climate change may also have impacts on the provision of natural resources. Natural resource management (NRM) is important in improving adaptive capacity of smallholder farmers and has both ecological and economic implications (Teshome et al. 2014). Ecological benefits of adapting NRM include improved soil fertility, temperature regulation, improved water retention and carbon sequestration (Alison 2010; FAO 2011); while economic benefits include improved crop yield and fodder production and agroforestry benefits, and less conflict over resources (see Teshome et al. 2014).

Third, climate change will affect water resources through changes the patterns of temperature, precipitation and river flow upon which agricultural systems in developing countries depend (FAO 2011). Despite the fact that there are large uncertainties concerning the impact of climate change on precipitation, models predict that there will be more variability in rainfall patterns, with increased occurrence of extreme events like intense precipitation or longer periods of dry weather pattern (Bates et al. 2008; FAO 2011). Practices that retain the surface runoff in the uplands and lowlands, improved water-holding capacity of the soil, and practices that increase groundwater recharge and protect the top soil have been suggested as water-related adaptation options (e.g. FAO 2014).

For the stakeholders' workshop, a team of 20 individuals was carefully selected and invited for a one-day workshop. The workshop was organized in the city of Debermarkos in East Gojjam, the heart of the upper Blue-Nile basin. Participants were invited by making sure that they represent government (decision makers), experts (who are directly involved in the design and execution of programs and projects including environmentalists, agriculturalists, water resources and natural resources experts), non-government organizations (particularly those who are concerned with environmental conservation), and farmers (who are the direct bearers of climate change impacts). Bedru et al. (2010) and Mendoza and Prabhu (2000a, b) indicate that a team of 12 persons is sufficient to generate criteria and indicators when carrying out an MCA evaluation such as ranking and pair-wise comparisons. During the workshop, a list of adaptation options in the Choke Mountan ecosystem was identified, based on stakeholders' views and perspectives.[22] Based on the literature and the stakeholder's workshop, we identified the adaptation options listed in Table 5.1.

[22] Choke mountain ecosystem is the largest stretched watershed found in the upper Blue-Nile basin.

Table 5.1. List of adaptation options identified both from literature and stakeholders' workshop

Agriculture	Water resources related	NRM
Improved varieties	River diversion	Carbon sequestration
Crop rotation	Prevent leaching and erosion	Max. water retention
Composting	Drip irrigation	Maximize crop yield
Change in fertilizer use methods	Water allocation rules	Temperature regulation
Water shed management	Use water evicting technologies	Minimize conflict over resources
Farming implements	Hand dig pumping	Minimize risk of pest harbouring
Introducing new harvest periods	Water efficient technologies	Enhance soil fertility
Use of pesticides	Water harvesting	Minimize soil losses
Integrated farming	Planting trees with high water store capacity	Agro forestry
DAP and urea application	Use of surface and ground water	Maximize fodder production
Modification of crop calendar	Cash crops using irrigation	
Terracing		
Storing technology		
Reduce tillage		
Budding[23]		

5.4 Selection of criteria and weights

To determine criteria and weights to evaluate climate change adaptation options, we first identified criteria in the literature and then discussed these in the stakeholder workshop. The criteria need to be non-overlapping and need to be consistent with the mandate and goals of governments or public agencies (Champalle et al. 2015).

De Bruin et al. (2009) used feasibility (technical complexity, social complexity, and institutional complexity), and importance, urgency, no regret, ancillary, and mitigation criteria set to evaluate a list of adaptation options in Netherlands. De Bruin (2009), underlined that it is possible to include feasibility with importance, urgency, no regret, co-benefit, and mitigation criteria together in the evaluation process, but due to the fact that the feasibility issues are too distinct from the criteria on importance, urgency, no regret, co benefit, and mitigation, it is preferable to use a separate listing. Caution should also be given to the use of different criteria to different sectors (Bhave et al. 2014), and criteria should reflect the specificity of the context (UKCIP 2010). Furthermore, in the presence of different actors having different objectives, evaluations need to be user-specific. What may be evaluated highly by a farmer for instance may be of little benefit to experts (Dolan et al. 2001). In most developing countries strategies are often top down, and farmers are less literate and have little bargaining power in the choice of a technology.

The data to rank and compare different adaptation options were generated from a survey of farmers and experts. The survey had the objective to score adaptation options based on sets of criteria. A total of 175 individuals composed of farmers (145) and experts (30) participated in the final survey. Farmers were selected from four villages found in two agro-ecosystems (AES 4 and AES 5). AES 4 covers midland slopping lands, and AES 5 covers hilly and mountainous highlands of the choke mountain ecosystem (see

[23] Budding is mostly used to improve productivity of local fruits by taking a bud from a high yield variety and transfer it to locals.

Simane et al. 2012). The survey was conducted by trained enumerators who are fluent in local languages. Effort was made to make the criteria and the options more transparent and understandable to farmers.

5.5 Results of identified adaptation options and their ranking based on MCA

5.5.1 Identified options, criteria and weights for the study area

In the evaluation process, we first select a feasibility (applicability, affordability and agro-ecosystem relevance), and importance, urgency, no-regret, ancillary and mitigation criteria for ranking agricultural related adaptation options following de Bruin (2009) and adapting to our research context (UKCIP 2010). Accordingly, feasibility in terms of applicability is defined as appropriateness, suitability, and easiness to comprehend by farmers; affordability refers to the feasibility of an option in terms of the cost of the technology or whether it is within the affordable limit of a given target group; and feasibility in terms of agro-ecosystem relevance- refers to whether the mentioned adaptation option is relevant to the agro-ecosystem under consideration and have the potential to increase ecosystem resistance and resilience. The criteria score takes 1 to 3 points, being three the highest feasible among others. Under the importance, urgency, no regret, ancillary and mitigation criteria, we follow the literature from Smit and Lenhart (1996), and Füssel (2007) and recently De Bruin (2009). Importance is then referred to the expected benefit that can be obtained; urgency reflects the need to act soon and not later; no regret refers to that it is good to implement, irrespective of climate change; co-benefits (ancillary) addresses a synergy to other sectors, and mitigation benefit. However, one can also argue that some criteria are overlapping and not all are completely mutually exclusive (De Bruin 2009). The criteria score takes 1 to 5, being five highly important. The importance, urgency, no regret, ancillary and mitigation criteria are also used to rank adaptation options related to natural resources management.

For water related adaptation options, we used criteria including technical, agro-ecosystem, institutional and socioeconomic feasibility. According to Bhave et al. (2014), these criteria sets are essential in evaluating water related adaptation options. As a result, technical feasibility–refers to water requirement, water supply benefits, agricultural water, technological feasibility, change in surface ground water storage, risk reduction, and efficiency/effectiveness; agroecosytem feasibility – related to increased ecosystem resistance and resilience, and environmental benefit; institutional feasibility refers to ease of implementation, and institutional capacity; and socioeconomic feasibility, refers to stakeholders acceptability, scale of beneficiary, intangible benefits, social benefits, implication in reducing vulnerability, and strengthening adaptability (Bhave et al. 2014). The criteria score takes 1 to 4 points being four the highest feasible among others. More importantly, in this paper we give due emphasis to agroecosystem feasibility criterion, following the stakeholders' workshop and recommendations by UKCIP (2010) on context specific, and Füssel (2007) on relevance.

Regarding to the weights to a criterion, stakeholders can have different objectives depending on their personal values and on their socio-economic circumstances (See Palma et al. 2007). Palma et al. (2007) suggested the use of neutral weight to avoid such variation in perception of different stakeholders. However, we get an input on the importance of the selected criteria from stakeholders' workshop and previous studies (De Bruin et al. 2009) to introduce a weight to each criterion in our study. As a result, we give higher weights to importance and urgency indicating that these criteria are essential (De Bruin et al. 2009). With regard to the feasibility (applicability, affordability, and agro-ecosystem relevance) criteria, we follow the same approach and give highest weight to applicability and technical feasibility. In addition, the PROMETHEE method allows us for a wide variety of weights to be applied in an interactive manner and we later see the performance of options by changing the weight of agro-ecosystem relevance criterion. One can also test the performance of an option under varying weights and test the sensitivity to a change in weights. This can be done using the "weight stability interval" of PROMETHE II. The weight stability interval of PROMETHEE helps to study the stability and the robustness of the weight attached to a criterion. Table 5.2 presents actual weights used in the evaluation, and the weight stability interval of the top 3 ranked alternatives.

Table 5.2. Summary of criteria and weight stability interval for top 3 ranked alternatives

Options related to	Criteria	Actual weights used (%)	Weight stability interval (WSI) in %	
			Max	Min
Agricultural	Applicability	50	58.28	26.09
	Affordability	25	50.00	00.00
	Ecosystem relevance	25	44.19	17.24
	Importance	40	61.29	33.33
	Urgency	30	33.96	14.29
	No regret	10	20.88	6.25
	Ancillary benefit	10	12.50	00.00
	Mitigation	10	27.74	5.26
Natural Resource Management	Importance	20	29.41	6.67
	Urgency	20	39.62	17.65
	No regret	20	25.00	00.00
	Ancillary benefit	20	25.00	00.00
	Mitigation	20	33.33	7.69
Water resources	Technical feasibility	30	42.04	23.91
	Agro-ecosystem feasibility	40	47.06	31.43
	Institutional feasibility	20	23.81	00.00
	Socioeconomic feasibility	10	23.17	4.55

The stability intervals indicate the range in which the weight of a criterion can be changed without altering the ranking results. The criteria and weights adopted in this paper have, therefore, empirical relevance, because we confirm their relevance through literature, stakeholder workshop, and finally using the weight stability interval in Table 5.2.

5.5.2 "Uni-criterion" analysis and outranking results

In this section, we present the performance of each adaptation option under each criterion evaluated by farmers and experts. Tables 5.3a and 5.3b present the uni-criterion performance of agricultural adaptation options. As explained in section 5.2, agricultural adaptation options are ranked and compared based on the feasibility (applicability, affordability and agro-ecosystem relevance), and importance, urgency, no regret, ancillary and mitigation criteria. Accordingly, in Table 5.3a improved varieties perform highest in affordability and agro-ecosystem relevance, and least in applicability criteria. Farming implements perform least in applicability and highest in agro-ecosystem relevance. This is in line with the suggestions made by Temesgen et al. (2012) in which farmers are willing to adopt conservation tillage- a farming implement developed specifically to the upper Blue-Nile basin. Over all, we can say that each adaptation option performs differently under different criterion; hence the selection of adaptation options evidently depends on the evaluation criteria applied.

Table 5.3a. Uni-criterion performance of agricultural adaptation options under feasibility (applicability, affordability and agro-ecosystem relevance) criteria

Options	Criteria		
	Applicability	Affordability	Agro-ecosystem relevance
Improved varieties	0.5000	1.000	1.000
Crop rotation	1.000	0.7143	-0.1429
Composting	0.8571	0.8571	-0.2857
Change in fertilizer use method	0.7143	0.4286	-0.4286
Water shed management	0.5000	-0.0714	0.0000
Farming implements	-0.3571	0.5714	0.8571
Introducing new harvest periods	0.0000	0.1429	0.1429
Use of pesticides	0.2857	0.2857	-0.8571
Integrated farming	-0.1429	-0.4286	0.5714
DAP and urea application	0.1429	-0.2857	-0.5714
Modification of crop calendar	-0.9286	0.0714	0.7143
Terracing	-0.5714	-0.5714	0.4286
Storing technology	-0.3571	-0.7143	-0.7143
Reduce tillage	-0.9286	-1.000	0.2857
Budding	-0.7143	-0.8571	-1.000

Table 5.3b presents the uni-criterion performance of agricultural adaptation options under importance, urgency, no-regret, ancillary and mitigation criteria. Accordingly, crop rotation performs highest in importance and least in ancillary benefits. Use of farming implements as an adaptation option performs highest in importance and urgency, and least in no regret criterion. Reduced tillage performs highest in

mitigation, and least in importance criterion. Terracing performs highest in urgency and no regret and least in mitigation criterion.

Table 5.3b. Uni-criterion performance of agricultural adaptation options under importance, urgency, no regret, ancillary and mitigation criteria

Options	Criteria				
	Importance	Urgency	No regret	Ancillary	Mitigation
Crop rotation	1.000	0.4286	-0.1429	-1.000	0.3571
Farming implements	0.7143	0.7143	-0.8571	0.0000	0.0714
Integrated farming	0.8571	0.2857	-0.2857	-0.4286	-0.1429
Terracing	0.4286	1.000	1.000	0.0000	-0.7143
Water shed management	0.0000	0.5714	-0.5714	-0.2857	0.6429
Chang fertilizer use methods	0.2857	0.1429	0.4286	0.2857	-0.8571
Composting	0.5714	0.0000	-0.7143	-0.8571	0.6429
Intro. New harvest period	0.1429	-0.1429	0.8571	0.1429	-0.4286
DAP and urea application	-0.2857	0.8571	-0.4286	-0.5714	-0.5714
Budding	-0.4286	-0.2857	0.2857	0.5714	0.3571
Modification of crop calendar	-0.1429	-1.000	0.7143	0.9286	-0.2857
Use of Pesticides	-0.6429	-0.4286	0.1429	0.9286	0.0714
Reduce tillage	-0.9286	-0.5714	0.5714	0.7143	0.8571
Storing technology	-0.9286	-0.7143	1.000	0.4286	1.000
Improved varieties	-0.6429	-0.8571	-1.000	-0.1429	-0.7143

Terracing has long been practiced in the study area, yet ever increasing intensity of farming (Simane et al. 2014), a fragile environment and climate change in the Upper Blue-Nile basin highlights the importance of terracing.

We argue that evaluation of climate change adaptation options should be seen from agro-ecosystem relevance and feasibility point of view (see Füssel (2007) on relevance of a criterion and UKCIP (2010) on context specificity of a criterion). PROMETHEE II also enables us to use a wide variety of weights in an interactive manner. We accordingly further change the weight of agro-ecosystem relevance to 50%, as an example[24], and identify which adaptation options perform best. Improved varieties, farming implements and modification of crop calendar are ranked highest under agro-ecosystem relevance criteria. The outranking results of the uni-criterion evaluation procedure shows that improved varieties do not work to all agro-ecosystems, and stakeholders claimed that blanket type technology disregards agro-ecosystem characteristics. Hence, the development of improved varieties should consider agro-ecosystem relevance of a technology. Conservation tillage in the form of improved farming implements are also suggested in studies by Temesgen et al. (2012). Temesgen et al. (2012) have also identified that farmers in the Upper Blue-Nile basin are willing to adopt improved farming implements. Furthermore, change in crop calendar becomes an adaptation options due to an ever changing weather patterns in the study area.

[24] Many different choices are possible and can be easily implemented in PROMTHEE II. The systems is available on request and users then can analyse the impacts of different sets of weights.

In Table 5.4a we present the performance of adaptation benefits of NRM under importance, urgency, no regret, ancillary and mitigation evaluation criteria; while in Table 5.4b, we present the performance of water related adaptation options under technical feasibility, feasibility in terms of agro-ecosystem relevance, institutional feasibility, and socioeconomic feasibility criteria.

Table 5.4a. Uni-criterion performance of adaptation benefits of NRM

NRM option	Criteria				
	Importance	Urgency	No regret	Ancillary	Mitigation
Carbon sequestration	1.000	0.7778	1.000	-1.000	0.3333
Max. water retention	0.5556	0.3333	-0.5556	-0.7778	-0.2222
Max. crop yield	-0.5556	1.000	0.1111	-0.1111	0.5556
Temperature regulation	0.7778	1.000	-0.3333	1.000	-0.7778
Min. conflict over resources	0.3333	-0.1111	-0.1111	0.1111	-1.000
Min. risk of pest harbouring	-0.1111	-0.3333	0.3333	0.3333	0.1111
Enhance soil fertility	0.1111	0.1111	-0.7778	-0.3333	-0.5556
Min. soil losses	-0.3333	0.5556	-1.000	-0.5556	-0.2222
Agro forestry	-0.7778	-0.5556	0.7778	0.5556	0.7778
Max. fodder production	-1.000	-0.7778	0.5556	0.7778	1.000

From Table 5.4a, we can see that carbon sequestration[25] performs highest in importance criterion and least in ancillary benefits. Agro-forestry and maximizing fodder production, on the other hand, perform highest in mitigation criterion and least in importance criterion. In addition to adaptation benefits like agro-forestry and fodder production can help mitigate climate change through the carbon sink functions (see for e.g. Albrecht, and Kandji 2003).

Table 5.4b. Uni-criterion performance of water related adaptation options

Water related options	Criteria			
	Technical feasibility	Agro ecosystem. feasibility	Institutional feasibility	Socio-economic feasibility
River diversion	0.9000	0.8000	-0.6000	0.6000
Prevent leaching and erosion	0.6000	0.4000	0.4000	0.6000
Drip irrigation	-0.4000	1.000	1.000	-0.8000
Water allocation rules	0.2000	0.0000	0.2000	0.6000
Use water evicting technologies	0.9000	-0.6000	0.7000	-0.4000
Hand dig pumping	0.4000	0.4000	0.0000	0.0000

[25] Carbon sequestration was explained to famers as a way out mechanism to the increase in temperature. It was observed that previously highland and temperate areas having cold and moderate temperature are now changed in to sub-tropical zones.

