Article

Dynamics of Smallholder Farmers' Livelihood Adaptation Decision-Making in Central Ethiopia

Dula Etana [1,2,*] **, Denyse J. R. M. Snelder** [3] **, Cornelia F. A. van Wesenbeeck** [4]
and Tjard de Cock Buning [2]

1 College of Development Studies, Addis Ababa University, P.O. Box 1176 Addis Ababa, Ethiopia
2 Athena Institute of Research, Vrije Universiteit Amsterdam, De Boelelaan 1085,
1081 HV Amsterdam, The Netherlands; tjard.de.cockbuning@vu.nl
3 Centre for International Cooperation, Vrije Universiteit Amsterdam, De Boelelaan 1105,
1081 HV Amsterdam, The Netherlands; d.j.r.m.snelder@vu.nl
4 Centre for World Food Studies, Vrije Universiteit Amsterdam, De Boelelaan 1105,
1081 HV Amsterdam, The Netherlands; c.f.a.van.wesenbeeck@vu.nl
* Correspondence: etanad29@gmail.com or d.e.gebremariyam@vu.nl

check for updates

Abstract: In previous studies mainly focusing on determinants of adaptation, evidence of the dynamic process of adaptation decision-making is negligible. The objective of this study was to investigate the effects of socio-cultural factors, changes in household characteristics, and climate variables on the transition from non-use to use of adaptation strategies. The study integrated primary data collected from households with secondary rainfall and temperature data. The quantitative and qualitative data were analysed using a dynamic random-effects probit model and a thematic approach, respectively. The result shows strong evidence of path dependence in which use of a strategy during the previous year significantly increases its current use. Climate-related risk perception and factual knowledge may not necessarily prompt adaptation action, whereas access to financial resources and farming-related trainings were consistent positive predictors of farmers' adaptation decisions. The findings entail that economic capacity and the associated intrinsic motivation help few farmers to utilise robust and contesting adaptation strategies. For most households, economic problems and the consequent fatalistic attitude and risk-avoidance behaviour induce either non-use or use of responsive and accommodating strategies aimed at ensuring survival. Path dependence in non-use of adaptation strategies and sub-optimal adaptation actions demand effective institutional supports to address the behavioural and economic barriers of these households in order to build overall community resilience.

Keywords: climate change; perception; value; resilience; path dependence

1. Introduction

It is almost invariably recognised that the livelihood of smallholder farmers in developing countries is at increasing risk of the threats posed by climate change and variability (CCV). The multifaceted environmental, economic (e.g., decline in crop yield) and social (e.g., health) effects of CCV are already being observed in these countries. The adverse effects of CCV challenge not only millions of smallholder farmers dependent on agricultural activities but also the national economy in which substantial share of the national GDP comes from agriculture. The impacts of CCV have led to an increasing concern about the importance of adaptation as a necessary response strategy to reduce current and future vulnerability [1–3]. Owing to increasing recognition of the effects of CCV, and advocacy for adaptation action, there is a surge of empirical works on the subject in the past decades [4]. These studies widely documented that demographic and socio-economic characteristics of households are important factors influencing adaptation decisions [5–11].

Nevertheless, there is scant evidence on the dynamics of adaptation decision-making and the roles of socio-cultural factors in shaping decisions [2,8]. Most studies investigated adaptation based on cross-sectional survey data that show the status of adaptation at the time of data collection. Although these studies are insightful to understand farmers' decision-making behaviour, they fail to show changes in adaptation decisions over time. Adaptation is not a discrete measure taken only once. It is a continuous and iterative process due to spatial and temporal variations in the contexts in which climate is experienced and livelihood system operates [1]. For instance, vulnerability, which necessitates adaptation, is a dynamic process that changes continuously as the sources and nature of risk factors change over time [1]. There are temporal changes and spatial differences in the occurrence of climate-related risk factors and their occurrence is also unpredictable to take precautionary measures due to which adaptation responses are expected to vary correspondingly. The social contexts in which CCV is experienced also vary across time [1]. These include changes in households' demographic structure, access to livelihood assets and the adaptation roles of institutions that are important for and have varying implications on adaptation decision-making. The societal dynamics of adaptation also involves social learning which improves understanding of risks and response strategies [4]. Barriers to adaptation change over time and may reinforce other barriers, leading to a vicious cycle [2]. These changes shape how climate risks are framed and adaptation actions are taken. Household adaptation decision-making processes are either enabled or constrained in these dynamic contexts [2–4]. Hence, it is not plausible to assume that adaptation decisions made by farmers at one time and in a given context will work when the context changes. This necessitates the importance of investigating the intertwined linkages and dynamic effects of changes in climate risk factors, farmers' sensitivity to CCV and the capacity to adapt.

Evidence on the roles of socio-cultural and behavioural factors in influencing adaptation is negligible [2,8,12,13]. Economic resources are not the only drivers or deterrents of adaptation, while economic outcomes are not also the only goals of adaptation. Barriers and facilitators of adaptation are embedded in both economic resources and socio-cultural factors. Since adaptation decision is often made in the context of uncertainty about climate risks, socio-cultural factors play important roles in shaping adaptation intentions and actions [13,14] through their mediating roles in the identification of risks, choices of adaptation strategies and implementation of adaptation [4,15,16]. Adaptation may necessitate changing existing ways of life to overcome the threats posed by CCV. However, cultural factors mediate farmers' readiness to deviate from traditional practices [16]. Even in the context of exposure to the same climate risks, adaptation responses could differ due to cultural practices [17]. Societal norms and values shape how farmers' frame climate risks [18] and determine the goals and priorities of adaptation, leading to differing decisions [16,19,20]. Therefore, in the presence of economic capacity to take action, socio-cultural practices and the socially constructed perception of climate risks, norms and values may constrain engagement in adaptation. These denote that integrating the economic aspects of adaptation decision-making and the underlying socio-cultural processes is central to the understanding of farmers' adaptation decisions to respond to CCV.

The objective of this study was to understand how the decision on the use of in-situ adaptation strategies changes over time, in response to households' access to livelihood assets and socio-cultural characteristics as well as changes in climate variables. Specifically, path dependence in adaptation decision-making and transitions from non-use to use of adaptation strategies was investigated. The study was based on mixed methods research in which qualitative and quantitative data were collected from smallholder farming households and other stakeholders. Unlike previous studies that considered adaptation action as a static decision, we generated a retrospective pseudo-panel dataset to examine dynamic binary choice of the use or non-use of adaptation strategies, which was integrated with qualitative data. Adaptation to CCV is a complex process in which biophysical, economic, socio-cultural and institutional factors are intertwined to shape farmers' preferences and decisions. This requires the use of hybrid methodology and plural epistemology for a richer understanding of

the research problem [3,21,22]. This understanding is crucial for interventions aimed at facilitating sustainable adaptation as well as ensuring sustainability of its livelihood benefits.