Water efficient technologies	0.0000	-0.2000	-0.3000	0.2000
Water harvesting	-0.2000	0.2000	-0.3000	-0.2000
Planting trees with high water store capacities	-0.6000	0.6000	-0.8000	-1.000
Use of surface and ground water	-0.8000	-0.8000	0.7000	-0.6000
Cash crops using irrigation	-1.000	-1.000	-1.000	1.000

In Table 5.4b, where the uni-criterion performance of water related adaptations are compared, drip irrigation performs highest in agro-ecosystem and institutional feasibility criteria and least in technical and socio-economic feasibility. It is evident that drip irrigation involves both cost and technical considerations. However, under sound institutional arrangements and considering the relevance of the technology to the specific agro-ecosystem, it is possible to enhance the uptake of drip irrigation technologies (see for e.g. FAO 2011). River diversion performs highest in technical feasibility and agro-ecosystem, and least in institutional feasibility. In the study area, we observed that sound water allocation rules are non-existent and there is frequent conflict over water user rights.

We also compare water related adaptation options performance under the agro-ecosystem feasibility criterion. Drip irrigation, river diversion, and use of surface and ground water perform highest under the agro-ecosystem feasibility criterion (ranked 1 to 3). The presence of abundant rivers, underground and surface water bodies in the Upper Blue-Nile basin makes these three prioritized options feasible in terms of agro-ecosystem relevance. FAO (2011) has also shown that climate smart technologies deserve to be viewed from the water lens so that sustainable NRM and emission reduction would be possible. Nigussie et al. (2016), on the other hand, found that the presence of sound irrigation practices (like river diversion, drip irrigation and use of surface and ground water) have created an enabling environment for the adoption of high yield crop and livestock varieties.

5.5.3 Ranking of adaptation options

5.5.3.1 Out ranking results of adaptation options by farmers and experts jointly

In this section, we present the complete outranking results of adaptation options. Each adaptation option is ranked based on the overall performance under Equation 5.5. The net flow preference ranking of adaptation options is indicated in Tables 5.5 and 5.6. In Table 5.5, we present the out ranking results of agricultural adaptation options evaluated by feasibility (applicability, affordability and agroecosystem relevance), and importance, urgency, no regret, ancillary and mitigation criteria. The results show that crop rotation and watershed management adaptation options have taken a rank from 1 to 5 in both criteria settings. Watershed management is seen as both a food security and climate change adaptation strategy in Ethiopia (Habtamu 2011), hence the ranking results in both criteria settings assures that watershed management is both highly important and feasible. Crop rotation is also found both highly feasible and important, because in the upper Blue-Nile basin, there is an ever increasing land degradation and poor soil fertility. Crop rotation is identified as the only cost efficient adaptation option in this context.

Outranking results by the feasibility (applicability, affordability and agro-ecosystem relevance) criteria are shown in Table 5.5. Table 5.5 shows that improved varieties, crop rotation and composting are ranked from 1 to 3; while in the importance, urgency, no regret, ancillary and mitigation criteria, crop rotation, farm implements, and integrated farming are ranked from 1 to 3. The outranking results based on the two criteria sets, in general, show that prioritized agricultural adaptation options refer to soil and land management issues. Temesgen et al. (2012) indicated that modern farm implements like conservation tillage improves crop production, and Teshome et al. (2014) recommends soil and water conservation practices on slope categories in the highlands of Ethiopia.

Table 5.5. Out ranking results of agricultural adaptation options

Options	Criteria			
	Feasibility (Applicability, Affordability and Agro-ecosystem relevance)		Importance, Urgency, No regret, Ancillary and Mitigation	
	Rank	Phi	Rank	Phi
Improved varieties	1	0.7500	15	-0.7000
Crop rotation	2	0.6429	1	0.4500
Composting	3	0.5714	7	0.1357
Change in fertilizer use method	4	0.3571	6	0.1429
Water shed management	5	0.2321	5	0.1500
Farming implements	6	0.1786	2	0.4214
Introducing New harvest per.	7	0.0714	8	0.3429
Use of Pesticides	8	0.0000	12	-0.2714
Integrated farming	9	-0.0357	3	0.3429
DAP and urea application	10	-0.1429	9	-0.0143
Modification of crop calendar	11	-0.3036	11	-0.2214
Terracing	12	-0.3214	4	0.3000
Storing technology	13	-0.5357	14	-0.3429
Reduce tillage	14	-0.6429	13	-0.3286
Budding	15	-0.8214	10	-0.1357

Generally, comparison of the two net flow tables shows that the feasibility (applicability, affordability and agro-ecosystem relevance) criteria conflicts with importance, urgency, no regret, ancillary and mitigation criteria, excluding watershed management and modification of crop calendar adaptation options which have the same outranking result in both criteria sets. An alternative which performs highest in feasibility performs least in importance, urgency, no regret, ancillary and mitigation and vice-versa.

In Table 5.6, we present the out ranking results of adaptation benefits of NRM. Benefits like carbon sequestration (ecological benefit), maximizing water retention (ecological benefit), and maximizing crop yield (economic benefit) ranked from 1 to 3. Studies by Simane et al. (2012, 2013, and 2014) indicated that ecological disturbances in the upper Blue-Nile basin are increasing and alarming, and suggested a strategy to focus on rehabilitation of the ecology. The priority ranks are therefore confirming this claim.

The third category of adaptation options identified in the upper Blue-Nile basin are water related adaptation options. The PROMOETHEE II complete outranking result shows that river diversion, prevent leaching and erosion, and drip irrigation are ranked from 1 to 3.

Table 5.6. Outranking results of water and NRM related adaptation options

Water related adaptation option	Rank	Phi	NRM adaptation options	Rank	Phi
River diversion	1	0.5300	Carbon sequestration	1	0.6667
Prevent leaching and erosion	2	0.4800	Max. water retention	2	0.2000
Drip irrigation	3	0.4000	Max. crop yield	3	0.0556
Water allocation rules	3	0.1600	Temperature regulation	4	-0.0222
Use water evicting technologies	5	0.1300	Min. conflict over resources	5	-0.0444
Hand dig pumping	6	-0.0400	Min. risk of pest harbouring	6	-0.1111
Water efficient technologies	7	-0.0600	Enhance soil fertility	7	-0.1111
Water harvesting	8	-0.1200	Min. soil losses	8	-0.1778
Planting trees with high Water store capacity	9	-0.2000	Agro forestry	9	-0.2111
Use of surface and ground water	10	-0.4800	Max. fodder production	10	-0.2444
Cash crops using irrigation	11	-0.8000			

These priority ranks are related to climate smart agricultural practices suggested by FAO (2010). FAO (2010) indicate that climate smart agriculture can sustainably increase productivity and system resilience while reducing greenhouse gas emissions.

5.5.3.2 Outranking results of experts' evaluation

In a smallholder economy, policies and programs are mostly designed in a top to down approach, and without consultation of farmers. It is, hence, essential to present the evaluation results made only by experts, and compare it with the evaluation results made by both farmers and experts. Appendices Table 1A and Table 1B present the PROMETHEE II outranking results of experts' evaluation. Comparing the rankings made by both farmers and experts jointly (section 5.5.3.1) with the evaluation made only by experts, we observe that there is difference in rankings. The differences in priority ranks solely arise from the difference in preferences of farmers and experts[26]. For instance, farmers and experts jointly rank crop rotation first as an agricultural adaptation option, while experts rank it second under the feasibility (applicability, affordability and agro-ecosystem relevance) criteria. Overall, one can argue that the evaluation result of the pooled data (farmers and experts) would give better implication in policy making because it contains the preferences of both groups. Results will depend on the numbers of each category represented in the pooled data.

[26] This is to recall that in the pooled data, there are only 30 experts, and the remaining 145 are farmers.

5.6 Concluding remarks

Identification and ranking of adaptation options in a country like Ethiopia have dual benefits: food security and adaptation to the negative impacts of climate change. In Ethiopia, it was projected that climate change will result in rainfall fluctuation and seasonal variation in patterns as well as high and low-temperature episodes. Because of the country's vulnerability to weather variability and low adaptive capacity, the current (2016) El-Niño affects about 15 million Ethiopians causing loss of livestock and crop failure. Though, there are micro level, fragmented and uncoordinated interventions, there are still limitations in terms of inclusiveness, participation and consensus among different parties who have a stake on climate change. It therefore requires to design an approach that brings stakeholders together and prioritize actions based on some agreed criteria. As part of this effort, this chapter tried to identify possible adaptation options from agriculture, natural resources, and water resources and rank them based on their performance on possibly conflicting criteria. Data was generated through stakeholders' workshop and a survey of farmers and experts. In combination with literature study, the stakeholder's workshop helped us to identify possible adaptation options, existing challenges, limitations and vulnerable natural resources; while we used the survey to rank and compare the different adaptation options. To analyse the data, PROMETHEE II complete outranking approach was used. PROMETHEE II helps to compare and outrank different adaptation options with an interactive feature and to test the sensitivity of weights (Brans and Mareschal 2005).

The findings from the stakeholders' workshop indicate that soil, and water resources are identified as the most vulnerable natural resources and identified as priority settings in the upper Blue-Nile basin. Stakeholders have also stressed the importance of agroecosystem specific interventions, which are preferred over a standard "blanket system". A blanket system according to experts is a technology package that is designed without considering the specific agro-ecosystem characteristics and relevance to the society at large. Stakeholders have also identified soil as the most vulnerable natural resource followed by water resources and forests. Lack of finance, awareness and motivation of farmers, population pressure, land fragmentation and encroachment, improper land use, inappropriate settlement, inability to reach consensus on matters which are crucial in climate adaptation, lack of follow up and upscaling efforts made at pilot level, lack of demonstration centers, short-term benefit seeking are also identified as the main contributing factors to mal-adaptation in the upper Blue-Nile basin.

We analysed and summarized the results of the outranking procedure in order to support decision makers in the process of adaptation to climate change. The top five ranked agricultural adaptation options evaluated based on the feasibility (applicability, affordability and agroecosystem relevance) criteria are *improved varieties*, *crop rotation*, *composting*, *change in use of fertilizer methods,* and *watershed management.* However, there is a reversal in the rank when the evaluation criteria are changed into importance, urgency, no regret and mitigation. This shows that the two criteria choices are conflicting, and evaluations made in such a manner can give better information to decision makers, i.e. whether feasibility (applicability, affordability and agroecosystem) or importance, urgency, no regret and mitigation benefits of adaptation options are most important to the upper Blue-Nile basin.

Adaptation of natural resources management practices in response to climate change and food insecurity have a list of benefits. The benefits have been evaluated and a preference ranking was made. Ecological importance of NRM like *carbon sequestration*, *maximizing water retention*, *regulating temperature* and *minimizing conflict over resources,* and economic benefit like *maximizing crop yield* are the top five ranked adaptation options. In the priority ranking, ecological benefits of NRM have dominated the economic benefits. According to Simane et al. (2012), there is frequent ecological disturbance in the upper Blue-Nile basin due to high population pressure accompanied by deforestation and land degradation.

Water resources are also fundamental livelihood bases in the process of climate adaptation to climate change under a smallholder economy. Water resources are mostly used as a way out mechanism under stressor climatic conditions. The study area is known as the home of many rivers and streams. Possible adaptation options related to water resources are, then, ranked and evaluated based on technical feasibility, agro-ecosystem feasibility, institutional feasibility and socioeconomic feasibility. *River diversion*, *prevention of leaching and erosion*, *drip irrigation*, *water allocation rules*, and *use of water evicting technologies* are accordingly the top five ranked adaptation options. These rankings are in line with the agro-ecosystem characteristics of the study area found in Simane et al. (2012) and the recommendation made by FAO (2013) on climate smart agriculture. Interventions to arrange for water user rights and allocation rules are also encouraged to be in place.

To compare the outranking results made by both farmers and experts, and only by experts, we report separate outranking results. The two outranking results informed us that there are differences in the order of rankings of adaptation options. The differences in priority ranks mainly arose from the deviation in preferences between farmers and experts. This reveals that joint evaluation is necessary to have an optimal preference ranking incorporating the evaluations made by farmers and experts.

Conclusion from this MCA study follows that the upper Blue-Nile basin is currently faced multifaceted stressors. Population pressure, land use change, deforestation coupled with climate change and variability are among the list of challenges that the upper Blue-Nile basin is facing. It is hence imperative to focus and target on adaptation options that are relevant to the specific agroecosystem. Reaching a consensus on the type of criteria (feasibility or importance, urgency, no regret, ancillary and mitigation) that should be used to evaluate adaptation opitons, and avoiding a blanket type intervention would also be essential in the successful implementation of adaptation options.

Recommendations towards future climate change adaptation and mitigation include avoidance of fragmented and independent actions by different sectors; previous programs and interventions, according to the results of this chapter, lack greater collaboration, inclusiveness and comprehensiveness. It is hence essential to put a priority rank for policies and strategies which have been prescribed through micro and macro studies through stakeholders' workshop, dialogue and evaluations. Putting the agenda in to the stakeholders' perspective can help fasten the pace of innovation uptake. In addition, scenario based ranking of climate change adaptation is recommended provided that there is accurate climate scenarios in developing countries. In this chapter, we managed to have sufficient lists of adaptation options in the upper Blue-Nile basin for an empirical examination; however, we did not have an inventory list for other regions in Ethiopia or at the national level. Hence, further studies are required to have a full inventory of adaptation options in Ethiopia.

Appendix

Table A1. Out ranking results of experts' evaluation of agricultural adaptation options

	Under feasibility (applicability, affordability, and agro-ecosystem criteria)				Under importance, urgency, no regret, ancillary and mitigation criteria			
Rank	Adaptation option	Phi	Phi+	Phi-	Adaptation option	Phi	Phi+	Phi-
1	Crop rotation	0.3750	0.4464	0.0714	Improved varieties	0.5857	0.6000	0.0143
2	Storing technology	0.3750	0.4464	0.0714	Watershed management	0.3429	0,4786	0.1357
3	Use of pesticides	0.3750	0.4464	0.0714	Use of pesticides	0.3429	0.4786	0.1357
4	Farming implements	0.1786	0.3036	0.1250	Crop rotation	0.1714	0.3857	0.2143
5	Modification of crop calendar	0.1786	0.3036	0.1250	Farming implements	0.1429	0.2643	0.1214
6	Improved varieties	-0.0893	0.0893	0.1786	Composting	0.1429	0.2643	0.1214
7	Watershed management	-0.0893	0.0893	0.1786	Integrated farming	0.1429	0.2643	0.1214
8	Composting	-0.0893	0.0893	0.1786	Chang fertilizer use methods	0.1429	0.2643	0.1214
9	DAP and urea	-0.0893	0.0893	0.1786	Terracing	0.0571	0.2286	0.1714
10	Budding	-0.0893	0.0893	0.1786	Modification of crop calendar	0.0571	0.2286	0.1714
11	Integrated farming	-0.0893	0.0893	0.1786	Budding	-0.2857	0.1214	0.4071
12	Intro new harvest per	-0.0893	0.0893	0.1786	Storing technology	-0.2857	0.1214	0.4071
13	Chang fertilizer Use methods	-0,0893	0.0893	0.1786	Intro new harvest period	-0.4857	0.1429	0.6286
14	Reduce tillage	-0.2679	0.2500	0,5179	Reduce tillage	-0.5071	0.0429	0.5500
15	Terracing	-0.5000	0.2143	0.7143	DAP and urea	-0.5643	0.1071	0.6714

Table A2. Outranking results of experts' evaluation of NRM adaptation options

Rank	option	Phi	Phi+	Phi-
1	maximize fodder production	0.7556	0.7889	0.0333
2	Agro forestry	0.2111	0.4111	0.2000
3	Minimize soil losses	0.1111	0.3667	0.2556
4	enhance soil fertility	-0.0444	0.3111	0.3556
5	Maximize crop yield	-0.0778	0.3000	0.3778
6	maximize water retention	-0.1000	0.2889	0.3889
7	carbon sequestration	-0.1222	0.1778	0.3000
8	Minimize risk of pest harboring	-0.1222	0.1778	0.3000
9	Minimize conflict over resources	-0.2556	0.2111	0.4667
10	temperature regulation	-0.3556	0.1111	0.4667

Table A3. Outranking results of experts' evaluation of water resources related adaptation options

Rank	option	Phi	Phi+	Phi-
1	Prevent leaching and erosion	0.4600	0.4700	0.0100
2	water harvesting	0.2400	0.2700	0.0300
3	river diversion	0.1600	0.2000	0.0400
3	cash crops using irrigation	0.1600	0.2000	0.0400
5	hand dig pump	0.1600	0.2000	0.0400
6	Water allocation rules	0.1600	0.2000	0.0400
7	drip irrigation	0.0400	0.1700	0.1300
8	Water efficient technologies	-0.2800	0.0800	0.3600
9	Water storing trees	-0.3600	0.1500	0.5100
10	use of surface and ground water	-0.3700	0.0600	0.4300
11	Use water evicting technologies	-0.3700	0.0600	0.4300

Chapter 6

General discussions and conclusions

6.1 Introduction

The threat of climate change to developing countries attracted many scientists and scholars to invest their time and effort to find out possible adaptation options. Accordingly, in the literature, challenges and barriers of adaptation and mitigation to climate change are identified. As part of this global effort, we need to improve our understanding of decisions related to adaptation to climate change by examining the behavioural, social, ecological, and agro-ecosystems' factors that determine decisions related to adaptation to climate change. Decision theory focuses on the behavioural mechanisms in relation to individuals' and social preferences. The understanding of behavioural mechanisms for public policy making and development programs is receiving more and more attention. This provides the opportunity to understand behavioural mechanisms in decisions related to adaptation to climate change. The thesis studies economic decision making on climate change adaptation by looking at behaviour of smallholder farmers in a developing country, Ethiopia.

To understand the behavioural mechanisms in decision related to adoption of climate innovations, we generated data using lab-in-the-field experimental approaches combined with a survey, focus group discussion, and a stakeholders' workshop. The thesis focused on understanding the complex interactions that undergird the relationship between climate innovation adoption and behavioural and personality factors. It also studied the linkage between the different stages of technology adoption, i.e. information acquisition, learning from social groups and networks, and adoption decisions. The thesis also gave a prioritization rank of adaptation options based on stakeholders' survey.

Finally this chapter draws conclusions from the results of the different chapters of the thesis and puts them in a wider context. Behavioural mechanisms like risk and time preferences, social norms, and personality traits affect the process of innovation uptake as a response to the serious threat of climate change to developing countries. The process of climate change adaptation is a complex and dynamic phenomenon going beyond the scope of conventional economics. Behavioural economics can assist to understand the challenges posed by climate change by relaxing the behavioural assumptions found in rational choice theory. The following sections present the main findings from each chapter and related key debates in the literature on the topic, discussing their implications for both policy and future research.

6.2 Answers to the research questions

6.2.1 What behavioural factors determine decisions related to adoption of climate innovations in a smallholder economy?

The importance of understanding social and individual preferences from environmental and social changes perspectives is growing (see Iversen 2001; Guiso and Paiella 2008). In this regard, economics science is becoming so fortunate to combine both field and laboratory experiments. Experimental approaches were for a long time almost absent in economics, but attention is now growing and experiments are becoming an important tool to understand the principles which govern economic decision behaviour (see Plott 1991; Gneezy and List 2006; Gneezy and List 2006). New insights from behavioural economics help to solve some of the puzzles that remain in conventional economics.

So far, experts and policy makers were prescribing innovation packages for smallholder famers through understanding of socioeconomic, demographic, and natural resources determinants. Repeated failures in innovation (Rogers and Shoemaker 1971; Reynolds 1988; UNDP/FAO 1988) underline the importance of understanding risk and time preference of farmers (Brekke and Johansen-Stenman 2008). Risk of failure of a technology accompanied by low applicability, affordability and relevance (see Gibbons 2004 and Choi et al. 2010), and the importance of time preferences in some technologies (Liu 2013) undermine the relevance of previous approaches. Many studies (e.g. Lusk and Coble 2008; Klemack and Yesuf 2008; Yesuf and Bluffstone 2009) have tried to address issues of risk and time preferences using simple gambles and mostly in a laboratory setting using student subjects. Later, more attention was given to the application of different forms of experimental settings including lab-in-the-field experiments by drawing participants directly involved in the domain of the analysis (see for e.g. Ihli et al. 2013; Liebenehm and Waibel 2015).

Chapter 2 focused on the risk and time preferences of smallholder famers to comprehend the adoption of climate innovations in Ethiopia. In developing countries, the innovation uptake tends to be slow and has consequently often resulted in technology failure. We tried to understand climate innovation adoption decision behaviour by examining farmers' risk and time preferences in a lab-in-the-field experimental setting. In Ethiopia, demographic and socioeconomic characteristics like age, wealth, education and ownership of assets are identified as important factors in decisions related to the adoption of farm technologies (see for e.g. Pender and Gebremedhin 2007; Deressa et al. 2009; Gebregziabher et al. 2014). There are also some studies which tried to address risk and time preferences using simple gambles and game plays (see for e.g. Yesuf and Bluffstone 2009; Klemack and Yesuf 2008). In this regard, we need to improve our understanding on behavioural mechanisms in decisions related to climate innovation adoptions, and interpret the results. Chapter 2 makes a contribution to the literature on innovation adoption through a better understanding of risk and time preference behaviour using multiple price elicitation exercises in a lab-in-the-field experiment.

Starting from the works of Binswanger (1980), different experimental elicitation methods have been introduced to arrive at risk and time preference parameters. The Holt and Laury (2002) multiple price elicitation exercise experimental approach often used to capture risk and time preference parameters of individuals. Under multiple elicitation exercises, subjects are exposed to a situation of decision making that involves both risk and time preferences. We employed a multiple price elicitation exercise to estimate subjects' risk and time preference parameters, and further tried to understand the implications on decisions related to climate innovations adoption.

From the experimental results we found that famers are highly risk averse, and have high rate of time preferences. The average risk aversion parameter and discount rate of smallholder farmers found in Chapter 2 are *0.57* and *0.58 (58 percent)* respectively. The results conform to the results of previous studies in developing countries (see Yesuf 2009; Ihli et al. 2013; Liebenehm and Waibel 2015). The experimental results have led us to a greater understanding of adoption of climate innovations as part of the larger food security and climate change adaptation objectives in developing countries. We accordingly framed adaptation decisions into three main categories: (i) Farm related, (ii) Off farm, and (iii) Institutional climate innovations. In the multivariate probit (MVP) model, we found evidence that high risk aversion and high rate of time preference parameters elicited in the field-in-the-lab experiment negatively and significantly influence smallholders' decisions to adopt farm related climate innovations. Furthermore, individuals' high rate of time preferences influence adoption decisions related to off-farm climate innovations positively and significantly. Farmers might need to allocate their effort and time to opportunities that bring immediate benefit (off-farm opportunities) than investments in farm related innovations which involve time and allocation of resources.

In standard economics, risk preferences and endogenous time preferences are considered as fixed characteristics of individuals. Recently, there is growing evidence showing that preferences are evolving over time (see Druckman and Lupia 2000). To confirm the hypothesis and further understand whether institutional aspects affect risk aversion and high rate of time preferences, we further interpreted results by estimating risk and time preference parameters under homogenous and heterogeneous agent case. The later estimation results helped us to understand how the different socioeconomic, demographic, institutional, and agro-ecosystem characteristics are explaining risk and time preferences of individuals'. Accordingly, the EUT CRRA estimates of the risk aversion parameter indicate that institutional arrangements like credit access significantly and positively determine the risk aversion parameter. We also considered how shocks (drought and flood experience) and location (representing differences in agro-ecosystems) are correlated with risk behavior. The correlation coefficient between risk loving behavior and location dummy "Machakil" is strong *(0.317*) compared to other locations. Socioeconomic and demographic variables are also found important in determining risk aversion parameter. Sex, age, family size and income are found significant in the first stage OLS regression of the risk aversion parameter. With regard to individual rate of time preference, we find that there is low correlation between individual rate of time preference and willingness to invest on tree planting (0.177) and water harvesting (0.194) as an adaptation option.

6.2.2 How do personality traits, learning, and recursive relationship of innovations determine adaptation decision to climate change?

In Chapter 3, we extended the analysis of Chapter 2 to further understand how formal and informal local institutions such as social groups (e.g. the group of homophilic adopters) and social networks facilitate learning. We also dealt with individuals' personality traits, because personality traits would possibly affect individuals' information search and inquiry process to further aid decision makings (see De Raad and Schouwenburg 1996). Learning from social groups and social networks, in combination with personality traits, are expected to play an important role in decisions related to climate innovation adoption. In addition, we studied how farm related technologies are related recursively, i.e. whether the adoption of one technology creates an enabling environment to the adoption of another.

Learning and experience sharing from social groups and social networks can change the high risk aversion and rate of time preference behaviour observed in Chapter 2. The presence of stock of homophilic adopters and other stocks of adopters in a social network can create a platform for learning. People learn from their peers and neighbours either for a positive concern or negative concern (Fehr and Camerer 2005). Learning for a positive concern from social groups and networks can facilitate decisions to adopt climate innovations. People can also learn from the experience of past shocks. Learning behavior is dynamics and complex. A large body of literature is available on the different theoretical approaches of learning (see Elias 1997; Wilson 1997; Camerer and George 2003). Due to the methodological challenges and complexities in some of the learning theoretical approaches, the use of proxy measures is getting more and more attention in the literature. Lindner (1987) argued that firm level innovation adoption can be explained by proxies like costs of acquiring information, education level, distance to the nearest current adopter and availability of extension services. In Chapter 3, therefore, we used proxy measures of learning to understand decision making behavior.

The process of innovation adoption decision has distinct stages: information inquiry stage, persuasion, decision, implementation, and confirmation (Rogers 2003). The information inquiry stage is critical, because it opens the opportunity to acquire new skills and share experiences from social groups and networks. Accordingly, we focused on understanding how the information inquiry process is affected by one's personality traits. We further analysed how the interaction terms between personality traits and information inquiry influence decisions related to adoption of farm related adaptation options.

In Chapter 3, we interpreted results both from descriptive statistics and empirical models. We primarily analysed the correlation results between one's personality traits and the process to acquire information. For instance, the correlation analysis shows that willingness to participate in training is associated with the personality traits of high agreeableness, high cconscientiousness, and low openness. Extension contact regarding high yield varieties is related to high agreeableness, high emotional stability, high cconscientiousness and high openness. Extension contact regarding soil and water conservations (SWC) and environmental protection are related to low conscientiousness and high conscientiousness.

The findings from the different learning procedures (learning from past shocks, learning from hemophilic groups, and learning from adopters in a social group and network) show that there are different sizes of adopters for different technologies. The number of adopters of irrigation technologies in a social network is higher in the sampled farmer households than other technologies. In addition, inclusion of learning indicator variables indicating the size of adopters in a social group and network, and number of homophilic adopters of a particular technology (homophilic adopters of irrigation, SWC, and HYV) in the trivariate model results in a significant positive impact on the adoption decisions of farm level adaptation options.

The findings of the interaction terms between one's personality traits and information inquiry indicator variables had also been explained in the trivariate probit model. Interaction terms between agreeableness and extension service related to SWC (AGREE_EXTSOILC), emotional stability and extension service on environmental conservation (EMOTI_EXTENVI), and conscientiousness and extension service on environmental conservation (CONSC_EXTENVI) significantly determine adoption of farm related irrigation technologies. An interaction term between extraversion and extension service related to environmental conservation (EXTR_EXTENVI), significantly determine adoption of high yield crop and livestock varieties. An interaction term between extraversion and experience sharing (EXTR_EXPS) significantly determined adoption decision of SWC technologies. People with certain type of personality have different tendency towards information inquiry. Apart from the indirect influence through information inquiry process, personality traits could also have a positive or negative influence on decisions related to adoption of farm related climate innovations. For instance, high conscientiousness personality trait influences positively and significantly the adoption decision of SWC; high emotional stability influences adoption decision of irrigation technologies negatively and significantly; and high openness personality trait influence negatively and significantly the adoption of HYV.

In addition, we observed a recursive relationship of farm related technologies which is an additional contribution to the literature on innovation adoption. We found that the adoption of HYV depends on the a priori adoption of SWC technologies and irrigation technologies. Therefore, the findings shed light on the importance of recursive relationship of the three main farm related technologies. We stress that it is not only socioeconomic, demographic and behavioural factors that limit adoption decision but also the recursive relationship of technologies.

6.2.3 Do social norms and ecological variables determine cooperative behaviour of smallholder farmers in the climate resilient management and use of common pool natural resources?

Synthesising the behavioural mechanisms with regard to climate innovation adoption is only addressing half of the impediments in the process of neutralizing climate change impacts in developing countries. Natural resources, directly or indirectly make up much of the livelihood structure of smallholder farmers in developing countries. However, open and common pool natural resources have frequently been affected by congestion and overharvesting (Ostrom 1990). They are characterized by non-excludability and exhaustibility. The mechanism that is suggested in the literature for the sustainable management and use of commons is organizing a cooperative local institution. The formation as well as the possibility of realizing local institutions in the management and use of commons has remained a debate in economics and other social sciences. The studies by Ostrom (1990) and Kimbrough and Vostroknutov (2015) have examined the hypothesis that social norms and ecological factors are key drivers limiting successful common pool governance. Game theoretic and behavioural economics approaches have so far been used to understand how local institutions are formed to sustainably manage and use common pool resources (CPRs). Cooperation in the case of commons is not only determined through material benefits, but also by social norms and preferences like rule following or breaking, and the ecological characteristics of the resources (see Ostrom 1990 and Kimbrough and Vostroknutov 2015). Ecological characteristics of the resources depend on climatic conditions, because climatic conditions have direct influence on re-growth of natural resources. Higher growth and replenishment rate may compensate the higher extraction efforts exerted by resource users.

According to Burns and Flam (1987), social norms are the rules of behaviour that are considered acceptable in a group or society. A society has both institutionalized and non-institutionalized rules embedded in the system. It is essential to understand individuals' social norms in order to plan for the formation of local institutions for the management and use of CPRs. Furthermore, understanding climate change impacts on the re-growth of CPRs and on cooperation behaviour would improve our understanding of the interactions that exist between the environment and society. Chapter 4, therefore, extends the findings under Chapters 2 and 3, and scales up our understandings on social preferences, social norms and the social role in the formation of cooperative local institutions. We also drew a conclusion on the possibility of carbon sinks by common pool forests and agricultural lands. There is an increasing tendency in developing countries in terms of higher greenhouse gas emissions due to deforestation and land use land cover changes. In addition, developing countries are recently following an ambitious growth strategy to counteract the increasing demand due to high population growth. The growth strategies are, however, contributing to higher greenhouse gas emissions largely, and predicted to increase in the near future (see Stern 2007).

We used lab-in-the-field experiments to understand social norms (rule following behaviour) and cooperative behaviour in the management and use of commons. We conducted a "route choice" and dynamic CPR experiment to comprehend on rule following and cooperative behaviour of smallholder farmers. Both games involved symmetric material incentives and information access. The dynamic CPR game was conducted under two treatments: favourable and unfavourable climate change scenarios.

Primarily, Chapter 4 attempted to understand the association between social roles and social norms (rule following and breaking) of subjects. Accordingly, we found evidence that subjects with a rule following social norm tend to depend more on their social role and their role as an elderly person. The number of rule breakers is larger in both non-elders and those having no role in the community. In the dynamic CPR game, on the other hand, groups of rule-followers preserve the resource indefinitely under sufficient re-growth of the resource due to favourable climate change. Comparison of effort endowment allocation to private activities over extraction of CPRs shows that there is a general higher effort allocation to private activities than extraction.

Furthermore, we run a regression analysis to further analyze the experimental findings. The regression analysis revealed that the average extraction levels of individuals are significantly influenced by social role and norm variables. In addition, variables like literacy level and age of individuals influence extraction rate positively and significantly. The significant influence of social role, elderly role, and norm indicator variables support our argument that sustainability of common pool resources depends on social role (leadership role in traditional community gatherings), elderly role, and social norm (rule following) behaviour of subjects.

The findings in Chapter 4 also gave us an explanation to the question posed in Chapter 2. In Chapter 2, we claimed that individual and social preferences are partly social and environmental constructs. Empirical findings in the literature suggested that preferences are ever changing and are partly social and environmental constructs (Druckman and Lupia 2000). Learning is possible through social groups and networks, because social interactions create an enabling environment for learning. We accordingly confirm this claim in Chapters 3 and 4. In Chapter 3, we found evidence that preferences like learning behaviour is shaped by social groups and networks. In addition, in Chapter 4 we understand that rule following behaviour is highly associated with social role and elderly role that an individual plays in the community. Social preferences like altruism and reciprocity behaviour can develop over time. Social roles and elderly roles can possibly enhance the positive concern (rule following) of one's social norms and preferences. The presence of rule followers in a local institution under favourable climate change can sustain common pool resources.

Understanding social norms and ecological variables in cooperative management of commons (Ostrom 1990) is the crucial first step in analyzing climate mitigation in forests and common pool agricultural lands. The possibility of climate change mitigation through carbon sinks on common agricultural and forested lands in developing countries was also highlighted in Chapter 4. Cooperative sustainable management of common agricultural and forested lands can improve the function as carbon sinks, possibly contributing to the global climate change mitigation effort.

6.2.4 What are the priority ranks of climate adaptation options in the Upper Blue-Nile basin?

Chapters 2, 3 and 4 of the thesis have devoted much time to identify the behavioural factors in decision related to climate innovation adoption, and cooperative CPR management in Ethiopia. In Chapter 5 we tried to understand climate change adaptation process from stakeholders' perspectives. To avail a technology package suitable to the interest of the beneficiaries, it needs a participatory opinion sharing and dialogue with groups representing decision makers from different backgrounds. Stakeholders can have valuable information about climate change adaptation and this can assist in prioritization and ranking. Screening adaptation options based on suitable and context specific criteria is only possible through participatory stakeholders' survey and evaluation. Selection of appropriate evaluation criteria is the first step in the process of stakeholders' level evaluation and analysis. Technology packages in developing countries are often not designed specific to a given agro-ecosystem. Sometimes such technology packages are referred to as [blanket] technologies, and they may not be suitable under different agro-ecological circumstances. Evaluation of adaptation options based on agro-ecosystem relevance criteria was considered in Chapter 5.

Stakeholders' based evaluation of climate change adaptation options has been the focus of many studies (see De Bruin et al. 2009; Bernardini 2010; Gough and Shackley 2006; Janssen and van Herwijnen 2006; Pearce et al. 2012; Debeles et al. 2009). Few et al. (2006) have underlined that stakeholders' level opinion and dialogue can help to plan climate change adaptation interventions. Accordingly, we analyzed experts and farmers evaluation of NRM, water related, and agricultural related adaptation options in the upper Blue-Nile basin. Adaptation options have been identified from previous studies, stakeholders' workshop, and from Chapters 2 to 4. The evaluation criteria are identified both from literature and stakeholders workshop. Relevance of the criteria to the context and sector was given emphasis in the analysis.