2. Conceptual Framework

Adaptation involves changes in social-ecological systems in response to the impacts of CCV in the context of interacting non-climate factors [3]. Adaptation decisions are made through non-linear and dynamic interaction between objective aspects of access to and control over resources and subjective aspects of socio-cultural factors in a given climate and non-climate contexts (Figure 1). Culture is a latent variable that can be understood through its manifestations such as meanings, beliefs, practices, norms and values [23]. Culture shapes the capacity to respond to CCV and people's motivation to take action [15].
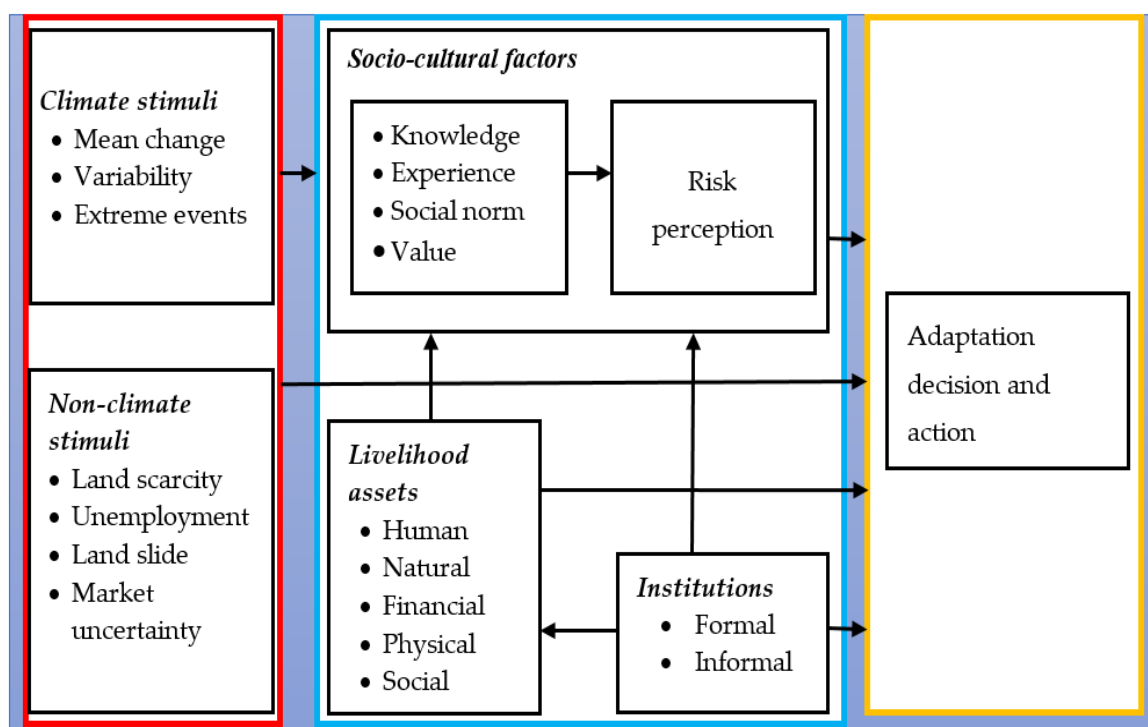

Figure 1. Conceptual framework of livelihood adaptation to climate change and variability.

Climate change risk perception is considered as a prerequisite for adaptation [24]. According to the Social Amplification of Risk Framework, an event of hazard interacts with social, institutional and cultural processes to amplify or attenuate people's perception of and responses to risks [25]. While risk information is obtained in manifold ways from different sources, perception is attenuated or amplified and meanings of the information are defined through social interactions, which, in turn, influence action [26]. Studies show that high risk perception is positively associated with increased likelihood of adaptation [10,27–29]. Nevertheless, perception is not sufficient for adaptation [30,31]. When people are uncertain about the occurrence of some climate events, they tend to interpret this uncertainty in line with their self-interest and hence less likely to take action [32]. High risk perception is translated to action when it is accompanied by high perceived behavioural control [32].

The differing effect of risk perception on adaptation is ingrained in knowledge about CCV, past experience of climate-related events, social norms and value orientations [33]. Knowledge and experience prompt adaptation by increasing understandings about the process of CCV and feelings of its impacts. Some studies show that greater knowledge is positively associated with taking actions [32,34]. Research also supports the positive effect of experiencing CCV on risk perception and adaptation [27,29,35]. Experience has an indirect effect on adaptation behaviour through its influence

on perception, attitude and values [36]. Conversely, negative experience related to CCV could result in people feeling helpless [29], resulting in inaction.

According to Lo [28], the process of risk amplification or attenuation is shaped by social norms. Risks are perceived and response actions are taken based on learnings that takes place in a social fabric being influenced by social referrals, expectations and pressures. Empirical works in this area show the positive effect of social norms on people's responses to the impacts of CCV [13,28,37,38]. The role of social norm on human action stems from the fact that people often perform actions that are popular and/or approved in their social settings [39]. However, norm does not always positively affect behaviour unless, as argued by the focus theory of normative conduct, it is salient at the time of action [40].

Value plays a significant role in adaptation decision-making [20,32]. According to cultural cognition theory, people form beliefs about risks in ways that reflect and reinforce their personal values and commitments to idealised form of social ordering [41]. The cultural ways of life that people subscribe to form a belief and disposed to react involve, among other things, values associated with adherence to tradition, responsibilities to take actions against risks, risk preferences and trusted sources of information/knowledge. Traditional values, emphasising conformity, may give priority to adaptation strategies that support local knowledge and cultural identities, whereas modern values, emphasising openness-to-change and self-enhancement values, may prioritise scientifically based technological adaptations [20]. Adaptation involves both proactive actions taken by individual farmers and planned actions implemented by the government. Given that most adaptation decisions are made at the household level [2], the roles that individuals play in adaptation and their responsibility to take action are imperative [42]. Even though people may believe that CCV is a threat, they may not take responsibility to take action due partly to externalisation of blame and accountability as well as motivational factors [43]. Uncertainty in weather conditions puts farmers in a value dilemma reflected in varying risk preferences and different response strategies. Studies show that risk averse households are less likely to undertake adaptation strategies that are more profitable but involve risks such as planting new crop varieties and using new technologies [8,10], but they do increase crop diversification [44]. Cultural cognition also determines the types of information that people find reliable [45]. Individuals attend to source of information/knowledge in a selective manner that reinforces their cultural predispositions towards environmental risks [41]. These competing value orientations result in different adaptation decisions and choices of strategies.

Notwithstanding the important roles of socio-cultural factors, demographic and economic factors play vital roles in adaptation decision-making. Farmers' adaptation decisions aimed at maximising economic utilities are the functions of their demographic and economic resources. As reported in several studies, farmers' adaptation decisions are positively influenced by education [5,7], being a younger farmer [11,46], male headship and household size [7], access to credit [5–7,9,46], wealth [6,11,47], livestock ownership [7] and land ownership or its level of fertility [6]. Social capital is also important for adaptation [5,11], as it helps to overcome constraints of adaptation activities. These are not only resources required for adaptation but also factors that influence risk perception, knowledge, experience, norm and value orientations [33]. Institutional support mechanisms are also among the enablers or barriers of adaptation [3,48]. Institutions mediate access to and control over livelihood assets that are crucial for households' to be resilient to climate risks or to have the capacity to adapt in the case of vulnerability. The adaptation roles of institutions are related to broader development interventions that directly enhance resilience or that may involve activities that are specifically tailored to adaptation. For instance, many studies have shown that access to agricultural extension services significantly promotes adaptation [5–9,46]. As part of the extension services, formal institutions support adaptation through provision of agricultural inputs (e.g., fertiliser, seed and pesticide), trainings on the use of technologies (e.g., use of surface water for irrigation, use of compost and crop storage techniques) and motivational activities (e.g., experience sharing visits) [49]. Informal institutions also serve as a safety net or build adaptive capacity by facilitating access to livelihood assets [22,50].

In general, household adaptation decision is the function of: (i) risk perception, knowledge, past experience, norms and values associated with CCV; (ii) access to livelihood assets; (iii) climate and non-climate factors; and (iv) institutional factors. Due to non-linear relationships and complexities involving multiple feedback mechanisms, the empirical interrelationships between these components are inconclusive on the one hand, and the importance of the variables and the magnitude of relationships between them are not the same in all contexts on the other hand. The framework of this study (Figure 1) integrated these components to uncover the heterogeneity of the characteristics of households and the contexts in which they make adaptation decisions and implement adaptation strategies [2].

3. Data and Methods

Study areas: Ethiopia is one of the sub-Saharan African countries that is most vulnerable to the impacts of CCV. Its vulnerability mainly arises from excessive dependence on nature-dependent agricultural activities in a fragile environment and lower capacity to adapt to the impacts of CCV. This study focused on agricultural system in three districts where mixed farming is the dominant means of livelihood. These three districts were Kimbibit, Kuyu and Boset selected from North Shoa and East Shoa Zones of Oromia region in Central Ethiopia (Figure 2). The districts were selected based on the consideration of similarity of livelihood systems (i.e., mixed farming), prevalence of food insecurity and representation of different agro-ecological settings. They dominantly represent highland (H), midland (M) and lowland (L) agro-ecological settings, respectively. Farmers follow bimodal rainfall distribution to produce crops: *belg* rain (short rainy season between March and May) and *kiremt* rain (long rainy season between June and September). Livestock production is integrated into crop production by almost all households in all areas. The areas are characterised by the prevalence of climate related risks (i.e., climate variability and extreme events). Due to exposure to these risks frequently occurring in the areas, they are under the support of the Productive Safety-net Program aimed at reducing vulnerability to climate and non-climate risks.