We come up with two rankings based on stakeholders' evaluation: uni-criterion and multi-criteria rankings. The uni-criterion based ranking results showed that adaptation options perform differently under different criterion. Adaptation options should therefore be viewed based on their performance under the different criteria sets. It is also important to consider adaptation options from the perspectives related to the objectives and expectations set by beneficiaries. The complete outranking results, on the other hand, resulted in a significant difference in priority rankings between evaluations made by experts only, and by both farmers and experts. The question remains as to which rankings we should follow. The great divergence in the evaluation results of the two groups partially gave us a potential explanation for the failure of previous technology packages. What is evaluated important by farmers may be less relevant to experts. For instance the highly ranked agricultural adaptation based on feasibility criteria set evaluated by farmers and experts jointly are improved varieties, crop rotation,and composting; while the highly ranked and evaluated options by experts are crop rotation, storing technologies, and use of pesticides. Joint evaluation, therefore, would offer an approach to reduce the polarity, because it incorporates views from both groups.

6.3 Discussion and missing elements

To facilitate climate innovation uptake and cooperative management of common pool natural resources, we tried to understand behavioural fundamentals, personality traits, social norms and roles, and the recursive relationship of different farm related technologies. We also tried to attest the list of identified adaptation options by stakeholders' survey and evaluation. This has been done throughout the chapters of the thesis; yet the institutional aspect and many other aspects that we still know little about are not yet fully covered. Institutional innovations are shown to be important for adaptation to climate change; and more importantly the findings in Chapter 2 highlight the importance of socioeconomic, institutional and agro-ecological shocks in the formation of preferences of individuals.

Institutional facilities like access to market can help to diversify income sources through availing alternative off-farm income sources to the rural poor. Farmers having access to markets can have alternative off-farm income sources which would help them reduce their dependency on subsistence farming. Availability of diversified income sources through the market mechanism can improve high risk aversion and high rates of time preference of farmers related to technology adoption (Yesuf and Kohlin 2008). Institutional support in terms of crop and livestock insurance are also recommended as an instrument to reduce risk aversion and high rates of time preference. For instance Greatrex et al. (2014) find that Index-Based Livestock Insurance (IBLI) project in Kenya and Ethiopia demonstrates innovative approaches to ensuring poor nomadic pastoralists in challenging circumstances. Absence of a well suited formal and informal financial institution also limits the pace of innovation uptake. Studies by Anang et al. (2015) have argued that the presence of micro and small scale lending and borrowing institutions inferred a positive influence on technology adoption. In addition, local formal and informal institutions can also act as a learning hub and centre for information sharing (Simane et al. 2012). It is hence essential to undertake a further systematic analysis of the institutional aspect to understand its influence on shaping preferences as well as facilitating climate innovation uptake. Framed and natural experiments can help understand how institutions facilitate preferences as well as decisions related adoption of climate innovations.

We also know little about learning behaviour. Learning behaviour takes many forms, and it is complex. To understand the complex human behaviour, it is important to follow an approach that can uncover the cognitive map of subjects. Studies related to neuroeconomics can shape our understanding of learning behaviour through a thorough analysis of the brain, and how neuroscientific discoveries guide models of economics related to decision making (see Fehr and Fischbacher 2005). Furthermore, behaviours like envy, reciprocity and altruism would have a direct influence on sustaining climate innovations. An experimental explanation of individuals' and communities' social preferences in a wider context would improve our understanding of climate innovations.

In Chapter 3 we tried to understand decision behaviour related to adoption of climate innovation. The possibility of learning through social groups, networks, and homophilic adopters are examined in Chapter 3. We also brought the concept of personality traits, in to the literature of climate innovation adoption. We hypothesized and tested how information inquiry is associated with one's personality traits. The psychological foundation of personality traits tells us that personality traits are constant throughout the life of an individuals'. There are, however, recent developments in the formation of personality traits. Fisher (2016) indicated that people are malleable; and if one needs to score high in one of the personality traits, it is possible to make progress by working hard on it. By understanding the personality of smallholder farmers, one can create a group by pairing them suit with their personality traits. Such an approach can sustain programs like climate change adaptation innovations. Development programs in developing countries involve the formations of groups such as water user groups, development groups, and work groups. In addition, we brought the importance of personality traits into understanding of innovation adoption through their influence on one's information inquiry process. Different strategies need to be devised to different groups based on their personality; because people have different tendancy towards the search and inquiry of informations. The personality foundation of innovation diffusion in developing countries needs further remark using larger data sets.

In Chapter 3, we also observed a recursive relationship between the different farm-related technologies. HYV are developed under a suited and controlled system. Practical challenges emerge during the diffusion stage of a technology. The variability in agro-ecosystem in terms of soil and natural resources characteristics hampers the adoption of HYV. Traditional agricultural management systems should combine with the use of agro-ecosystem based management strategies (According to Altieri and Nicholls 2013). Productivity, sustainability and resilience can best be achieved through agro-ecosystem based adaptation strategy. According to our results, improving soil and water conservation works, and irrigation technologies (some HYV need specific water (irrigation) and soil requirements (Ramamasy and Baas 2007)) can fasten the uptake of HYV. However, we believe that these results may bit be generally valid as there might be small sample bias. It gives an opportunity for further research to examine the relationship in a more comprehensive manner and using larger data sets.

Scenario based treatment of behaviour under varying and uncertain climate change is also indispensable. Studies on climate change are mostly based on scenarios, because climate change is slow and complex process and lot of things including human behaviour can change in many ways over time. Social and economic conditions are also dynamic which make it difficult to have accurate forecasts. Climate scenarios are recently published for the coming 100 years plus in many countries. In Ethiopia, however, there are limitations to having appropriate climate scenarios (Calow et al. 2013). Understanding cooperative behaviour under a set of specific established climate scenario would also be possible and can give a better outlook to understand climate adaptation and mitigation processes. Stakeholders' preference ranking under uncertainty and varying climate scenarios deserve further scrutiny in developing countries.

The findings in Chapter 5 gave us a wider understanding of priority setting and ranking of adaptation options in developing countries, and specific to the upper Blue-Nile basin in Ethiopia. It is imperative to assume that the sustainability of climate adaptation intervention can be gauged by the degree to which the different stakeholder's are taking part in the design, implementation, and evaluation stages of adaptation planning. Evaluating adaptation initiatives is important for tracking whether the identified options are feasible or important, urgent, no regret, ancillary or having mitigation benefits. This would have implication for successes and failures in climate innovation diffusions so that it would be possible to foster learning. Further more, it is evident that climate adaptation is often about integrating climate aspects into other policy fields, hence a criteria that assess the interlinkages between different policy objectives like noreget (co-benefits) and mitigation benefits are of particular importance.The involvement and participation of different groups in priority setting and evaluation criteria development of climate adaptation options, can thus be considered to be a prerequisite for achieving the objectives of creating a climate resilient smallholder economy. Future stakeholder level studies under varying climate change scenarios are possible provided that there are sound climate scenarios for Ethiopia and other developing countries.

6.4 Conclusions

Africa is vulnerable to future climate change and Ethiopia is often cited as one of the most extreme examples (Conway et al. 2007). Policies and strategies are already prescribed in different contexts to address climate change impacts in developing countries. As part of this effort, we need to improve our understanding of decision behaviour related to adaptation to climate change based on behavioural and experimental evidences. Thus, the thesis demonstrates the instruments to understand the behavioural factors underlying the process of adaptation to climate change in developing countries by a specific study for Ethiopia.

The fundamental challenges that limit the pace of adaptation have long been the subject of research. Adequate local adaptation requires the understanding of the interactions between the environment and society. Fundamental challenges like socioeconomic, demographics, and natural resource characteristics were identified as key factors for decisions on adaptation to climate change. Perspectives related to social and individual preferences, and the interactions with the environment need to be understood to design appropriate adaptation policies. This thesis adopted experimental based preference elicitation exercises to understand the relationship between preferences (social and individual) and decisions related to adaptations to climate change, and cooperative management of CPRs. We focus on three fundamental and interrelated decision problems in the process of adaptation to climate change: Decision problems at individuals level (farmers), cooperative level (group of farmers), and stakeholder' level (farmers and experts). In the thesis we argue that the success of adaptation effort depends on the level of understanding of these three decision problems. We were interested in the behavioural mechanisms that undergird decision problems related to climate change adaptation. The adaptation kit will always be incomplete if we fail to address one of the three decision problems. It was clearly shown that understanding individual behavioural mechanisms by itself is not sufficient; it should also be followed by a study to understand the environmental and social factors that contribute to the formation of preferences.

We follow an approach to understand individual level preferences, the mechanisms how preferences are formed, and approaches to unlock the negative concerns. We also entail to understand group behaviour through understanding cooperative management of commons, and stakeholder level decision making. The thesis accordingly, combined a list of interrelated experimental, survey, and stakeholders' evaluation methods to generate data and address the research problems envisaged in each chapter. Accordingly, the conclusions are formulated as follows:

- Climate change adaptation involves choices which involve both risk and time preferences; and these preferences can be explained using behavioural economics (Brekke and Stenman 2008). We followed an experimental approach to elicit risk and time preference behaviour and linked the results in decision related adoption of climate innovations. We accordingly conclude that: (i) Adaptation options can be framed in to farm, off-farm, and institutional climate innovations separately, and should not deliver all as a single package, because farmers are not making decisions simultaneously, (ii) High risk aversion and high rate of time preference could be addressed through the institutional facilities (like access to credit, market and, institutional climate innovations), and by improving the social (social learning and experience sharing) and environmental system (rehabilitation of the degraded land, water bodies and forests).
- In Chapter 3 we brought the concept of personality traits in to the literature of innovation adoption. We also stressed on the importance of traditional social groups and networks, and the presence of homophilic groups as fundamental learning centres, through which it is possible to diffuse climate change adaptation innovations to farmers. We accordingly conclude that adaptation to climate change could be successful if: (i) We understand the influence of one's personality trait on his/her search and inquiry process of information regarding technology adoption, (ii) We create a favourable environment for learning through participation in social groups and networks, (iii) Adoption of HYV is preceded by an a priori adoption of SWC and irrigation technologies.

- The importance of social norms and roles in the sustainable management and use of CPRs is demonstrated in Chapter 4. Apart from social norms and social roles, we also showed the effect of climate change on the formation of cooperative local institutions through its direct effect on re-growth and replenishment of CPRs. Accordingly, we conclude that social norms and roles are important in realising a climate resilient cooperative local institutions to sustainably manage common pool natural resources. Members of a local cooperative institution in the management and use of CPRs should therefore be comprised of rule followers, elders, and individuals having a social role. In addition, we also conclude that, to realize climate mitigation through carbon sinks in common pool agricultural and forested lands in developing countries, attention should be given to the social and ecological determinants of cooperative CPR management.
- Developing countries traditionally follow a top down approach for policy and strategy making. An inclusive and coordinated stakeholder level dialogue and opinion sharing can help identify priority adaptation options. In Chapter 5, we presented and analysed stakeholder survey and evaluation of climate change adaptation in developing countries context and specific to Ethiopia. Context specific criteria like agro-ecosystem relevance criteria were given emphasis in the analysis. Stakeholders can also bring the different debates and interests together and open an opportunity for dialogue. The stakeholders' workshop showed that natural resources like soil, forests, and water resources are identified as highly vulnerable segments. The results of multi criteria analysis, on the other hand, showed that different groups have different views and priority to the different adaptation options. We therefore conclude that joint evaluation (both by experts and farmers) of adaptation options can be considered as a prerequisite for successful adaptation.
- Finally, we draw a conclusion on the approach we followed. The use of experimental approaches is getting more and more attention, because sometimes it is difficult to acquire data using conventional methods. However, caution should be given in the use and application of field experiments in developing countries. In developing countries, using farmers as subject of analysis can have benefits in terms of external validity and drawing inferences. Field experiments are however highly sensitive to contamination and at times very hard to be managed as a perfectly controlled experiment. It is also challenging to frame sophisticated experimental protocols with farmers. In multiple elicitation exercises, there is a problem of multiple switching. The low level of literacy and cognitive capacity are negatively affecting the performance in sometimes complex experimental tasks. There is sometimes a complete discrepancy between a behaviour observed in lab and real life practices. Decisions in real life depend on many factors including information seeking, time and support, and most importantly on heuristics and framing (Loewenstein et al. 2008). There is also high cost consideration in conducting field experiments, because most experiments like natural experiments involve real life practices. Experimenter bias in the process of

demonstration the choice problem is also a potential source of inadequacy. Though there are no fine tune solutions to all challenges of field experiments, different scholars have suggested to combine experimental results with survey, qualitative studies, and sometimes to use natural experiments. Accordingly, we conclude that grounding the experimental results with key informant and focus group discussion would improve our understanding of decision behaviour. In addition, applications of qualitative and quantitative approaches like MCA analysis, and enhancing educational and institutional facilities to smallholder farmers are important mechanisms to reduce the drawbacks in experimental approaches.

6.5 Policy implications

Policy implications are drawn from the empirical and experimental results. Chapters 2 and 3 demonstrated the importance of institutions in facilitating learning mechanisms. Preferences like risk and rate of time preference are a result of social and environmental constructs. The presence of institutions like credit access and social services like education can improve risk aversion and high rate of time preferences. Institutions can enhance social, environmental and market interactions. We believe that fostering new ideas and organizing farmers in local institutions can enable information sharing and learning schemes. It would also be possible to bring sustainable adaptation mechanisms through off-farm and institutional innovations to smallholder farmers. The introduction of off-farm innovations suitable to a specific agro-ecosystem is found plausible in the study area (Simane et al. 2012). Policy makers are therefore encouraged to pay greater attention to the behavioural mechanism of "institutional facilities" to encourage uptake of climate innovations. Institutions can facilitate climate adaptation efforts through availing opportunities to reduce high risk aversion and high rate of time preferences. Creation of an enabling environment for institutions, for instance, designing institutional climate innovations suitable to a particular agro-ecosystem can unlock negative concerns towards technologies.

The relevance of social groups and networks in innovation diffusion is highlighted in Chapter 3. Encouraging social groups and networks through capacity building programs would enhance and upgrade the state of innovation diffusion. Informal local institutions like, work groups, development groups, and informal traditional gatherings should be encouraged and supported to facilitate adoption of climate innovations. Social groups and networks are systems that hub both new and indigenous knowledge. In addition, we recommend that the adoption of HYV has better proceeded by the adoption of SWC and irrigation technologies. Institutions working in food security and climate change agenda should give due focus to the relationship between different technologies as well as encourage an environment suitable for technology diffusion. For instance, government and non-government organizations working on food security and climate change better invest on SWC and irrigation works as an entry for HYV. HYV can help to realize food security and improve adaptive capacity to climate change impacts.

In Chapter 4 we observed that social role, social norm and ecological variables are important determinants in realizing local institutions for the management and use of CPRs. To introduce sustainable local institutions in the context of CPRs, attention should be given to the composition of members in local institutions. Composing groups from elders, youth and rule followers can help sustain local institutions. Furthermore, to realize climate change mitigation through sustainable management of CPRs in developing countries, it is essential to understand the behavioural and ecological factors affecting cooperative behaviour. Common pool forests and agricultural lands can act as carbon sinks. It is, therefore, found important to include the possibility of carbon sinks in the strategy package of developing countries. Interventions in the management and use of common pool forests and agricultural lands have dual benefits: food security and carbon sink functions. Hence, developing countries should give due focus to the management problem of CPRs both for food security and carbon sink objectives.

The stakeholders' evaluation result shows that natural resources related adaptation options are prioritized highest, making agro-ecosystem relevance criterion as a centre piece in the evaluation process. To rescue agriculture both from anthropogenic and climate change impacts, policy makers should give greater attention to natural resources related adaptation options. In the study area, natural resources degradation reaches to the point of no return, resilience is unlikely, and population pressure is mounting. As a way out mechanism, attention should be given to natural resources fundamentals. Therefore, it is encouraged to follow an approach that enables to bring stakeholders together and analyse climate change adaptation options at a larger scale.

6.6 Recommendations for further research

The thesis has raised important research questions relevant to decisions related to adaptation to climate change. However, in each chapter there are issues that deserve further attention. This opens an opportunity for future research. The following topics could be relevant for further study:

1. The role of institutions in the formation of preferences

   In Chapter 2 we showed that the presence of a working institution can improve the negative concerns related to technology adoption. A further investigation of behavioural mechanisms by adopting a framed field experimental approach would also be interesting. Experiments can also be developed to understand the role of institutions on the formation preferences. Studies on social preferences like envy, reciprocity and altruism would also be interesting to understand the complex and dynamic interactions between society and environment due to climate changes. Hence, a further experimental explanation of individuals' and communities' social preferences in a wider context would improve our understanding of adoption decisions related to climate innovations.
2. Learning behaviour related to adaptation to climate change

In Chapter 3, we showed that the presence of social groups and networks improves learning. The approach we followed is very simple. However, learning behaviour is dynamic and complex. A further analysis using experimental neuroeconomics can shape our understanding of learning behaviour through a thorough analysis of the brain, and how the discoveries from experimental neuroeconomics guide economic decision makings related to adaptation to climate change.

3. Climate scenarios and uncertainties

   Chapters 4 and 5 draw a conclusion without taking into consideration the role of uncertainties and climate scenarios in decisions related to cooperative CPR management and stakeholders' evaluation of adaptation options. Provided that there are reliable climate scenarios, it would be interesting to frame MCA studies and cooperative CPR problems under uncertainty and varying climate scenarios.

References

Abadi-Ghadim A K and DJ Pannell (1999). A conceptual framework of adoption of an agricultural innovation. Agricultural Economics, 21 (2):145–154.

Abera H (2008). Adoption of improved teff and wheat production technologies in crop-livestock mixed systems in northern and western Shewa Zones of Ethiopia. Un-published PhD Dissertation, University of Pretoria, South Africa.

Adegbola P Y and G Cornelis (2007). The Effect of Different Information Sources on Technology Adoption and Modification Decisions. Agricultural Economics, 37 (1): 55–65.

Adger WN, S Huq, K Brown, D Conway, M Hulme (2003) Adaptation to climate change in the developing world. Progress in Development Studies, 3:179–195.

Adgo E, A Teshome, and B Mati (2013). Impacts of Long-Term Soil and Water Conservation on Agricultural Productivity: The Case of Anjenie Watershed, Ethiopia. Agricultural Water Management, 117: 55-61.

Albrecht A and S T Kandji (2003). Carbon sequestration in tropical agro-forestry systems. Agriculture, Ecosystems and Environment 99: 15–27.

Alison G (2010). Ecosystem services and agriculture: tradeoffs and synergies. *Philosophical Transaction of Royal Society London B Biological Sci*ence, 365,(1554): 2959–2971.

Allais M (1953). Le comportement de l'homme rationnel devant le risque: critique des postulats et axiomes de l'école Américaine. Econometrica, 21: 503–46.

Alston M (2013). Introducing Gender and Climate change: Research, Policy and Action, in Alston M and K Whittenbury (eds.) Research, action and policy: addressing the gendered impacts of climate change [Electronic]. Dordrecht: Springer Netherlands.

Altieri M A and C I Nicholls (2013). The adaptation and mitigation potential of traditional agriculture in a changing climate. Climatic Change, 1-13.

Altieri MA and VM Toledo (2005) Natural resource management among small scale farmers in semi-arid lands: building on traditional knowledge and agroecology. Annals of Arid Zone 44:365–385.

AMCEN (2011). Addressing Climate Change Challenges in Africa; A Practical Guide Towards Sustainable Development, UNEP.

Anaeto F C, C C Asiabaka, FN Nnadi, O O Aja, J O Ajaero, M A Ukpongson, and F O Ugwoke (2013). Integrating indigenous knowledge system in extension education: The potential for sustainable agricultural development in Nigeria. Research Journal of Agriculture and Environmental Management, 2(11): 332-340.

Anang B T, T Sipilainen, S Backman and J Kola (2015). Factors influencing smallholder farmers access to agricultural microcredit in Northern Ghana. African Journal of Agricultural Research, 10(24): 2460-2469.

Andersen S, GW Harrison, M I Lau, and EE Rutström (2006). Elicitation using multiple price list formats. Experimental Economics, 9 (4): 383–405.

Anthoff D, R Tol and W Yohe (2009). Risk aversion, time preference, and the social cost of carbon. Environmental Research Letter, 4:024002.

Arrow K (1958). Utilities, attitudes, choices: a review note. Econometrica, 26 (1): 1–23.

Arrow KJ (1994). Methodological Individualism and Social Knowledge. American Economic Review, 84 (2): 1—9.

Asfaw S, N McCarty, L Lipper, A Arslan and A Cattaneo (2013). Adaptation to Climate Change and Food Security: Micro-evidence from Malawi. Invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013, Hammamet, Tunisia.

Asrat S, M Yesuf, F Carlsson, W Edilegnaw (2010). Farmer's preferences for crop variety traits: lessons for on-farm conservation and technology adoption. Ecological Economics, 69: 2394–2401

Axelrod R (1984). The Evolution of Cooperation. New York, Basic Books.

Ayinde O E, M Muchie, B Olatinwo, A H Adenuga, and A E Oyewole (2014). Analysis of adoption and risk perception in innovation system in Kwara state Nigeria: A case study of improved rice. International Journal of agricultural Sciences, 10 (2): 816-822.

Aymone G (2009). Understanding farmers' perceptions and adaptation to climate change and variability: The case of the Limpopo basin, South Africa. IFPRI Discussion paper 00849, International Food Policy Research Institute: Washington DC.

Babu S C, C J Glendenning, K Asenso-Okyere, S K Govindarajan (2012). Farmers' Information Needs and Search Behaviors: Case study in Tamil Nadu, India. Discussion paper.

Baggio J A and M A Janssen (2013). Comparing agent-based models on experimental data of irrigation games, In R Pasupathy, S-H Kim, A Tolk, R Hill, and M E Kuhl (eds.), Proceedings of the 2013 Winter Simulation Conference, pp. 1743-1753.

Balana BB, E Mathijs, and B Muys (2010). Assessing the sustainability of forest management: an application of multi-criteria decision analysis to community forests in northern Ethiopia. Journal of Environmental Management, 91: 1294–1304.

Baland J M and J P Platteau (1996). Halting Degradation of Natural Resources. Is there a Role for Rural Communities? Oxford: Clarendon Press.

Bana e Costa CA and JC Vansnick (1997). Applications of the MACBETH approach in the framework of an additive aggregation model. Journal of Multi-Criteria Decision Analysis, 6 (2): 107-114.

Banerjee A V, and E Duflo (2008). The Experimental Approach to development Economics. Annual Review of Economics, 1(1): 151–178.

Bardsley N, R Cubitt, G Loomes, P Moffatt, C Starmer, and R Sugden (2010). Experimental Economics: Rethinking the Rules. Princeton University Press.

Barr A (2003). Risk pooling, commitment, and information: an experimental test of two fundamental assumptions. Working Paper CSAE WPS/2003–05, Centre for the Study of African Economies, Oxford, University of Oxford.

Barr A and G Genicot (2008). Risk Sharing, Commitment, and Information: An Experimental Analysis. Journal of the European Economic Association, 6: 1151-85.

Bates BC, Zw Kundzewicz, S Wu, JP Palutikof (2008). Climate change and water. Technical Paper VI of the Intergovernmental Panel on Climate Change. IPCC Secretariat. Geneva, 210 pp.

Becchetti L, S Castriota, and P Conzo (2016). Social capital dynamics and collective action: the role of subjective satisfaction in a common pool resource experiment. Environment and Development Economics, 21 (04): 512-531.

Becker G S (1974). A Theory of Social Interactions. Journal of Political Economy, 82(6): 1063–93. S

Bedru B, M Erik, and M Bart (2013). Assessing the sustainability of forest management: An application of multi-criteria decision analysis to community forests in northern Ethiopia. Journal of Environmental Management, 91 (2010):1294-1304.

Belay K (2003). Agricultural Extension in Ethiopia: The Case of Participatory Demonstration and Training Extension System. Journal of Social Development in Africa, 18 (1): 49–83.

Belderbos R, M Carree, B Diederen, B Lokshin and R Veugelers (2004). Heterogeneity in R&D cooperation strategies. International Journal of Industrial Organization, 22: 1237-1263.

Belton V and TJ Stewart (2002). Multiple Criteria Decision Analysis—An Integrated Approach. Kluwer Academic Publishers, Boston. 396 pp.

Bernardini A, Q Hayez, C Macharis, Y De Smet (2010). Multicriteria analysis of policy options scenarios to reduce the aviation climate impact – an application of the PROMETHEE based D-SIGHT software. Operational Research Society, OR52 Royal Holloway, London.

Bezabih M and M Sarr (2012). Individual Risk Preferences and Environmental Uncertainty: Implications for Crop Diversification Decisions in Ethiopia. Environmental and Resource Economics, 53: 483-505.

Bhave A G, A Mishra and N S Raghuwanshi (2014). A brief review of assessment approaches that support evaluation of climate change adaptation options in the water sector. Water policy, 16 (5): 959-972.

Bhave A G, Mishra A and Raghuwanshi N S (2014). A brief review of assessment approaches that support evaluation of climate change adaptation options in the water sector. *Water policy,* 16 (5): 959-972.

Binswanger H P (1980). Attitudes Toward Risk: Experimental Measurement in Rural India. American Journal of Agricultural Economics, 62:395–407.

____________(1981). Attitude toward risk: Theoretical implications of an experiment in rural India. Economic Journal, 91 (364): 867-890.
____________(1982). Attitude towards risk: Empirical Estimation and Use of Risk Preferences Discussion. American Journal of Agricultural Economics, 64: 391-393.
Biswas A K (2004). Integrated Water Resources Management: A Reassessment - a Water Forum Contribution. Water International 29(2): 248-256.
Blickle G (1996). Personality traits, learning strategies, and performance. European Journal of Personality, 10,:337-352.
Blomquist W (1992). Dividing the Waters: Governing Groundwater in Southern California. San Francisco, CA: ICS Press.
Blume L E and D Easley (2008). Rationality, The New Palgrave Dictionary of Economics, 2nd Edition.
Boggia A, and Cortina C (2010). Measuring sustainable development using a multi-criteria model: a case study. Journal of Environnemental Management, 91: 2301–2306.
Böhm-Bawerk, Eugen (1889). Kapital und Kapitalzins. Band II. Jena: Gustav Fischer Verlag.
Botelho A., A Dina, L M Costa Pinto, A Rapoport (2014). Time and uncertainty in resource dilemmas: equilibrium solutions and experimental results. Experimental Economics, 17:649–672.
Bradshaw B, H Dolan and B Smit (2004). Farm-Level Adaptation to Climatic Variability and Change: Crop Diversification in the Canadian Prairies. Climatic Change, 67: 119–141.
Brans J, B Mareschal (2002). PROMETHEE-GAIA, Uneméthodologie d'aide à la décision en présence de critères multiples Editions de L'Université de Bruxelles- Elipses Éditions Marketing, Bruxelles- Paris. 187 pp.
Brans J, P Vincke P(1985). A preference ranking organisation method — the PROMETHEE method for multiple criteria decision-making. Management Science, 31: 647–656.
Brans J, P Vincke, B Mareschal (1986). How to select and how to rank projects: the PROMETHEE method. European Journal of Operational Research ,24: 228–238.
Brans JP, B Mareschal (1990). The PROMETHEE methods for MCDM; The PROMCALC, GAIA and BANKADVISER software. In: Bana e Costa, C. (Eds.), Readings in Multiple Criteria Decision Aid. Springer, Berlin, pp. 216–252.
Brans JP, Mareschal B (1990). The PROMETHEE methods for MCDM; The PROMCALC, GAIA and BANKADVISER software. In: Bana e Costa, C. (Eds.), Readings in Multiple Criteria Decision Aid. Springer, Berlin, pp. 216–252.
Brans JP, Mareschal B (2005). PROMETHEE methods. J. Figueira, J Figueira, S Greco, S Greco, M Ehrgott, M Ehrgott (Eds.), Multi-Criteria Decision Analysis: State of the Art Surveys, Springer, New York (2005).
Brekke k A and O J Stenman (2008). The Behavioural Economics of Climate Change. Working papers in Economics, Gotheborg University, Sweeden.
Brick K A, M Visser and J Burns (2012). Risk Aversion: Experimental Evidence from South African Fishing Communities. American Journal of Agricultural Economics ,94(1): 133-152.
Broome J (1991) Weighing Goods. Oxford: Blackwell.
Brosig J (2002). Identifying cooperative behavior: some experimental results in a prisoner's dilemma game. Journal of Economic Behavior and Organization, 47: 275–290.
Burns T R, and H Flams (1987). The Shaping of Social Organization: Social Rule System Theory With Applications. London: Sage Publications.
Butt A, B McCarl, J Angerer, P Dyke, and J Stuth (2005). The economic and food security implications of climate change. Climate Change 68, (3):355–378.
Calow R, E Ludi, and J Tucker (Eds.) (2013). Achieving Water Security - Lessons from research in water supply, sanitation and hygiene in Ethiopia, Rugby, UK: Practical Action Publishing Ltd.
Camerer C F,and L George (2003). Behavioural Economics: Past, Present, and Future, in Advances in Behavioural Economics. Camerer C F, L George and R Matthew (Eds). Princeton: Princeton University Press.
Cameron L A (1999). The importance of learning in the adoption of high-yielding variety seeds. American Journal of Agricultural Economics, 81: 83-94.
Cappellari L and P Jenkins (2003). Multivariate probit regression using simulated maximum likelihood. Stata Journal, 3 (3).

Cardenas J C (2011). Social norms and behavior in the local commons as seen through the lens of field experiments. Environmental and Resource Economics, 48 (3): 451–485.
Cardenas J C and Carpenter J (2004). An inter-cultural examination of cooperation in the commons. Working paper, Department of Economics, Middlebury College.
Cardenas J C and J P Carpenter (2008). Behavioral development economics: lessons from field labs in the developing world. Journal of Development Studies, 44 (3): 311-338.
Cardenas J C, and E Ostrom (2001). What Do People Bring into the Game? How Information Helps to Reduce the Tragedy of the Commons. Working Paper W 01-4. Workshop in Political Theory and Policy Analysis, Indiana University.
Cardenas J C, L A Rodriguez and N Johnson (2011). Collective action for watershed management: field experiments in Colombia and Kenya. Environment and Development Economics, 16: 275-303.
Cardenas J C, M A Janssen, and F Bousquet (2013). Dynamics of Rules and Resources: Three New Field Experiments on Water, Forests and Fisheries', in John A, List and P Michael (eds.). Handbook on Experimental Economics and the Environment, Cheltenham, Edward Elgar publishing.
CARE (2015). Adaptation Learning Program Midterm review final report. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/204897/Evaluation-CARE-adaptation-learning-programme.pdf. Retrived on February, 2016.
Carpenter J (2005). Endogenous social preferences. Review of Radical Political Economy, 37: 63-84.
Carpenter J P and E Seki (2005). Competitive Work Environments and Social Preferences: Field Experimental Evidence from a Japanese Fishing Community. Journal of Economic Analysis and Policy, De Gruyter 5(2): 1-25.
Carr D L (2004). Proximate population factors and deforestation in tropical agricultural frontiers. Population and Environment, 25(6): 585–612.
Champalle C, D F James and M Sherman (2015). Prioritizing Climate Change Adaptations in Canadian Arctic Communities. Sustainability, 7: 9268-9292.
Chandler W, R Schaeffer ,Z Dadi, P R Shukla P R, F Tudela , O Davidson , S Alpan-Atamer (2002). Climate change mitigation in Developing countries. Pew center on Global climate change: Arlington, VA.
Charness G and A Viceisza (2012). Comprehension and risk elicitation in the field: Evidence from rural Senegal. IFPRI Working Paper 01135, Washington DC.
Charness G, Gneezy and A Imas (2013). Experimental methods: eliciting risk preferences. Journal of Economic Behavior and Organization, 87 (2013): 43–51.
Charness G. and U Gneezy (2010). Portfolio Choice and Risk Attitudes: An Experiment. Economic inquiry, 48 (1): 133–146.
Chattopadhyay R, and E Duflo (2004). Women as Policy Makers: Evidence from a Randomized Policy Experiment in India. Econometrica, 72(5): 1409–1443.
Chhetri N, C Pashupati, R T Puspa and R M Yadaw (2012). Institutional and technological innovation: understanding agricultural adaptation to climate change in Nepal. Applied Geography, 33: 142-150.
Choi H, SH Kim, J Lee (2010). Role of Network Structure and Network Effects in Diffusion of Innovations. Industrial Marketing Management, 39 (1): 170–177.
Cinelli M, RS Coles, K Kirwan (2014). Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment. Ecological Indicators, 46: 138.
Cochran I (2012).On the Commons and Climate Change: Collective Action and GHG Mitigation. CDC climate Research, Working paper 2012-2013.
Coleman J S (1990). Foundations of Social Theory, Harvard University Press, Cambridge.
Coller M and B Williams (1999). Eliciting Individual Discount Rates. Experimental Economics 2: 107-127.
Conley T G, and Udry C R (2010). Learning About a New Technology: Pineapple in Ghana. American Economic Review, 10: 35-69.
Conway D, ELF Schipper (2011). Adaptation to climate change in Africa: challenges and opportunities identified from Ethiopia. Global Environmental Change, 21:227–237.
Costa P T and R R McCrae (1992). NEO PI-R. Professional manual. Odessa, FL: Psychological Assessment Resources, Inc.
Cox J, V Sadiraj and U Schmidt (2014). Paradoxes and mechanisms for choice under risk. Experimental Economics, 1-36.

D'Exelle B, E Lecoutere and B Van Campenhout (2012). Equity-efficiency trade-offs in irrigation water sharing: Evidence from a field lab in rural Tanzania. World Development, 40: 2537–2551.

Dastjerdi RB, R D Isfahani, and J Hosaini (2009). Time Preference and its Effects on Intertemporal Optimization of Economic Resources, A Critical Viewpoint. International Economic Studies, 34 (1), 69-78.

Davis M D (2007). Integrated Water Resource Management and Water Sharing. Journal of Water Resources Planning and Management-ASCE, 133(5): 427-445.

De Bruin K, R B Dellink, A Ruijs, L Bolwidt, A Van Buuren, J Graveland, R S De Groot, P Kuikman, S Reinhard, Roetter R P, Tassone V C, Verhagen A, and Ierland E C Van (2009). Adapting to climate change in the Netherlands: An inventory of climate adaptation options and ranking of alternatives. Climatic Change, 95 (1–2): 23–45.

De Raad B and H C Schouwenburg (1996). Personality in learning and education: a review. European Journal of Personality, 10:303-336.

De Smet Y (2014). D-SIGHT. http://www.d-sight.com/, (accessed on November 2015).

Demuth J L (2015). Developing a valid scale of past tornado experiences. Ph.D. thesis, Colorado State University, Colorado.

Deresa T, Hassan R M, and Ringler C (2011). Perception of and Adaptation to Climate Change by Farmers in the Nile Basin of Ethiopia. The Journal of Agricultural Science, 149: 23-31.

Deressa T (2010). Assessment of the vulnerability of Ethiopian agriculture to climate change and farmers' adaptation strategies, PhD theses University of Pretoria S. Africa. Pretoria.

Deressa T, R Hassan and C Ringler (2010). Factors Affecting the Choices of Coping Strategies for Climate Extremes. IFPRI Discussion Paper 01032, Washington, DC.