Research design: This study used a mixed methods research design. It is a type of research involving combination of quantitative and qualitative research techniques, methods, approaches and concepts in a single study to address a research question [51]. Its main advantage is that it draws from the strengths of quantitative and qualitative research methods, and it recompenses for their respective limitations to provide stronger and complete understanding of a research problem, validation of one set of findings with the other through corroboration of findings and further exploration of knowledge based on contrasting findings than using either quantitative or qualitative approach alone [52,53]. It also provides different types of information as well as detailed accounts of the research participants [52]. The results of the quantitative strand enable generalisation, whereas those of the qualitative strand capture understanding of respondents' perspectives and contextual explanatory factors [53]. Understanding the multifaceted interaction between and the dynamics of adaptation decision-making require the generation of a broad spectrum of data for which mixed methods is appropriate.

Among the diverse mixed methods research designs, this study employed convergent parallel mixed methods [54] with an equal emphasis on the quantitative and qualitative research approaches. In the convergent parallel mixed methods design, the quantitative and qualitative data are collected concurrently but analysed separately and the two results are merged in the interpretation stage [52,54]. As suggested in Creswell and Plano Clark [54] and shown in Figure 3, the convergent design was implemented in four steps. First, both quantitative and qualitative data were collected concurrently. Second, the quantitative and qualitative data were analysed separately and independently. Third, the two sets of results were merged make comparisons. The results were compared for the purpose of identification of convergences, divergences and complementarities of the findings obtained from the two research methods [54]. Fourth, the comparative results were interpreted.
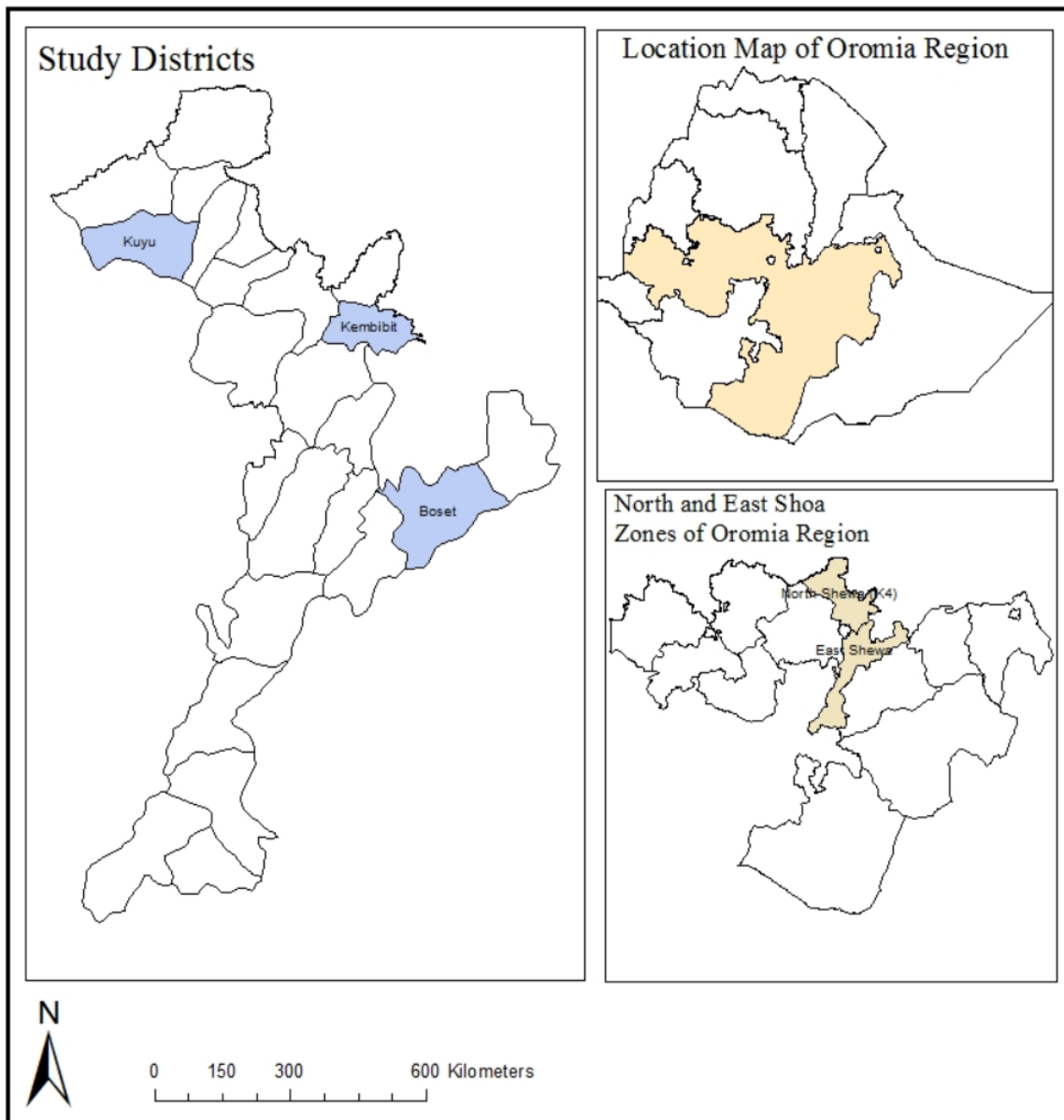
Figure 2. Location map of the study areas.

Sample size and sampling techniques: Given that adaptation decisions are mainly made at the household level, and barriers to adaptation operate at this level [2,12], this study focused on households as the centre of adaptation decision-making. The sample size of the study was determined using sample size calculation for finite population [55]. The population size of the district with smallest number of households yielded a sample size of 270 households. Considering each study area as an independent unit, the total sample size was computed to be 810 households. The sampling unit was farming households and multi-stage sampling technique was used to identify them. While the districts (agro-ecological settings) and the *kebeles* (lowest administrative units in Ethiopia) were selected using purposive sampling being stratified by agro-ecological settings, households were selected using simple random sampling technique. For qualitative data collection, the participants were selected through purposive sampling technique with due consideration of different demographic and socio-economic groups of farmers.

Sources of data and methods of collection: The primary sources of data were household heads and officers in governmental and non-governmental organisations. Primary data were collected using