Deressa T, R Hassen, T Alemu, M Yesuf, C Ringler (2008). Analysing the Determinants of farmers' choice of adaptation measures and perceptions of climate change in the Nile Basin of Ethiopia. International Food Policy Research Institute (IFPRI) Discussion Paper No. 00798, Washington.

Deressa T, R M Hassan, C Ringler, T Alemu, and M Yesuf (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change, 19:248-255.

Devereux S (2000). Famine in the Twentieth Century. Working Paper 105, Brighton; Institute of Development Studies, University of Sussex.

Di Falco S, M Veronesi and M Yesuf (2011). Does adaptation to climate change provide food security? A micro perspective from Ethiopia. American Journal of Agricultural Economics, 93(3): 829–846.

Dilling L, and J Berggren (2014). What do stakeholders need to manage for climate change and variability? A document-based analysis from three mountain states in the Western USA. Regional Environmental Change, 15 (4): 657–667.

Dinar A, F Stefano, P Fioravante, R Kate (2006). Water allocation strategies for the Kat Basin in South Africa :comparing negotiation tools and game theory models. Policy, Research working paper 4083. Washington, DC: World Bank.

Dinar A, M Stefano, P Fioravante and Z Stefano (2006). Application of stochastic cooperative games in water resources', Policy Research Working Paper 4073. Washington, DC: World Bank.

Doebeli M, C Hauert (2005). Models of cooperation based on the Prisoner's Dilemma and the Snowdrift game. Ecology, 8: 748–766.

Doerr U, T Mahmoud and U Schmidt (2011). Overconfidence and Risk Management of Ethiopian Farmers. Working Paper, University of Kiel.

Dolan H, B Smit, W Mark, B Skinner, C Bradshaw, R Bryant (2001). Adaptation to climate change in agriculture: evaluation of options. Report. Department of Geography University of Guelph, Occasional Paper No. 26.

Dolisca F, R D Carter, J M McDaniel, D A Shannon, and C M Jolly (2006). Factors influencing farmers' participation in forestry management programs: A case study from Haiti. Forest Ecology and Management, 236: 324-31.

Drichoutis A C and J L Lusk (2014). Judging statistical models of individual decision making under risk using in- and out-of-sample criteria. PLoS ONE 9 (7): e102269.

Druckman J N and A Lupia (2000). Preference formation. Annual Review of Political Science,3:1–24. Earth Institute (2009). The Earth Institute, Columbia University.
Eckel C and J Grossman (2008). Differences in the economic decisions of men and women: experimental evidence', C Plott and V Smith (eds), In Handbook of Experimental Economics Results 1: 509-519.
Ecological Impacts of Climate Change Collection (2013). Retrieved from: http://www.Ploscollections.org/ecoclimatechnage.
Elias D (1997). It's time to change our minds: An introduction to transformative learning. ReVision, 20(1).
Ellsberg D (1961). Risk, Ambiguity, and the Savage Axioms. Quarterly Journal of Economics, 75 (4): 643–669.
Epstein G, I Perez Ibarra, C Meek, and M Schoon (2014). Governing the Invisible Commons: Ozone Regulation and the Montreal Protocol. International Journal of the Commons, 8(2): 337–360.
Esteban E and A Dinar (2013). Cooperative Management of Groundwater Resources in the Presence of Environmental Externalities. Environmental and Resource Economics, 54:443–469.
Ethiopian EPA (2011). Ethiopia's Climate-Resilient Green Economy (CRGE). Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia, pp 188.
FAO (2001). The state of food security in the world. How does international volatility affect domestic economies and food security? Rome.
FAO (2002). Crop Biotechnology: A working paper for administrators and policy makers in sub-Saharan Africa. Rome.
FAO (2011). The state of the world's land and water resources for food and agriculture (SOLAW)–Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome.
FAO **(**2013). Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment, by Opio C, Gerber P, Mottet A, Falcucci A, Tempio G, MacLeod M, Vellinga T, Henderson B and Steinfeld H, Rome.
FAO (2014). Adapting to climate change through land and water management in Eastern Africa Results of pilot projects in Ethiopia, Kenya, and Tanzania. Food and Agriculture Organization of the United Nations, Rome.
FAO and GTZ (2006). Framework on effective rural communication for development. FAO, Rome.
Feder G, E Richard and D Zilberman (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. Economic Development and Cultural Change, 33(2): 255-298.
Federal democratic republic of Ethiopia (FDRE) (2011). Ethiopia's Climate-Resilient Green Economy Green economy strategy, Addis Ababa, Ethiopia.
Fehr E and A Leibbrandt (2011). Afield study on cooperativeness and impatience in the tragedy of the commons. Journal of Public Economics, 95(9):1144–1155.
Fehr E and J A List (2004) The Hidden Costs and Returns of Incentives —Trust and trustworthiness Among CEOs. Journal of the European Economic Association, 2(5): 743–771.
Fehr E and U Fischbacher (2005). Neuroeconomic Foundations of Trust and Social Preferences: Initial Evidence. American Economic review, 95(2): 346-351.
Fetene A, A Demelash, and M Yoseph (2014). Effects of land use land cover change on the extent and distribution of Afroalpin Vegetation of Northern western Ethiopia: case of Choke Mountains. Research Journal of Environmental Science, 8(1):17-28
Few R, K Brown and E L Tompkins (2006). Public participation and climate change adaptation. Tyndall Centre for Climate Change Research Working Paper 95.
Fishe R P, R P Trost and P Lurie (1981). Labor force earnings and college choice of young women: An examination of selectivity bias and comparative advantage. Economics of Education Review, 1 (2): 169-191.
Fisher H E (2016). Anatomy of love: A natural history of mating, marriage, and why we stray. W W Norton & Company Incorporated.
Foster D and M R Rosenzweig (1995). Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. Journal of Political Economy, 103(6): 1176-1209.
Frederick S, G Loewenstein and T O'donoghue (2002). Time Discounting and Time Preference: A Critical Review. Journal of Economic Literature, 40 (2): 351–401.
Fresco L O (1986). Cassava in Shifting Cultivation; A systems approach to agricultural technology development in Africa. Royal Tropical Institute, Amsterdam, The Netherlands.

Friedman M (1953). The methodology of positive economics. In Essays in positive economics, 3 –43. Chicago: University of Chicago Press.
Fuhrer J (2003). Agroecosystem responses to combinations of elevated CO2, ozone, and global climate change. Agriculture, Ecosystems and Environment, 97:1–20.
Fujisaka S (1993). A case of farmer adaptation and adoption of contour Hedgerows for soil conservation. Experimental agriculture, 29, 97-105.
Füssel H M (2007). Adaptation planning for climate change: concepts assessment approaches and key lessons. Sustainability Science, 2: 265–275.
Galarza F (2009). Choices under Risk in Rural Peru. MPRA Paper 17708, University Library of Munich, Germany.
Gans N, G Knox and R Croson (2007). Simple models of discrete choice and their performance in bandit experiments. Manufacturing and Service Operations Management, 9(4): 383-408.
Gebregziabher G, A M Giordano, L J Simon, and R E Namara (2014). Economic analysis of factors influencing adoption motor pumps in Ehiopia. Journal of Development and Agricultural Economics, 6(12): 490-500.
Genius M and J Christos (2006). Information Acquisition and Adoption of Organic Farming Practices. Journal of Agricultural and Resource Economics, 31(1): 93-113.
Genius M P, C Koundouri, C Nauges, and V Tzouvelekas (2014). Information Transmission in Irrigation Technology Adoption and Diffusion: Social Learning, Extension Services, and Spatial Effects. American Journal of Agricultural Economics, 96(1), 328-344.
Geoffrion A, J Dyer, and A Feinberg (1972). An Interactive Approach for Multicriterion Optimization with an Application to the Operation of an Academic Department. Management Science, 19: 357–368.
Gerber A, and D Green (2012). Field Experiments: Design, Analysis, and Interpretation. Norton & Company.
Gershon F, M Rinku, and B Jaime (2004). The Acquisition and Diffusion of Knowledge: The Case of Pest Management Training in Farmer Field Schools, Indonesia. Journal of Agricultural Economics, 55(2): 221-243.
Getnet B (2012). Valuation of Choke Mountain Range Wetland Ecosystem, East Gojjam, Amhara Region, Ethiopia: Application of Choice Experiment Valuation Method, MSC Theses Addis Ababa University, Addis Ababa, Ethiopia.
Gibbons D (2004). Network Structure and Innovation Ambiguity Effects on Diffusion in Dynamic Organizational Fields. The Academy of Management Journal, 47 (6): 947.
Gifford R (2011). The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. American Psychologist, 66 (4): 290–302.
Glendenning C J, S Babu, and K Asenso-Okyere (2010). Review of Agricultural Extension in India, Are Farmers' Information Needs Being Met? IFPRI Discussion Paper 01048, Washington DC.
Gneezy U and A Rustichini (2004). Gender and Competition at a Young Age. American Economic Review: Papers and Proceedings, 94(2): 377–381.
Gneezy U and J A List (2006). Putting Behavioural Economics to Work: Testing for Gift Exchange in Labor Markets Using Field Experiments. Econometrica, 74(5): 1365–1384.
Gneezy U, K L Leonard and J A List (2009). Gender Differences in Competition: Evidence from a Matrilineal and a Patriarchal Society. Econometrica, 77(5): 1637–1664.
Goldberg L R (1993). The structure of phenotypic personality traits. American Psychologist, 48, 26–34.
Gosling S D, P J Rentfrow, and Swann W B (2003). A very brief measure of the Big-Five personality domains. Journal of Research in Personality, 37, 504-528.
Gough C, Shackley S (2006) Towards a multi-criteria methodology for assessment of geological carbon storage options. Climate Change, 74:141–174.
Greatrex H, JW Hansen, S Garvin, R Diro, S Blakeley, M Le Guen, KN Rao, DE Osgood (2015). Scaling up Index Insurance for Smallholder Farmers: Recent Evidence and Insights. CCAFS Report 14. Copenhagen: CGIAR Research Program on Climate Change, Agriculture, and Food Security.
Greaves S P and A Ellison (2011). Personality, risk aversion and speeding: An empirical investigation. Accident Analysis and Prevention, 43(5): 1828-1836.
Greene W (2000). Econometric Analysis. Fourth Edition. New York: Prentice-Hall, USA.
Greene W (2008). Econometric Analysis. Sixth Edition. New Jersey: Prentice Hall, USA.

Greene W H (2003). Econometric Analysis (fifth edition), USA: Prentice Hall.
Grothmann T, and A Patt (2005). Adaptive capacity and human cognition: the process of individual adaptation to climate change. Global Environmental Change Part A, 15(3):199-213.
Guiso L and M Paiella (2008). Risk-aversion, Wealth, and Background Risk. Journal of the European Economic Association, 6(6):1109–50.
Habtamu T (2011). Assessment of sustainable watershed management approach case study lenche dima, tsegur eyesus and dijjil watershed. A project paper presented to the Faculty of the Graduate School of Cornell University, May 2011, 1-118.
Hagmann J, E Chuma, K Murwira, and M Connolly (1999). Putting process into practice: operationalizing participatory extension. Network-Paper-Agricultural-Research-and-Extension-Network,-ODI (UK), 94 (23).
Hailu A T (2012). Multifunctionality of smallholder farming: a way towards sustaining food security and carbon neutral. Institute for Sustainable Development. Addis Ababa, Ethiopia.
Hajivassiliou V, D McFadden, and P Ruud, (1996). Simulation of multivariate normal rectangle probabilities and their derivatives theoretical and computational results. Journal of Econometrics, 72 (1-2): 85-134.
Hajkowicz S (2007). A comparison of multiple criteria analysis and unaided approaches to environmental decision making. Environmental Science and Policy, 10:177–184.
Hajkowicz S, GT McDonald, and PH Smith (2000). An evaluation of multiple objective decision support is weighting techniques in natural resource management. Journal of Environmental Planning and Management, 43: 505–518.
Hanna R, S Mullainathan, and J Schwartzstein (2014). Learning Through Noticing: Theory and Experimental Evidence in Farming. Quarterly Journal of Economics, 129(3): 1311-1353.
Hardin G (1968). The Tragedy of the Commons. Science, 162: 1243-1248.
Harless D and C Camerer (1994). The predictive utility of generalized expected utility theories. Econometrica, 62: 1251-1289.
Harrison G W and J T Swarthout (2014). Experimental payment protocols and the bipolar behaviorist. Theory and Decision 77:423–438.
Harrison G, and J List (2004). Field experiments. Journal of Economic Literature, 42: 1009-1055.
Harrison G, M Lau, and M Williams (2002). Estimating Individual Discount Rates for Denmark: A Field Experiment. American Economic Review, 92(5): 1606-1617.
Harrison G, S Humphrey, and A Verschoor (2010). Choice Under Uncertainty: Evidence from Ethiopia, India and Uganda. The Economic Journal 120:80-104.
Heckman J J (1976). The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. Annals of Economic and Social Measurement, 15, 475-492.
Heinström J (20003). The impact of personality and approaches to learning on information behaviour. Information Research, 5(3).
Hellmuth M E, A Moorhead, M C Thomson, and J Williams (eds) (2007). Climate Risk Management in Africa: Learning from Practice. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.
Herzberg P, B Yorck and Elmar (2006). Assessing the Big-Five personality domains via short forms: A cautionary note and a proposal. European Journal of Psychological Assessment, 22(3): 139-148.
Hey J and C Orme (1994). Investigating Generalizations of Expected Utility Theory Using Experimental Data. Econometrica, 62(6): 1291-1326.
Hildebrand P E (1981). Combining Disciplines in Rapid Appraisal: the sondeo approach. Agricultural Administration, 8:423-432.
Hill V and A Viceisza (2012). A field experiment on the impact of weather shocks and insurance on risky investment. Experimental Economics 15(2): 341–371.
Holden S, B Shiferaw and M. Wik (1998), Poverty, credit constraints, and time preferences: of relevance for environmental policy?', Environment and Development Economics, 3: 105–130.

Holm and J N Arednt (2013). Evaluating the performance of simple estimators for probit models with two dummy endogenous regressors. Journal of Statistical Computation and Simulation, 83(6):1156-1178.

Holt C A and S K Laury (2002). Risk Aversion and Incentive Effects. American Economic Review, 92(5): 1644–1655.

Houghton J T, L Filho, B A Callander, N Harris, A Kattenberg, and K Maskell (1996). Climate Change 1995: The Science of Climate Change, Intergovernmental Panel on Climate Change 572, Cambridge University Press, Cambridge, GB.

Humphrey S and A Verschoor (2004), 'Decision-Making under Risk among Small Farmers in East Uganda. Journal of African Economies, 13(1):44-101.

IFAD (2013). Smallholders, Food Security, and the Environment. IFAD, UNEP, Rome.

Ihli H, B Chiputwa and O Musshoff (2013). Do Changing Probabilities or Payoffs in Lottery-Choice Experiments Matter? Evidence from Rural Uganda, Global Food Discussion Papers, No. 24. Transformation of Global Agri-Food Systems: Trends, Driving Forces, and Implications for Developing Countries, Goettingen.

IPCC- Intergovernmental Panel on Climate Change (2007). Climate change 2007: synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Pachauri R K and Reisinger A (Eds.)]. IPCC, Geneva, Switzerland, 104 pp.

IPCC-Intergovernmental Panel on Climate Change (2001). Climate Change: The Scientific Basis. New York: Cambridge University Press.

Iversen T, and S David (2001). An Asset Theory of Social Policy Preferences. The American Political Science Review 95 (4): 875–893.

Jackson C A, M Henderson, W F John, and J Sally (2012). An overview of prevention of multiple risk behaviour in adolescence and young adulthood. Journal of public health 34(1):31-40. Journal of Public Healthjpubhealth, 34(1):31-40.

Jactel H, M Branco, P Duncker, B Gardiner, W Grodzki, B Langstrom, F Moreira, S. Netherer, B Nicoll, C Orazio, D Piou, M Schelhaas, and K Tojic (2012). A multicriteria risk analysis to evaluate impacts of forest management alternatives on forest health in Europe. Ecology and Society 17(4): article 52

Janssen M A and J M Anderies (2011). Governing the commons: Learning from field and laboratory experiments. Ecological Economics, 70:1569-1570.

Janssen R and M Herwijnen (2006). A toolbox for multicriteria decision-making. International Journal of Environmental Technology and Management, 6 (1):20–39.

Javier A L and H J Alejandro (2015). Climate Change and use of Common-Pool Resources: An experimental approach in the Bolivian altiplano. LACEA Working paper 2015.

Jin J, Y Gao, X Wong, NK Pham (2015). Farmers' risk preferences and their climate change adaptation strategies in the Yongqiao District, China. Land Use Policy, 47 (2015):365–372.

Johnson JA (1997). Units of analysis and the description and explanation of personality. In: Hogan R, Johnson J, Briggs S, editors. Handbook of personality psychology. San Diego: Academic Press; 1997. pp. 73–93.

Jovanovic B and Y Nyarko (1994). Learning by Doing and the Choice of Technology. NBER Working Paper No. w4739.

Juana J, Z Kahaka, F Okurut (2013). Farmers' perceptions and adaptations to climate change in sub-Sahara Africa: a synthesis of empirical studies and implications for public policy in African agriculture. Journal of Agricultural Science, 5:121–135.

Kabubo-Mariara J (2008). Climate change adaptation and livestock activity choices in Kenya. An economic analysis. Natural Resources Forum, 32:132–142.

Kahneman D (2003). Maps of bounded rationality: psychology for behavioral economics. The American Economic Review, 93 (5): 1449–75.

Kahneman D, and A Tversky (1979). Prospect theory: An analysis of decision under risk. Econometrica, 47: 263 – 291.

Kebede B and Zizzo D. (2015). Social Preferences and Agricultural Innovation: An Experimental Case Study from Ethiopia. World Development, 67:267-280.

Keeney RL. and Raiffa H (1993). Decisions with multiple objectives–Preferences and value tradeoffs, Cambridge University Press, Cambridge & New York.

Kimbrough E O, and A Vostroknutov (2015). The Social and Ecological Determinants of Common Pool Resource Sustainability. Journal of Environmental Economics and Management, 72: 38-53.

Klein R J T, G F Midgley, B L Preston, M Alam, F G H Berkhout, K Dow, and M R Shaw (2014). Adaptation opportunities, constraints, and limits. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 899-943.

Klemack H and M Yesuf (2008). Does Discount Rate Change Overtime: Experimental Evidence in Ethiopia. RFF/EfD discussion paper 08-06. Washington, D.C., 2008.

Kolb D (1984). Experiential Learning: experience as the source of learning and development. Englewood Cliffs, NJ: Prentice Hall.

Kovacs K and M Larson (2008). Identifying Individual Discount Rates and Valuing Public Open Space with Stated-Preference Models. Land Economics, 84(2):209-224.

Krauskopf C J and D R Saunders (1994). Personality and Ability: The Personality Assessment System. University Press of America, Maryland. p. 263.

Laubach T and J Williams (2003). Measuring the natural rate of interest. Review of Economics and Statistics 85 (4): 1063–70.

Legesse B (2003). Risk Management Strategies of Smallholder Farmers in the Eastern Highlands of Ethiopia. (Ph.D. Thesis). Swedish University of Agricultural Sciences, Uppsala.

Liebenehm S and H Waibel (2014).Simultaneous Estimation of Risk and Time Preferences among Small-scale Cattle Farmers in West Africa. American Journal of Agricultural Economics, 96: 1420–1438.

Lindner R K (1987). Adoption and diffusion of technology: an overview In: Champ, B.R., Highly, E., & Remenyi, J.V. (Eds.), Technological Change in Postharvest Handling and Transportation of Grains in the Humid Tropics. ACIAR Proceedings No. 19, Australian Centre for International Agricultural Research, Canberra, pp. 144-151.

List J A (2014). Using Field Experiments to Change the Template of How We Teach Economics. Journal of Economic Education, 45(2): 81–89.

Liu E (2013). Time to Change What to Sow: Risk Preferences and Technology Adoption Decisions of Cotton Farmers in China. Review of Economics and Statistics, 95(4):1386–403.

Lo A Y (2013). The role of social norms in climate adaptation: Mediating risk perception and flood insurance purchase. Global Environmental Change, 23: 1249 -1257.

Loewenstein G, S Rick, and J Cohen (2008). Neuroeconomics. Annual Reviews, 59: 647-672.

Loomes G. (2005). Modelling the stochastic component of behavior in experiments: Some issues for the interpretation of data. Experimental Economics, 8 (4): 301-323.

Lusk J L, and H C Keith (2008). Risk- aversion in the Presence of Background Risk: Evidence from the Lab. Research in Experimental Economics, 12:315–40.

Lwin M, P S Rajendra, E Theo, and J Damien(2015). Farmers' perception of and adaptation to climate-change impacts in the Dry Zone of Myanmar. Climate and Development, 7(5): 437-453.

Lynch A (1994). The evolution of cooperative behavior, in Tested studies for laboratory teaching, C A Goldman, (Eds). Proceedings of the 15th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 390 pages, 15: 319–333.

Maddala G S (1983). Limited-Dependent and Qualitative Variables in Econometrics. Econometric Society Monographs. Cambridge University Press.

Maddison D (2006). The perception and adaptation to climate change in Africa. CEEPA. Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria.

Marra M C, Pardey P G and J Alston (2002). The payoffs to transgenic field crops: An assessment of the evidence. AgBio-Forum, 5(2): 43-50.

McLeman R, E Mayo and B Smit (2008). Drought adaptation in rural eastern Oklahoma in the 1930s: Lessons for climate change adaptation research. Mitigation and Adaptation Strategies for Global Change, 13(4): 379-400.

McSweeney C, G Lizcano, M New, X Lu (2010). The UNDP climate change country profiles. Bulletin of the American Meteorological society, 91:157–166.

Meinzen-Dick, R. S., R. Chaturvedi, L. Domenech, R. Ghate, M. A. Janssen, N. Rollins, and K. Sandeep (2014). Games for groundwater governance: Field experiments in Andhra Pradesh, India. Center for the Study of Institutional Diversity Working Paper Series #CSID-2014-006. Tempe, AZ, USA.

Mendelsohn R, W Nordhaus and D Shaw (1994). The Impact of Global Warming: A Ricardian Analysis. American Economic Review, 84: 753–71.

Mendoza GA, Prabhu R (2000a). Development of a methodology for selecting criteria and indicators of sustainable forest management: a case study on participatory assessment. *Environmental Management,* 26:659–673.

Mendoza GA, R Prabhu (2000b). Multiple criteria decision making approaches to assessing forest sustainability using criteria and indicators: a case study. Ecological Management, 13: 107–126.

Mezirow J (1994). Understanding transformative theory. Adult Education, 44:222–223.

Mezirow J (1997). Transformative learning: theory to practice. New Directions for Adult and Continuing Education, 74:5–12.

Mokhtarian P. and T Wei (2012). Trivariate Probit Models of Pre-purchase/Purchase Shopping Channel Choice: Clothing Purchases in Northern California. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-12-21.

Moser S C, and EkstromJ A (2015). A framework to diagnose barriers to climate change adaptation. Roger E. K (Eds), Clark University, Worcester, MA.

Munshi K (1999). Learning From Your Neighbours: Why Do Some Innovations Spread Faster than Others? Working paper, Department of Economics, University of Pennsylannia.

Narayana D, and R Babu (1985). Closure to Estimation of Soil Erosion in India. Journal of Irrigation and Drainage Engineering, 4(408): 408-410.

National Research Council (2002). The Drama of the Commons. Committee on the Human Dimensions of Global Change, in: Ostrom E, Dietz T, Dolšak N, P C Stern, S Stonich, and E U Weber (Eds.), Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy of Sciences Press.

Neimann L I, and J W Hughes (1951). The Problem of the Concept of Role: A Resurvey of the Literature. Social Forces, 30.

Neumann J and O Morgenstern (1944). Theory of Games and Economic Behaviour', Princeton University Press. Princeton, USA.

Newey W (1987). Efficient estimation of limited dependent variable models with endogenous explanatory variables. Journal of Econometrics, 36: 231-250.

Nhemachena C, and R Hassan (2008). Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute. Washington DC.

Nielsen U (2001). Poverty and Attitudes towards Time and Risk-Experimental Evidence from Madagascar', Working Paper. Royal Veterinary and Agricultural University of Denmark.

Nigussie Y M, E C van Ireland, Z Xueqin, B Kebede, J Klomp (2016). How do personality traits and learning determine adaptation to climate change? A study on smallholder farmers in the upper Blue Nile Basin. Climate and development, under review.

Nijkamp P, P Rietveld, and H Voogd (1990). Multicriteria Evaluation in Physical Planning, Amsterdam: North-Holland.

Niyibizi A, A Komakech (2013). Climate Change Mitigation in Developing Countries Using ICT as an Enabling Tool, in Walter L F, F Mannke, R Mohee, V Schulte, D Surroop (eds.). Climate-Smart Technologies , Springer.

Nyamadzawo G, Wuta M, Nyamangara J, Gumbo D (2013).Opportunities for optimization of in-field water harvesting to cope with changing climate in semi-arid smallholder farming areas of Zimbabwe. Springer Plus, 2(100):9.

Nyangena W. (2007). Social determinants of soil and water conservation in rural Kenya. Environment, Development and Sustainability, 10(6): 745-767.

Oses-Eraso N, and Viladrich-Grau Montserrat (2007). On the sustainability of common property resources. Journal of Environmental Economics and Management, 53(3):393-410.

Ostrom E (1990). Governing the Commons: The Evolution of Institutions for Collective Action, Cambridge, UK: Cambridge University Press.

Ostrom E (2010). The Challenge of common-pool resources. Environment: Science and Policy for Sustainable Development, 50 (4): 8-21.

Ostrom E, R Gardner, J Walker (1994). Rules, Games, and Common-Pool Resources, Ann Arbor: University of Michigan Press.

Palma J, A R Graves, P J Burgess, W van der Werf, F Herzog (2007). Integrating environmental and economic performance to assess modern silvoarable agroforestry in Europe. Ecological Economics, 63: 759–767.

Panne G, C Beers, and A Kleinknecht (2003). Success and failure of innovation: a literature review. International Journal of Innovation Management, 7 (3):309–338.

Pannell D J (1999). Social and economic challenges in the development of complex farming systems. Agroforestry Systems, 45 (1-3): 395-411.

Pannell D, G Marshall, N Barr, A Curtis, F Vanclay, and R Wilkinson (2006). Understanding and promoting adoption of conservation technologies by rural landholders. Australian Journal of Experimental Agriculture, 46(11): 1407-1424.

Pearce T, J Ford, A Caron, B Kudlak (2012). Climate change adaptation planning in remote, resource-dependent communities: An arctic example. Regional Environmental Change, 12 (4): 825–837.

Pender J and B Gebremedhin (2007). Determinants of agricultural and land management practices and impacts on crop production and household income in the highlands of Tigray, Ethiopia. Journal of African Economies, 17: 395–450.

Pennings J M E and A Smidts (2003). The shape of utility functions and organizational behaviour. Management Science 49: 1251–1263.

Plot C (1991). Will Economics become and Experimental Science, Southern Economic Journal, 57:901-19.

Posthumus H, C Gardebroek, and R Ruerd (2010). From Participation to Adoption: Comparing the effectiveness of Soil Conservation Programs in the Peruvian Andes. Land Economics, 86 (4): 645-667.

Power A G (2010). Ecosystem services and agriculture: tradeoffs and synergies. Philosophical Transaction of Royal Society London B Biological Science, 365,(1554): 2959–2971.

Price T J and M E Wetzstein (1999). Irreversible investment decisions in perennial crops with yield and price uncertainty. Journal of Agricultural and Resource Economics, 24(1): 173–185.

Purvis A, W Boggess, C Moss and J Holt (1995). Technology Adoption Decisions under Irreversibility and Uncertainty: 'An Ex Ante' Approach. American Journal of Agricultural Economics, 77(3): 541–551.

Ramamasy S, and S Baas (2007). Climate variability and change: adaptation to drought in Bangladesh, A resource book and training guide, Institutions for Rural Development, FAO, Rome, Italy.

Reddy V R, M S Reddy, and S K Rout (2014). Groundwater Governance: A Tale of Three Participatory Models in Andhra Pradesh, India. Water Alternatives, 7(2).

Reynaud A and S Couture (2010). Stability of Risk Preference Measures: Results From a Field Experiment on French Farmers. Working Paper. Toulouse School of Economics.

Reynaud A, and S Couture (2012). Stability of risk preference measures: results from a field experiment on French farmers. Theory and Decision, 73(2): 203-221.

Reynolds S G (1988). Pastures and cattle under Coconuts. FAO Prod. and Prot. Paper 91, FAO Rome, 321.

Rodriguez-Sickert, R A Guzmán, and J C Cárdenas (2008). Institutions influence preferences: evidence from a common pool resource experiment. Journal of Economic Behaviour Organization 67: 215–227.

Rogers E M (1983). Diffusion of innovations. Third edition. New York: Free Press, 453pp.

__________ (1995). Diffusion of innovations: Fourth edition. New York: Free Press, 518pp.

__________(2003). Diffusion of innovations. A comprehensive textbook that reviews the main investigations of diffusion and provides a general framework. Fifth edition. New York: Free Press.

Rogers E M, and FF Shoemaker (1971). Communication of Innovations: A cross-cultural approach. The Free Press Collier Macmillan, India.
Rosenzweig C and D Hillel (2008). Climate change and the global harvest: impacts of El Nino and other oscillations on agroecosystems. Oxford University Press, New York.
Ross N, P Santos and T Capon (2010). Risk, Ambiguity and the Adoption of New Technologies: Experimental Evidence from a developing economy. Selected Paper prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguau, Brazil, 18-24 August, 2012.
Saaty TL (1980). The Analytic Hierarchy Process, New York: McGraw-Hill. International, Translated to Russian, Portuguese, and Chinese, Revised Editions, Paperback (1996, 2000), Pittsburgh: RWS Publications.
Saha A, H Alan Love and S Robert (1994). Adoption of Emerging Technologies under Output Uncertainty. American Journal of Agricultural Economics, 76 (4): 836–46.
Salvatore D F, M Yesuf, G Kohlin, C Ringler (2011). Estimating the Impact of Climate Change on Agriculture in Low-Income Countries: Household Level Evidence from the Nile Basin, Ethiopia. Environment and Resource Economics, 52(4):457-478.
Schlager E and H Tanya (2009). Resolving Water Conflicts: A Comparative Analysis of Interstate River Compacts. Policy Studies Journal, 37(3): 367–92.
Schmidt E and F Tadesse (2014). Sustainable agriculture in the Blue Nile Basin: land and watershed management practices in Ethiopia. Environment and Development Economics, 19: 648-667.
Schulman S (1978). Kin Selection, Reciprocal Altruism, and the Principle of Maximization: A Reply to Sahlins. The Quarterly Review of Biology, 53(3): 283-286.
Sebastian P, V Björn, and F Markus (2011). The impact of culture and ecology on cooperation in a common-pool resource experiment. Ecological Economics, 70 (9): 1599–1608.
Seki E, and J P Carpenter (2005). Do Social Preferences Increase Productivity? Field Experimental Evidence from Fishermen in Toyama Bay. IZA Discussion Paper No. 1697; University of Aberdeen Working Paper Series.
Sen A K (2008). Rational behaviour. The New Palgrave Dictionary of Economics, 2nd Edition.
Shrapnel M, and J Davie (2001). The influence of personality in determining farmer responsiveness to risk. Journal of Agricultural Education and Extension, 7: 167-178.
Simane B, B Zaitchik (2014). The Sustainability of Community-Based Adaptation Projects in the Blue Nile Highlands of Ethiopia. Sustainability, 6: 4308-4325.
Simane B, B Zaitchik, D Mesfin (2012). Building climate resilience in the Blue Nile/Abay Highlands: A framework for action. International Journal of Environmental Resources and Public Health, 9: 610-631.
Simane B, B Zaitchik, M Ozdogan (2013). Agroecosystem Analysis of the Choke Mountain Watersheds, Ethiopia. Sustainability, 5: 592-616.
Simane B, Zaitchik BF (2014). The Sustainability of Community-Based Adaptation Projects in the Blue Nile Highlands of Ethiopia. *Sustainability*, *6*: 4308-4325.
Simane B. (2011). Building Resilience to Climate Change and Green Economy in Mountain Ecosystems of Ethiopia. Integrating Research, Capacity Building and Sustainable Development Activities; Proceedings of Stakeholders Workshop, Debre-Markos, Ethiopia, 10–13 June 2011; Addis Ababa University Press: Addis Ababa, Ethiopia, 2011; p. 78.
Simon H (1957). A Behavioral Model of Rational Choice, in Models of Man, Social and Rational: Mathematical Essays on Rational Human Behaviour in a Social Setting. New York: Wiley.
Smit B, Burton I, Klein RJT, Street R (1999). The science of adaptation: a framework for assessment. Mitigation and Adaptation Strategies for Global Change, 4:199–213.
Smith P, et al. (2007). Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agriculture, Ecosystem and Environment, 118: 6–28.
Smith V H, R K Michael, and E C Mary (1995). The Private Provision of Public Goods: Altruism and Voluntary Giving. Journal of Public Economics, 58(1): 107-126.

Sova C, Helfgott A, Chaudhury A (2013). Multilevel stakeholder influence mapping in climate change adaptation regimes. Working Paper No. 46. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).
Sova C, Helfgott A, Chaudhury A (2013). Multilevel stakeholder influence mapping in climate change adaptation regimes. Working Paper No. 46. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).
Srinivas R (1988). Agricultural Extension and the Small Farmer: Revealing the Communication Gap in an Extension Project in Kenya. The Journal of Developing Areas, 22(2): 239–252.

Stern N (2007). The Economics of Climate Change: The Stern Review. Cambridge and New York: Cambridge University Press.

Stock J, J Wright and M Yogo (2002). A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments. Journal of the American Statistical Association, 20 (4): 518–529.

Suarez P, J Benn and C Macklin (2011). Putting vulnerable people at the centre of communication for adaptation: The case for knowledge sharing through participatory games and video tools', World Resources Report 2011-Expert perspectives. Online at :www.worldresourcesreport.org/responses/putting-vulnerable-people-center-communication-adaptation-case-knowledge-sharing-through-p (accessed January 2014).

Tanaka T, C Camerer and Q Nguyen (2010). Risk and Time Preferences: Linking Experimental and Household Survey Data from Vietnam. American Economic Review, 100(1): 557-71.

Tarnoczi T J (2009). Climate change in the Prairie agro-ecosystem: information exchange and producer-level learning. PhD Dissertation. University of Manitoba, Canada.

Taylor M and S Singleton (1993).The communal resource: transaction costs and the solution of collective action problems. Politics & Society, 21(2): 195-214.

Teferi E, S Uhlenbrook, W Bewket, J Wenninger, and B Simane (2010). The use of Remote Sensing to Quantify Wetland loss in the Choke Mountain range, upper Blue Nile basin, Ethiopia. Hydrology and Earth System Science, 14: 2415–2428.

Teklewold H, L Dadi, A Yami and N Dana (2006). Determinants of adoption of poultry technology: a double-hurdle approach. Livestock Research for Rural Development, 18(40).