event history calendar, cross-sectional survey questionnaire, focus group discussion, in-depth interview and key informant interview. The use of event history calendar is suitable to collect retrospective data on farmers' adaptation decisions across time. To overcome memory related problems as well as the cognitive task of recalling the timing of various past events, visual cues (years, ages and respondents' reports of other life events) and "noteworthy" events (national and local) that can be easily remembered by the respondents were used [56]. In addition, the reporting period was limited to a maximum of 15 years to avoid the challenges of recalling events of the distant past. A cross-sectional survey questionnaire was used to collect data on general household information; households' knowledge about CCV, past experience of climate variability and extreme events, social norms and values. Twelve focus group discussions (FGD), 30 in-depth interviews (IND) and 19 key informant interviews (KII) were conducted to generate data on how smallholder farmers deal with the problem of CCV as well as on the roles of institutions in facilitating adaptation. Primary data were collected between February and August 2018. The secondary data on rainfall and temperature of the study areas were obtained from the National Meteorological Agency of Ethiopia. The data covered a period of 30 years (1988–2017).
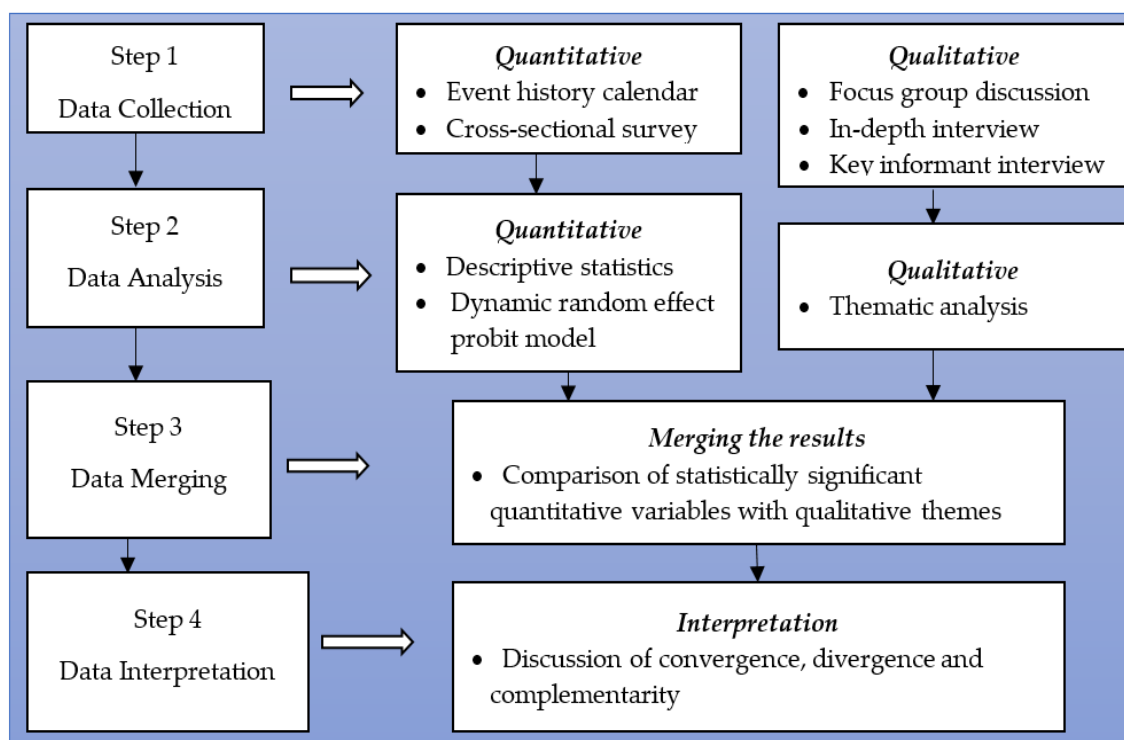

Figure 3. Flow chart of convergent mixed methods research design.

Definition of variables: The dependent variables were the status of use of adaptation strategies in different years. They were time-varying variables recorded for a maximum of 15 years for each household (2003–2017). They took the value of 1 during the years they were used by households and 0 otherwise. Three groups of explanatory variables were used: socio-cultural, demographic and economic (livelihood assets) and climate variables. The socio-cultural variables were risk perception, knowledge, experience, social norm and value orientations. The socio-cultural variables were measured on Likert scale with number of responses ranging from three to five. The number of responses was determined based on related literature, assumed complexity of the content to be measured and convenience for farmers, with dominantly lower levels of education, to comprehend and distinguish between the different choices. A well-known issue in Likert scale is the use of a midpoint response option mostly referring to an undecided/neutral position. If its essence is wrongly understood, attribution of specific values to midpoint responses biases the final computed score. In our unidimensional measurement scale, the lowest values show absence of the attribute and highest values show the maximum amount

of the attribute. Thus, the midpoints indicate moderate amounts of the attributes, instead of neutral or undecided position, as evidenced from the categories (low, medium and high).

Risk perception was measured using a list of eight questions, measured on a five-point scale, that comprehensively assess farmers' concern about CCV (the questions had high scale reliability coefficient to jointly measure risk perception, alpha = 0.93). The index was then classified into three categories (low, moderate and high). Farmers' knowledge was measured based on households' responses to ten factual questions about causes and consequences of and responses to climate change (alpha = 0.74). The knowledge index was grouped into three categories of responses (low, medium and high). Past experience related to CCV was measured by asking respondents whether or not they have experienced drought, flood, snowfall, frost, early termination and delayed onset of rainfall and waterlogging during the last 15 years. It was a yes/no question and the responses were added-up to get the number of events the households were exposed to. The variable was recoded into three categories (low, medium and high). Descriptive norm was measured by asking four questions, measured on four-point scale, on whether the household head observed important others (relatives, neighbours, model farmers and most farmers in their village) on the use of different adaptation strategies (alpha = 0.89). The index was categorised into three classes (low, medium and high). For all indices, the cut-off points to create categories were determined using cumulative square root of the frequency method.

Four value dilemma domains were used to collect data on farmers' value orientations pertaining to the impacts of and responses to CCV. These values, which were adapted from Schwartz's value scale and referring to openness-to-change vs. conservatism dimension, were tradition vs. change, societal responsibility vs. individual responsibility, risk avoidance vs. risk taking and trust of institutional knowledge vs. local knowledge. Value pairs were used as some farmers endorse one value while others endorse its counter-value. Farmers were requested to indicate their positions on how often they adhere to either of the two opposing values or both. Since households might be in a value dilemma and less rigid to adhere to either of the extremes, the third category of response was created for each value domain and labelled as "both", which shows context-specificity in farmers inclination to either of the two opposing values.

Demographic and socio-economic characteristics of households that were reported in previous studies to be influencing adaptation decisions were used as control variables in this study. Following the sustainable livelihoods framework [57], these variables were categorised into five groups of assets: human, financial, physical, natural and social capital (Figure 1). Specifically, these variables were age of the household head (grouped as 20–39, 40–59 and ≥60), sex of the household head, educational level of the household head (no education, primary or above), size of land owned, household size, number of oxen owned, financial capital (received credit/remittance/had savings or not), attended farmer trainings, member of farmer groups and agro-ecological setting (highland, midland and lowland).

Standardised scores were used to measure changes in *belg* and *kiremt* rainfall as well as extreme events to make the indices comparable. Relative change was first computed as a difference between annual values and the 30-years long-term average, followed by division by the standard deviation. Extreme climate events were measured using Consecutive Dry Days (CDD) with precipitation of less than 1 mm and Consecutive Wet Days (CWD) with precipitation of at least 1 mm. These indices, developed by The World Meteorological Organization Expert Team on Climate Change Detection and Indices, were computed using ClimPACT2 software [58]. Times of onset of *belg* and *kiremt* rainfall were used to measure rainfall variability in the study areas. The probability of exceedance of 75%, 50% and 25% were computed using RAINBOW software [59] to categorise the time of onset of *kiremt* rainfall as early, normal or late, respectively, during each year. All the climate indices were calculated on annual basis.

Data analysis: The study used results-based convergent synthesis design in which quantitative and qualitative data were analysed separately and the results were integrated during the final synthesis. The changes in households' adaptation decisions were investigated using a dynamic random effects binary probit model in STATA [60,61]. Random effects models were preferred to fixed effects

models primarily for two reasons. First, estimates of fixed effects models are based on time-variant characteristics with limited or no contribution of time-invariant variables to the analysis [62]. Random effects models, however, allow for estimation of the effects of both time-variant and time-invariant explanatory variables, both of which were the key interests of this study. Second, although fixed effects models control for unobserved characteristics that do not change over time, failure to account for unobserved heterogeneity arising from unmeasured or unknown time-varying variables biases the estimates [62].

Dynamic random effects probit model is used to model dichotomous outcomes of dynamic processes which is suitable to examine transitions between different adaptation decisions. Dynamic panel models are particularly important to estimate path dependence, the impact of past adaptation decision on the current decision. In this model, path dependence was accounted for by modelling lagged values of the adaptation decision (y_{it-1}) on the outcome variable (y_{it}). We investigated the dynamic linkage between changes in adaptation decisions and household and community characteristics over time by modelling time-varying and time-invariant household characteristics and exogenous changes in climate variables.