Temesgen M, Uhlenbrook S, Simane B, van der Zaag P, Mohamed Y, Wenninger J, Savenije HHG (2012). Impacts of conservation tillage on the hydrological and agronomic performance of fanya juus in the upper Blue Nile (Abbay) river basin. Hydrology and Earth System Science, 16: 4725–4735.

Terracol A. (2002). Triprobit and the GHK Simulator: A Short Note, appendix of the Triprobit Stata procedure.

Tesfaye A, Brouwer R (2012) Testing participation constraints in contract design for sustainable soil conservation in Ethiopia. Ecological Economics, 73:168-178.

Teshome A, de Graaff J, Stroosnijder L (2014). Evaluation of soil and water conservation practices in the north-western Ethiopian highlands using multi-criteria analysis. Frontiers in Environmental science, 2 (60).

Tesso G, Emana B and Ketema M (2012). Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia. Agricultural Sciences, 3:871-888.

The Federal Democratic Republic of Ethiopia (2007). Climate change National Adaptation Programme of Action (NAPA) of Ethiopia. Available at http://unfccc.int/resource/docs/napa/eth01.pdf

Tom R B, and F Helena (1987). The Shaping of Social Organization: Social Rule System Theory With Applications. London: Sage Publications.

Tschakert P, and K A Dietrich (2010). Anticipatory learning for climate change adaptation and resilience. Ecology and Society, 15(2):11.

Turcksin L, A Bernardini, C Macharis (2011). A combined AHP-PROMETHEE approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet. Journal of Social and Behavioural Sciences, 20: 954–965.

Tversky A and D Kahneman (1992). Advances in Prospect Theory: Cumulative Representations of Uncertainty, Journal of Risk and Uncertainty, 5(4): 297-323.

UK climate Impact Programme (UKCIP) (2010). Local climate impact profile. Oxfordshire Country council Website. Available via :

http://www.ukcip.org.uk/index.php?option=com_contentandtask=view&id=660&Itemid=377. Accessed on April 2016.
UNDP/FAO (1988). Dissemination of renewable energies in farms and rural villages: barriers and policy measures. UNDP/FAO project REUR Tech. Series 5, PER/90/001, 132p.
UNFCCC Secretariat (2008). Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change [online]. Available from: http://unfccc.int/files/adaptation/nairobi_workprogramme/compendium_on_methods_tools/application/pdf/20080307_compendium_m_t_complete.pdf [Accessed 22 July 2016].
UNFCCC(2007). Investment and Financial Flows to Address Climate Change. UNFCCC Secretariat, Bonn.
Upadhyay B M, L D Young, H H Wang, and P Wandschneider (2003).How Do Farmers Who Adopt Multiple Conservation Practices Differ from Their Neighbors? American Journal of Alternative Agriculture, 18 (1): 27–36.
Van den Berg M, R Fort and K Burger (2009). Natural Hazards and Risk Aversion: Experimental Evidence from Latin America. Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009.
Varughese G, E Ostrom (2011). The contested role of heterogeneity in collective action: Some evidence from community forestry in Nepal. World Development, 29 (5):747–765.
Velez A and J J Murphy (2009). What motivates common pool resources users? Experimental evidence from the field. Journal of Economic behavior organization, 70:485-497.
Walker B, Carpenter S, J Anderies, N Abel, G S Cumming, M Janssen, L Lebel, J Norberg, G D Peterson, and R Pritchard (2002). Resilience management in social-ecological systems: a working hypothesis for a participatory approach. Conservation Ecology, 6(1): 14.
Wang L Z, L Fang, K W Hipel (2003). Water Resources Allocation: A Cooperative Game Theoretic Approach. Journal of Environmental Informatics, 2(2): 11-22.
Watkins JWN (1957). Historical Explanation in the Social Sciences. British Journal for the Philosophy of Science 8: 104—117.
weADAPT (2014). A Framework for Climate Change Vulnerability Assessments. https://www.weadapt.org/knowledge-base/vulnerability/climate-change-vulnerability-assessments. Accessed on April, 2016.
Wegayehu B, and L Drake (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: A case study of the Hunde-Lafto area. Ecological Economics, 46: 437–51.
Weikard H-P, and X Zhu (2005). Discounting and environmental quality: When should dual rates be used? Economic Modelling, 22:868-878.
Wilcox N T (2011). Stochastically more risk averse: A contextual theory of stochastic discrete choice under risk. Journal of Econometrics, 162 (1): 89-104.
Wilde J (2000). Identification of Multiple Equation Probit Models with Endogenous Dummy Regressors. Economics Letters, 69 (3): 309–12.
Wilkinson N and M Klaes (2012). An Introduction to Behavioural Economics. 2nd Edition. Palgrave Macmillan, New York, USA.
Wilson T D (1997). Information behaviour: an inter-disciplinary perspective. in Information seeking in context, edited by Vakkari, Savolainen and Dervin. London: Taylor Graham, 39-49.
Winnie JF and J W Gittinger (1973). An introduction to the personality assessment system. Journal of Clinical Psychology, Monograph Supplement, 38:1-68.
Worku G B and G S Friedrich (2016). Preferences for forms of land conservation investment in the Ethiopian Highlands: a household plot-level analysis of the roles of poverty, tenure security and market incentives. Environment and development Economics, 21: 78-108.
World Bank (2006). Sustainable land management: Challenges, opportunities and trade-offs. Washington, DC: The International Bank for Reconstruction and Development, The World Bank.
World Bank (2010). Economics of adaptation to climate change -- Ethiopia. World Bank Group, Washington DC.

World Bank (2011). Ethiopia: climate risk factsheet. pp. 16, The World Bank, Washington DC, USA. http://siteresources.worldbank.org/INTAFRICA/Resources/Ethiopia_Country_Note.pdf. Accessed 01 Nov 2015

WWF (2011). Enabling the transition: Climate innovation systems for a low-carbon future. Stockholm, Sweden.

Yesuf M (2004). Risk, Time and Land Management Decisions under Market Imperfections: Applications to Ethiopia. Ph.D. thesis, Department of Economics, University of Gothenburg, Sweden.

Yesuf M and G Kohlin (2008). Market Imperfections and Farm Technology Adoption Decisions: A case study from the Highlands of Ethiopia. EfD DP 08–04, RFF, Washington D.C.

Yesuf M, and R A Bluffstone,(2009). Poverty, Risk Aversion and Path Dependence in Low Income Countries: Experimental Evidence from Ethiopia. American Journal of Agricultural Economics, 91 (4): 1022-1037.

Yesuf M, S Di Falco, C Ringler and G Köhlin (2008). Impact of Climate Change and Adaptation to Climate Change on Food Production in Low-Income Countries: Household Survey Data Evidence from the Nile Basin of Ethiopia', IFPRI Discussion Paper 00828. Washington, DC.

Yitbarek TW, S Belliethathan, and LC Stringer (2012). The onsite cost of gully erosion and cost-benefit of gully rehabilitation: a case study in Ethiopia. Land Degradation and Development, 23: 157–166.

Zhu X and E C van Ierland (2010). Report on review of available methods for cost assessment. MEDIATION Technical Report No.3.1, Wageningen University, Wageningen, the Netherlands, p38.

Summary

The literature on climate change adaptation in developing countries focused on the socioeconomic and demographic determinants of adaptation decisions to climate change. We need to improve our understanding on the effect of individual and social preferences on decisions related to adaptation to climate change using field experimental approaches. We use field-in-the-lab experimental evidence combined with survey, personality test, and multi criteria analysis for various categories of stakholders. The data were generated from one of the hotspot areas in developing countries: the upper Blue-Nile basin, Ethiopia. The evidence covers the behavioural mechanisms ranging from individual and social preferences to personality traits. We also tried to understand how preferenes of different types are formed by examining the effect of social and environmental factors on preference formation. Adaptation options are also examined from an "agro-ecosystem" perspective

In Chapter 1 we introduce the concepts used in the thesis and give a general objective, research questions and outline.

Chapter 2 focuses on how individual preferences like risk and time preference influence adaptation decisions to climate change. We elicited risk and time preference parameters of subjects using a lab-in-the-field experiment. Later, the findings are incorporated to a larger household data to understand how risk and time preference influence household's decisions related to adoption of farm, off-farm, and institutional climate innovations. We find that, farmers are highly risk averse and have high rates of time preference. Inclussion of risk and time preference parameters in an MVP model results in a negative significant relationship with adoption decisions. This reveals that adaptation to climate change is a challenge in a smallholder economy under high risk aversion and high rate of time preference of farmers. It was also observed that risk aversion and rates of time preference are highly correlated with agro-ecosystem characteristics giving further evidence that preferences are shaped by both social and environmental constructs.

In Chapter 3 we tried to understand the concepts like personality traits, social groups and networks, and their role in the process of learning to adapt. We measure farmers' personality traits using a simple personality test and comprehend how personality traits influence one's information inquiry in the process of adoption decision related to farm climate adaptation options. Social groups and networks can play a great role in facilitating learning, and experience sharing in the smallholder economy social system. We understand the fact that learning can shape one's attitude, and some personality traits may hamper the pace of innovation diffusion through their negative influence on farmers information inquiry process. Learning is also possible through traditional and informal social groups and networks which further facilitates the uptake of innovation uptake. In addition, we see how the different farm related innovations are interlinked. We find evidence that the adoption of high yield crop and livestock varieties are recursively related to the adoption of SWC and irrigation technology.

In Chapter 4 we look into cooperative behaviour of farmers in the management and use of common pool natural resources. Common pool natural resources make up the larger livelihood base of smallholder farmers in developing countries and can help realize a climate resilient economy. Hence, sustainable management and use of commons through cooperative local institutions is a means to sustain livelihood structure of famers. We used lab-in-the-field experiments to understand the influence of social norms and preferences, and ecological variables on cooperative management and use of common pool natural resources. We find evidence that rule following behaviour depends on the social role, and elderly role that an individual plays in the community. In turn, rule following behaviour and the presence of favourable climate change are found pivotal in sustaining the commons. The presence of favourable climate change enables regrowth and replenishment of degraded common pool natural resources. The formation of local institutions are suggested to follow an approach that make up members composed of elders, youth and rule followers and breakers. The possibility of carbon sink is also highlighted in Chapter 4. Common pool agricutural and forested lands can possibly act as carbon sink functions if they are managed through cooperative local institutions.

In Chapter 5, we put stakeholders opinion and dialogue into perspective and draw a conclusion on the priority rankings of adaptation options. Therefore, stakeholders'evaluate agriculture, NRM and water resources related adaptation options based on a set of possibly conflicting criteria. Agriculture, natural resources and water related adaptation options are livelihood bases for smallholder economies, like the one in Ethiopia. The list of possible adaptation options are identified from the literature, stakeholders workshop, and previous chapters. The results show that soil and farm land management related adaptation options are ranked highest. Further more, soil, forest and water resources identified as highly vulnerable, and require a strategy to rehabilitate and improve resilience from climatic shock events. It was also indicated in Chapter 5 climate change adaptation interventions should consider the involvement of both farmers and experts in the planning, implementation and evaluation stage, because we find evidence that priority ranks of different groups are different and it is necessary to further discus the differences with policy makers and then to chose the best options. In addition, evaluation of adaptation options should consider the agro-ecosystem relevance of an option when designing an evaluation criteria. This would help to design an adaptation technology based on agroecosystem characteristics, whcich will be better than simply applying a blanket package.

In this thesis, we have shown the importance of considering decision problems at three levels: the individual level (farmers), cooperative level (group of farmers), and stakeholder level (farmers and experts) in the planning of adaptation strategies to climate change in developing countries. Failure to understand the social and individual preferences of farmers would have a negative consequence in mainstreaming climate change adaptation through climate innovations.

Acknowledgements

Quite a number of people have taken part directly or indirectly for the successful accomplishment of this PhD work, hence I may forced to extend my gratitude and thank for a long list of individuals. However, such a long list of individuals may not fit to such a small section of acknowledgements.

The one who took the upper hand in the success of this PhD research is my promoter Professor Ekko van Ierland. Dear Ekko, your are such a humble and keen man who goes beyond the limits to help others. Your skeptical views have shaped me to see things in different directions. You provided me many opportunities to strengthen myself both in theoretical and analytical skills. You opened up the opportunity to see myself in an international lens. You are always at my next door when I need any help from you. That won't go out of my mind.

I would like to extend my heartfelt gratitude to Dr Xueqin Zhu my co-promoter for her thoughtful guidance, encouragement and willful suggestions through out my study. Xueqin, you are tireless when extending your help to me. Words are not enough to express my appreciation for all the support you extended to me. You devoted much time starting from the initial proposal development stage up to writing individual chapters.

My next thank goes to my second co-promoter Dr Bereket Kebede. Dr Bereket, I am lucky enough of having you in this project. You were very pleased when I first contact you and proposed to be my co adviser. From the very beginning, I didn't have much knowledge about behavioral and experimental economics. The interest grows up once I started communication with you, and which finally flourished in me. Thanks for opening up to such new economic thinking. Throughout the chapters, your touch is visible. You also showed me up a good hospitality while I was in University of East Anglia. I deeply thank you and wish to continue collaborating with you in the future.

Special thanks also go to my co-author Dr Hans-Peter Weikard. Hans-Peter, you are special to me. You are beyond a co-author of a single article; you contributed a lot to many of the chapters. Your door is open to those who need your help. You are closer enough to others who are in need of your help. I don't have words to say more except simply thank you. I would also like to thank other co-authors Dr Edwin vander Werf, Dr Belay Simane and Dr Jeroen Klomp who have played a key role in the accomplishment of chapters.

My friends here in wageningen-deserve appreciation and special thanks. I enjoyed working with you and learned a lot. I have learned from you like open-mindedness, being straight forward, punctuality, planning and meeting schedule. I will never forget the fun I had share with you. Ethiopian students here in wageningen, you are special families while we are far from home. Baye, Sete, Yeshwas, Akalu, and members in the Sunday school are those whom I share the challenge of loneliness in wageningen. The 3:00 pm coffee break chats that I share with Mekuanint, Tsion, Worku, Wudu, Temesgen, and Beshir are non-forgetable.

My next thanks go to my Ethiopian friends for their friendship and encouragement. My lifetime brothers and friends Tekle, Zewdu, Dires,and Mengesha you have special place in me. Teferi, Abraraw, Habtamu, Getachew, Worku, and Gebeyaw you deserve special thanks as you were always a moral in my academics. I share a lot of my challenges and seek advice in matters which are crucial to my study. You were always next to my door to extend your unreserved support.

My families have a special place to be thanked. Words are not enough to express my gratitude and appreciation. Mekdi, my beloved wife, you are always my courage; your patience, love and endurance during my absence gave me the strength at times when I face challenges. This PhD is yours. Ananiah and Azariah, my beloved sons, it was hard for me to miss you and live in a small room in which I couldn’t hear your voices. Anu and Azu, my absence gave you a special challenge in your childhood. I am truly and eternally grateful to you and will always love you. Yared, my brother you are keen enough to love and care my sons during my absence. I thank you for the kind ness and brotherhood you gave it to me. Etalem and Gashe you are not only a father and mother; you are more than that to me. Gashe you are always gaving me an energy and pushed me forward during times when I retreat. I love you both.

I also preserve special thanks to my grandmother Emahoy Ebistie Tessema. You raised me in such a way that education can pave my future life, while you are illitrate. You are special to me; my love remains the same as my childhood. Though oldage forced you to spent at home, I am lucky enough to have you at this time.

Finally, I would like to extend my gratitude and thanks to the administrative stuffs at Wageningen University. Wil and Gre, you are helpful and always closer to those who need your help. I am indebted for the willful and kind support you extended to me while I was in Netherlands.

Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment

D I P L O M A

For specialised PhD training

The Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment
(SENSE) declares that

Yalemzewd Molla Nigussie

born on 17 July 1978 in Debremarkos, Ethiopia

has successfully fulfilled all requirements of the
Educational Programme of SENSE.

Wageningen, 18 January 2017

the Chairman of the SENSE board

Prof. dr. Huub Rijnaarts

the SENSE Director of Education

Dr. Ad van Dommelen

The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)

KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

The SENSE Research School declares that **Mr Yalemzewd Nigussie** has successfully fulfilled all requirements of the Educational PhD Programme of SENSE with a work load of 36.9 EC, including the following activities:

SENSE PhD Courses

- Introduction to R for statistical analysis (2012)
- Dealing with uncertainties in research for climate adaptation (2012)
- Environmental research in context (2012)
- Research in context activity: 'Contributing to a short course on "Basic econometrics and behavioural and experimental economics", given to Master students in Development studies, Addis Ababa University' (2014)

Other PhD and Advanced MSc Courses

- Techniques for writing and presenting a scientific paper, Wageningen University (2012)
- Advanced microeconomics, Wageningen University (2012)
- Advanced macroeconomics, Wageningen University (2012)
- Advanced econometrics, Wageningen University (2014)

External training at a foreign research institute

- Development of an experimental protocol, University of East Anglia, UK (2013)

Management Training

- Organising a one-day stakeholder workshop to identify climate change adaptation options in the upper Blue-Nile basin, Debremarkos, Ethiopia (2015)

Oral Presentations and Conference Visits

- *Implication of risk and time preferences on climate innovations adoptions.* Workshop at the college of Development studies, Addis Ababa University, 13 March 2014, Addis Ababa, Ethiopia
- Participating in the 5th African Association of Agricultural Economist (AAAE) Conference, 23-26 September 2016, Addis Ababa, Ethiopia

SENSE Coordinator PhD Education

Dr. ing. Monique Gulickx

The research described in this thesis was financially supported by the Netherlands Organization for International Cooperation in higher Education (NUFFIC).