Accurate parameter estimate of a dynamic random effects model requires addressing the problems of initial condition and unobserved heterogeneity. The initial condition problem arises from the difference between the beginning date of observation and the actual start of the process that leads to the outcome variable [60]. When the two are different, as is the case in this study, there is correlation between initial observation and unobserved factors, which biases the estimate [60]. The other concern is the difficulty to distinguish between genuine path dependence and spurious dependence when there is a correlation between outcome variable and unobserved heterogeneity. To address these problems, modelling the unobserved effect conditional on the initial and within average values of the explanatory variables (and also on the initial status of the dependent variable) is suggested [61]. However, if the panels are short and the means are based on all periods, the use of within means of time-varying explanatory variables performs poorly [63]. Thus, Rabe-Hesketh and Skrondal [63] suggested the inclusion of initial-period values of the time-varying variables as additional explanatory variables. Accordingly, the probability of transition from non-use to use of an adaptation strategy between t−1 and t was estimated as a function of lagged values of the dependent variable, a set of explanatory variables and household unobserved heterogeneity. Unobserved heterogeneity was captured by modelling initial period of the dependent variable, initial period of the time-varying explanatory variables and within-unit averages of the time-varying explanatory variables [60]. Households entered the risk of adaptation in 2003 if they were established in or before 2003. For households established after this time, the year of establishment was the beginning year of observation of their adaptation history. Households leave the risk at the end of the observation period in 2017, with the duration of observation ranging from 1 to 15 years. Given that generation of lagged values drops the first observation of each household, the computation was made based on unbalanced panel of 792 households, yielding 9190 observations (household-years). Year fixed-effects were included in all models to control for the effects of time on adaptation decisions.

Thematic analysis was used to analyse qualitative data [64] using ATLAS.ti. First, themes were identified based on the research objectives and the conceptual framework. Second, coding schemes were established through repeated readings of selected transcripts. Third, the issues in the transcripts were coded following the coding scheme. Lastly, similarities, differences and connections between the contents in the coding schemes were analysed to get qualitative understanding of the data (interpretation and making of meanings). The findings were compared with the statistical results for in-depth understanding and unpacking of new perspectives on the dynamics of adaptation decision-making. Integration of the quantitative and qualitative results and comparison of the findings were made when presenting the results of the study by major topics [54].

4. Results

4.1. Description of the Sample

Most households had male household heads (86.7%). About 37% of the households were headed by young persons (20–39), whereas household headed by adults (40–59) constituted 39% of the respondents (Table A1). The remaining one-fourth were headed by aged persons (≥60 years). Nearly two-third of the household heads had no formal education. About 40% of the household heads had high risk perception, whereas 21% had low risk perception. The share of households who had high, medium and low knowledge about climate change was 47%, 36% and 17%, respectively. About 44.4% of the households had high past experience of climate variability and extreme events, whereas slightly over one-fourth (28.9%) had low experience. Higher proportion of the household heads (43.7%) had low descriptive norm. About 40% of the households value tradition over change. Nearly half of the household heads (49%) reported that addressing the problem of CCV is the responsibility of both farmers and the government. More than half of the households (53%) were risk-averse and 43% of the households reported trust in institutional knowledge over local knowledge.

The average *belg* and *kiremt* rainfall for the period 2003–2017 were higher in the midland areas (Table A2). Conversely, the average number of CDDs was higher in the highland and lowland areas. Failure of *belg* rain was observed in slightly over half of the years of observation in the highland and lowland areas but it was only one in five years that it occurred in the midland areas. During about two-third of the year of observation in the lowland and midland areas, *kiremt* rain started at the normal time.

4.2. Farmers' Adaptation Responses to Multiple Threats and Selection Rationales

Farmers faced multiple threats to their livelihoods and these threats played key roles in necessitating adaptation and shaping decision structures. As noted by farmers, rainfall variability (in amount, distribution and time of onset and cessation) and extreme events (e.g., drought and flood) were the common climate stimuli in the study areas. Farmers reported that their livelihoods were further challenged by non-climate risk factors. These included price volatility of consumption goods and farm products, youth unemployment, landlessness or owning small plot of land and inter-communal conflict. There were also biophysical hazards such as worms affecting crops, yellow rust (*Puccina striiformis f.* sp. *Tritici*) and landslides. Landslides were a major problem in the midland areas.

Households used a wide range of adaptation strategies to respond to these climate and non-climate risks (Figure 4). Crop diversification was the most commonly used strategy in all areas. Due to high variability in the time of onset of rainfall, farmers used changing planting time and crop type as a response strategy. Although shifting to production of new types of crops was very limited in the study areas, changing crop type mainly follows seasonal calendar. Maize and sorghum are planted following *belg* rain in April. If there is no *belg* rain, farmers shift to sowing other crops such as *teff* (*Tef eragrostis*)—an annual cereal crop, in *kiremt*. The percent of households using improved seed varieties ranged from about 28% in the midland areas to 50% in the highland areas. The proportion of households using irrigation was very small in the highland areas due to lack of water sources. In the midland areas, many farmers relied on small streams to irrigate small plots of land to produce vegetables. Irrigation in some parts of the lowland areas was mainly based on one of the largest rivers in Ethiopia, Awash. Water harvesting and hand-dug wells were used by very few farmers to produce vegetables. Terracing was the dominant land management activity in the study areas. Some households also planted trees. Very few households produced compost for use around homesteads.
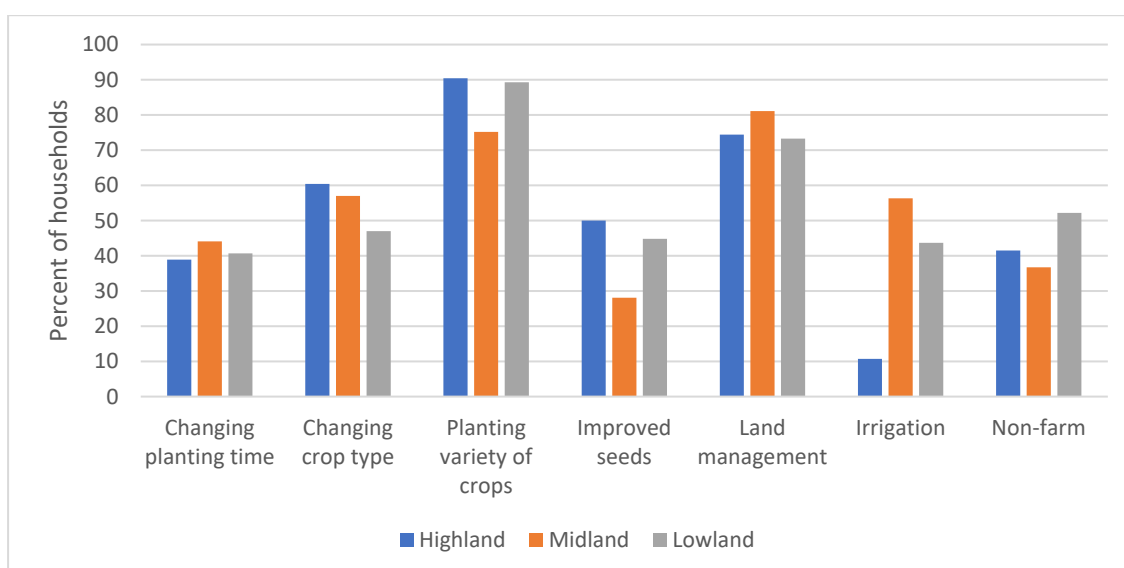
Figure 4. Variation in the use of adaptation strategies by agro-ecological settings.

Most non-farm activities involved trading (grain, livestock, local drinks and small shops) and daily labour works. Women engaged in activities such as spinning, preparation of locally prepared alcoholic and non-alcoholic drinks and production of handcrafts. Due to uncertain climate conditions and sensitivity of farming to manifold adversities, households in all areas used multiple adaptation strategies and diversified sources of income. Although few in number, there were households engaged in rearing dairy cows, poultry and apiculture. Farm-based adaptation strategies were also coupled with the use of production-enhancing farm inputs such as inorganic fertiliser, herbicide and pesticide. In the highland areas where waterlogging is highly problematic, a technology called Broad Bed and Furrow Maker (BBM) was used by many farmers to drain water from the crop field.

Farmers' selection of adaptation strategies was influenced by perceived importance of the strategies, experimentation, peer experience, financial resources and physical factors. Farmers explained the perceived importance of using improved seeds as follows: "*people here are using improved varieties . . . Unless we sow these, we do not get yield from other crops . . . Other crop types require longer time to mature*" [FGD-L-10]. There were also farmers who used their own experimentation to select the most preferred strategies. One farmer explained this saying that "*we use different amount of fertilizer on a small plot of land to see its differential impacts as compared to the remaining farmland. If the yield is good, we use that amount of fertilizer on wider farmland during the next cropping season*" [IND-M-15]. In one FGD, the role of peer experience in the selection of adaptation strategies was stated as follows: "*if a farmer in an adjacent plot obtains good production, other farmers start thinking about how that person obtained good production. So, a farmer can observe the situation on the farm plot of others and use that strategy*" [FGD-M-5]. Denoting the selection effect of financial resources, farmers asserted that strategies such as irrigation, livestock fattening and trading require relatively higher financial capital and hence less used by most farmers. Farmers with limited capacity resort to conventional farming or activities that are not capital-intensive such as daily labour works. Physical factors (e.g., soil fertility, plain or sloping topography and rainfall conditions) were stated to have influenced selection by encouraging or restraining the use of specific adaptation and productivity-enhancing strategies.

4.3. Correlates of Adaptation Dynamics

Smallholder farming households were highly heterogeneous in their decisions to use adaptation strategies that there is a move between use and non-use of strategies. In addition, whilst some households continuously use specific or a combination of adaptation strategies, others do not use the strategies at all. The results of this study show that these variations in farmers' adaptation decisions

are the functions of fatalistic attitude, path dependence, households' access to livelihood assets, socio-cultural factors and climate and non-climate risks.

Fatalism: Farmers' fatalistic attitude as a cause for non-use or exit from use of adaptation strategies was manifested through the belief that the problem of CCV is beyond the capacity of actions to be taken; perceiving that available strategies are either inappropriate or ineffective; lack of intrinsic motivation to attend farmers' trainings presuming that it is not useful; and lack of commitment to make efforts for improvement. This is clearly observed from farmers' expressions such as "*nothing is undone by farmers*"; "*we did everything but no improvement*"; "*can't do anything to overcome this problem*"; "*we don't have the capacity to tackle the cold weather condition*".

Path dependence: Table 1 shows the results of dynamic random effects binary probit model that was fitted to examine adaptation decisions in different years. Controlling for unobserved heterogeneity and households' socio-cultural and economic characteristics as well as climate variables, the results show strong evidence of path dependence in which the probability of using a strategy in a given year was positively affected by the probability of using the strategy during the preceding year. Path dependence was observed in all adaptation strategies considered in this study. The findings from the qualitative data similarly show persistence in both adaptation and non-adaptation, as evidently described in one of the FGDs that "*those who have resources get improved overtime whilst the poor continue going down from year to year*" [FGD-H-3].

Livelihood assets: Adaptation involves the capacity to make investments. However, farmers do not have the same capacity (livelihood assets) to use adaptation strategies, due to which they make varying adaptation decisions. The probabilities of using improved seed varieties and land management were lower respectively by 5.1% and 2.5% for female-headed households compared to their male counterparts. Household size was positively associated with higher probability of changing planting time in response to varying rainfall conditions. The propensity to change crop type, use improved seeds and irrigation and engage in non-farm activities was positively affected by educational level of the household heads (Table 1).

Increase in land size significantly increased crop diversification but significantly reduced the use of improved seed varieties. The number of oxen owned by households significantly increased the probability of changing crop type and planting various crops. The finding of the qualitative data similarly showed that farmers who lack oxen fail to make use of the opportunity to sow seeds when rain falls. "*A person who does not have oxen waits for the support of others to plough his/her farmland. While waiting to get oxen from someone, raining time may pass and the farmland gets dry*" [FGD-L-9]. Access to financial capital during a given year significantly increased the probability of changing planting time and crop type, using improved seeds and engaging in land management and non-farm activities. Complementing evidence from qualitative data show that the poor benefitted less from loans given by microfinance institutions. Since it is provided as a group loan, the poor are often excluded from groups assuming that they are unable to pay back the credit or claimed to use the money for purchase of consumption goods without making any productive investments. When they get a loan, the money is mostly used to buy fertilisers or improved seeds, the benefit of which is reliant on the weather condition. If productions are lost, they will be obliged to dispose the very few assets they have to pay back the money. These, coupled with high interest rate, discouraged farmers from taking loans for adaptation investments.

Table 1. Estimated marginal effects of dynamic random effects probit model for adaptation decisions (n = 9190).

Variable Name	Category	Changing Planting Time	Changing Crop Type	Planting Various Crops	Improved Seeds	Land Management	Irrigation	Non-Farm
Y_{t-1} (TV)	Lagged status	0.107 ***	0.071 ***	0.024 ***	0.105 ***	0.218 ***	0.136 ***	0.139 ***
Livelihood Assets								
Age of the head (TV) (RC = Adult)	Young	−0.012	0.005	−0.001	0.004	−0.011	0.005	−0.005
	Old	0.005	−0.001	−0.004	−0.003	−0.012	0.006	−0.017
Sex of the head	Female	−0.012	−0.004	0.001	−0.051 ***	−0.025 *	−0.008 *	−0.013
Household size (TV)	Number of household members	0.005 **	0.001	0.001	0.002	0.001	0.001	0.002
Education	At least primary education	−0.004	0.012 **	0.002	0.014 *	−0.001	0.008 *	0.021 ***
Land size (TV)	Size of land owned	−0.001	0.007	0.007 *	−0.022 **	−0.001	0.011	−0.016
Oxen (TV)	Number of oxen owned	0.003	0.008 **	0.004 **	0.003	0.012 **	−0.002	0.004
Farmer training (TV)	Attended farmers' training	0.025 ***	0.019 ***	0.003	0.015 **	0.037 ***	0.003	−0.013
Farmer group (TV)	Member of farmer group	−0.013	0.001	0.002	0.013	0.021	−0.001	−0.002
Financial capital (TV)	Access to credit and had savings	0.012 *	0.013 **	−0.001	0.021 **	0.021 **	0.007	0.015 **
Socio-cultural factors								
Risk perception (RC = Low)	Medium	−0.001	−0.005	−0.002	0.001	−0.004	0.003	0.003
	High	−0.034 **	−0.004	−0.001	−0.009	0.011	0.001	0.004
Climate Change Knowledge (RC = Low)	Medium	−0.009	−0.021 **	−0.012 *	−0.004	0.029 *	0.001	−0.011
	High	−0.006	−0.031 ***	−0.003	0.011	0.028 *	0.002	−0.009
Descriptive Norm (RC = Low)	Medium	0.003	−0.007	−0.003	0.006	0.021 *	−0.001	0.011 *
	High	−0.007	−0.011 *	−0.001	0.009	0.008	0.001	−0.011
Past Experience (RC = Low)	Medium	0.005	0.001	−0.001	−0.007	0.034 **	0.008 *	0.003
	High	−0.009	0.004	0.001	0.009	0.057 ***	0.007 *	0.014 **
Change vs Tradition (RC = Tradition)	Change and Tradition	−0.009	0.009	0.008 *	0.024 **	0.011	0.007 *	0.011
	Change	−0.001	0.007	0.002	0.023 **	0.004	0.006	0.007
Responsibility (RC = Social responsibility)	Social and individual	−0.019 *	0.015 **	0.004	0.007	−0.029 **	0.002	−0.013 *
	Individual responsibility	0.034 **	0.043 ***	0.006	0.036 **	−0.009	0.012 **	−0.009
Risk avoidance vs. Risk taking (RC =Risk avoidance)	Avoidance and taking	0.015	−0.004	−0.014 **	0.015	0.026 **	0.005	0.014 *
	Risk taking	0.018 *	−0.009	−0.008	0.002	0.027 **	0.003	−0.005
Knowledge source (RC = Institutional)	Institutional and local	0.027 **	−0.011	0.001	0.017 **	−0.023 *	−0.003	0.011
	Local	0.004	−0.016 **	0.003	0.002	−0.037 **	−0.004	0.011

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.001$. TV—time varying variables; RC—reference category. Note: All models were estimated including initial status and mean values of time-varying explanatory variables as well as climate variables.

Socio-cultural factors: Contrary to our expectation, high climate change risk perception was associated with significantly lower probability of changing planting time. The use of the other strategies did not differ by the level of risk perception. Surprisingly, households with high or medium knowledge about climate change had lower probability of changing crop type and diversifying crops. We found the same result with different model specifications. On the other hand, the probability of undertaking land management activities was significantly higher for households with better climate knowledge. Compared to households with low descriptive norm, those that have moderate descriptive norm had higher probabilities of engaging in land management and non-farm activities. Conversely, the probability of changing crop type was low for households with high descriptive norm. The qualitative evidence similarly showed that observation of adaptation experience of other farmers is both a motivating and discouraging factor. Farmers asserted that they use adaptation strategies by observing the successes of others and also get demotivated when the outcome of the observed behaviour is contrary to their expectation. Discontent discontinuation was particularly high when the observed failure is associated with the use of new technologies. *"In the past years, technologies were changing. We were told to plant in line mixing together seeds and fertilizers. Farmers who used this method obtained little production than those who have sown in the conventional way. So, farmers concluded that the advice they received was wrong. In the other time, new method of sowing came. It was to spread fertilizer first and then sow the seeds. We tried this method. We were not successful. This year, the third technology came . . . We are swinging between diverse ideas. These issues are responsible for failure of farmers to follow technologies in similar patterns"* [FGD-M-5]. The model results further show the positive effect of high past experience of climate events on the use of land management activities, irrigation and non-farm activities.

Farmers' adaptation decisions vary by value orientations. The use of improved seeds was significantly higher by about 2% for household heads valuing change in farming activities instead of adhering to traditional methods of production. Likewise, the qualitative evidence show that farmers who tend to adhere to traditional farming practices were more conservative to try new technologies. Farmers noted that *"when we use emerging technologies, we try on small plot of land since we lack confidence. We suspect that the traditional method may be superior and the new technology is risky. The trainer knows only theoretically. But, we know the traditional method practically, which we feel it is better"* [FGD-M-5]. Valuing individual responsibility to take adaptation action was significantly associated with higher probability of changing planting time and crop type, using improved seeds and irrigation. Risk-taking households had higher probability of changing planting time and engaging in land management and non-farm activities. However, they were less likely to diversify crops. The qualitative evidence complemented that risk avoidance behaviour is particularly related to the local weather conditions. For instance, farmers' preference to avoid risks tends to be high in the study areas due to failure of *belg* rain which results in production only once a year. In FGD-M-5, this was explained as follows: *"Had we harvested every three or four months, we would have tried frequently. If this annual production is damaged, the family will be severely affected by food shortage"*. Repeated exposure to weather-related problems seemed to have also increased risk avoidance behaviour. *"We have stopped sowing with the fear that lack of rain may occur again. Last rainy season [kiremt], most farmers did not plough their farmland due to fear of lack of rainfall that they have experienced during the last five years"* [FGD-L-11]. Trust of local knowledge was negatively associated with changing crop type and land management. On the other hand, trusting both institutional and local knowledge increased the use of improved seeds.

Institutional support: Informal institutions in the study areas supported adaptation through facilitation of access to livelihood assets such as labour and oxen, supports that are crucial for poor farmers. The supports were mainly based on reciprocity which not only excludes the poor but also limits their social support domain to close relatives. As one farmer disclosed, *"we help each other on farming activities. If I help them, they also help me . . . No one helps you for free. There is no free service here"* [IND-M-16]. The power relation underlying the support system also seemed to have worked against the poor. Another farmer succinctly pointed-out this as, *"nobody thinks that they [better-off farmers] should provide assistance to the weak and poor individuals. Even, those who are stronger [economically] are exploiting*

the weak and the poor" [IND-H-6]. Furthermore, farmers emphasised the gradual decline in mutual support due to the effects of CCV that made most people economically weak. Local government offices were the main formal institutions providing adaptation support, through agricultural extension workers, in terms of trainings and advices on farming techniques and use of technologies, which was found to have favourably shaped farmers' adaptation decisions. The quantitative results indicated that the probability of changing planting time and crop type, using improved seeds and undertaking land management activities was significantly higher for household heads who attended farmers' trainings. Government was also the main supplier of farm inputs (e.g., fertilisers, improved seeds and treatments). However, there was substantial difference between households in access to and use of these inputs which farmers attributed to lack/inadequate supply, delayed supply, unequal distribution and supply of poor quality inputs. When farmers failed to obtain from the government, they were obliged to buy from the market. Despite limited availability in the market, it is sold with highly inflated price which discouraged farmers from using. There was also quality concern (required brand and expiry date). Farmers also disclosed that they do not get adequate and continuous support from agricultural extension workers as their support is mainly limited to geographically accessible areas. Farmers further explicated lack of access to modern weather information as a constraint to their adaptation decisions. The interviewed agriculture officers themselves noted that they do not have specific weather information to share with farmers. The adaptation support of non-governmental organisations was observed in very few areas. Their spatiotemporally limited supports included providing improved seed varieties, engagement in land management activities, trainings and construction of water harvesting schemes and irrigation canals.

Climate factors: The probability of changing planting time was significantly low during years of high *belg* rain but significantly high during years when the amount of *kiremt* rainfall was one standard deviation higher than the 30 years average *kiremt* rainfall (Table 2). Compared to the years when the time of onset of *belg* rainfall was normal, failure of *belg* rain was associated with significant decline in changing planting time and crop type as well as the use of improved seed varieties. Similarly, the probability of changing planting time and crop type was lower during years of early onset of *belg* rain as compared to normal time of onset. However, during years of late onset of *belg* rain, the probability of changing planting time was significantly higher. Late onset of *kiremt* rainfall was associated with lower probability of changing planting time. Increase in the amount of *belg* rainfall significantly increased crop diversification. The probability of undertaking land management activities was significantly higher during years of increased CDD but lower during years of smaller CWD. While increase in the number of CWD decreased the use of irrigation, late onset of *belg* rain and early onset of *kiremt* rain increased the probability of using irrigation. The probability of involving in non-farm activities was significantly lower during years when the amount of *kiremt* rain was higher than the 30 years average.

The likelihood of undertaking different adaptation measures varied by agro-ecological settings. Compared to midland areas, the probability of changing planting time was lower by about 7% and 3% in the highland and lowland areas, respectively. In both the highland and the lowland areas, farmers had higher probabilities (3% and 6%, respectively) of using improved seed varieties than those in the midland areas. Farmers in the highland areas had lower probabilities of using terracing than farmers in the midland areas, which is partly related, as indicated by farmers, to the dominantly plain topography of the area. In the highland areas where there is limited access to water, the probability of using irrigation was significantly lower than the midland areas whereas farmers in the lowland areas had significantly higher probability of using irrigation. There was no difference between the three areas in changing crop type, planting various crops and involving in non-farm activities.

Table 2. Marginal effects of climatic variables and agro-ecological settings on adaptation decisions.

Variable Categories	Changing Planting Time	Changing Crop Type	Planting Various Crops	Improved Seeds	Land Management	Irrigation	Non-Farm
Average rainfall							
Belg rainfall (TV)	−0.006 **	0.001	0.003 *	0.001	0.004	0.001	0.003
Kiremt rainfall (TV)	0.007 **	0.003	−0.001	0.003	0.003	−0.002	−0.005 **
Extreme events							
CDD (TV)	0.001	0.001	−0.001	0.003	0.009 *	−0.001	0.003
CWD (TV)	−0.001	0.001	−0.001	−0.004 *	−0.010 *	−0.005 **	0.004
Belg variability							
Belg failure (TV)	−0.024 ***	−0.013 **	0.001	−0.024 **	0.002	−0.001	0.009
Early onset (TV)	−0.027 **	−0.012 *	−0.003	−0.018	−0.007	−0.003	−0.004
Normal onset (RC)							
Late onset (TV)	0.017 **	−0.003	0.004	−0.007	0.011	0.011 **	−0.002
Kiremt variability							
Early onset (TV)	−0.001	−0.005	−0.004	0.002	−0.007	0.015 ***	0.004
Normal onset (RC)							
Late onset (TV)	−0.018 **	0.004	−0.001	0.005	−0.012	0.001	0.001
Agro-ecological setting							
Highland	−0.069 ***	−0.004	0.009	0.025 **	−0.037 **	−0.022 **	0.015
Midland (RC)							
Lowland	−0.026 **	−0.012	0.003	0.062 ***	−0.012	0.011 **	0.012

* *p* < 0.1; ** *p* < 0.05; *** *p* < 0.001; TV—time varying variables; RC- reference category.

Non-climate factors: In the midland areas, landslide was a critical challenge to the use of some strategies as it damages farmlands and irrigation canals. As noted by one farmer, "*there is no solution for land slide. There are farmers who have totally abandoned their farmlands. I do not think that farmers can earn their means of living from farming*" [FGD-M-7]. Although it was observed only in one of the study *kebeles* in the lowland areas, intercommunal conflict on natural resources was among the causes for not using adaptation strategies. Farmers in this area explained that "*this year* [2018], *there was mass mobilization to construct terraces. We did not participate because of security problem. We have no confidence in our security issues. There are water harvesting schemes constructed by the community though we did not use because of security problems. People became hopeless. As you can see, we have no good houses; because we are living in a dilemma*" [FGD-L-11]. Lack of farmland and limited employment opportunities were stated as pressing problems of young farmers in the study areas.

4.4. Transitions between Non-Use and Use of Adaptation Strategies

Figure 5 shows the probabilities of transition between non-use and use of adaptation strategies by agro-ecological settings. Entry refers to the transition of households from not using a strategy at year t−1 to using it at year t. Exit shows households using a strategy at year t−1 but not using it at year t. While persistence refers to using a strategy during two consecutive years, steady-state means continuous use of a strategy. These probabilities were predicted controlling for household characteristics and climate variables. Since crop diversification was one of the widely used strategies to manage various risks, it had higher probability of entry, persistence and continuous use than the other strategies, with no noticeable difference between the three areas. Likewise, the probability of entry to the use of land management was relatively higher in all areas but exit was lower, resulting in a relatively higher persistent and continuous use. Conversely, the use of improved seeds was characterised by low entry and higher exit probability. Perceptible difference was observed between the agro-ecological settings in the transition probabilities of using irrigation. There was a very low probability of entry to the use of irrigation (<6%) than all the other strategies which reflects lack of access to water. However, once started using, the probability that the users exit during the subsequent year was very small, signifying high persistent use. High probability of continuous use of irrigation was observed in the lowland areas (67%) due to availability of perennial river covering some of the villages in the district. There was lower entry (<15%) and higher exit (about 30%) probability of using non-farm activities.

The probability of continuously using this strategy ranges from 19% in the highland areas to 32% in the midland areas.
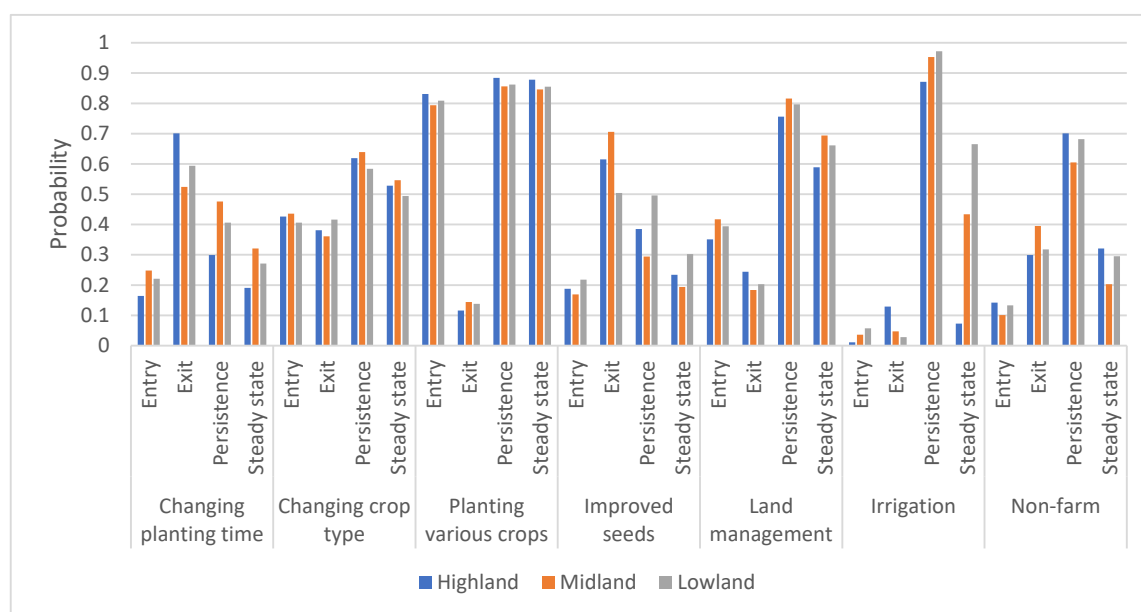

Figure 5. Predicted probabilities of transition between use and non-use of adaptation strategies by agro-ecological settings.

Continuous use of adaptation was the function, among other things, of the economic benefits obtained from the use of the strategies which is translated to behavioural adjustment in terms of motivation, eventually leading to consideration of the use of the strategies as a normative behaviour. Since human beings are positively motivated by their past successes, benefits obtained from using a strategy made farmers more enthusiastic to sustainably use the strategies. Use for longer years also built farmers' confidence about its benefits, as clearly indicated in the following excerpts. "*I use them because they are profitable. According to my opinion, the strategies improve the life of my family. I realized from the benefits I obtained that the strategies are beneficial*" [IND-M-15]; "*I am satisfied with the use of the strategies. It is because I have seen improvements in the life of my family. My children and I are living in good condition because of these strategies*" [IND-M-17]; and "*I use the strategies always. Once you see the benefits, you will not refrain from using the strategies*" [IND-L-21].

Farmers' aspiration for improved lives was an encouraging factor for continuous use of strategies. One farmer explained that, "*if we stop using these methods, we bring poverty on ourselves. We need the use of more strategies this year than last year. If I get 105 birr this year, I should get 110 next year, 115 in the following year. I should not wear this year the clothes that I wore last year. I have to change it. If I do not work and sit idle, it means that I will continue to live in poverty*" [IND-H-9]. With intrinsic motivation, the use of some strategies becomes normative behaviour of farmers that they are continuously used. For instance, fertiliser and pesticides/herbicides were more persistently used as farmers were well aware of their importance during long years of practice. In support of this, one farmer explicated that "*I am using fertilizer. If we stop using it, there is nothing that we will get to live. There is no life without using fertilizer*" [IND-H-4]. This is the case particularly when the strategies are well-known by farmers as shown in the following quote: "*I have chosen the strategies I use because I may face a problem if I do not use them. In addition, the strategies are known*" [IND-L-17].

4.5. Farmers' Decision-Making Structures

The results of this study show that farmers' decision to respond to the impacts of CCV generally follow four patterns: innovative and experimental, nature-dependent, sub-optimal use and desperate

decision-making. Very few households used innovative and experimental approach to make adaptation decisions. For example, in the midland areas, some farmers started forage production using fertiliser due to high crop production risks. This helped to engage in more robust adaptation strategies such as rearing dairy cows and cattle fattening. Some households also used innovative risk minimisation strategies that prevent total asset disposal. For instance, "*when they sell oxen, they buy calves [as a replacement]; the remaining money is used to buy grain and fertilizer*" [FGD-M-6]. In the highland areas where the problem of waterlogging is common, some households used locally prepared tools to drain water from the crop field. Multiple strategies were also utilised by many farmers as a means to spread risks.

In nature-dependent decision-making logic, farmers followed the time of onset of rainfall to decide on the type of crops to be sown. These households plant *belg* crops if there is rainfall. During years of *belg* failure, they wait for the subsequent rainy season to produce *kiremt* crops. Season also determined engagement in non-farm activities. For instance, one farmer noted his experience saying that "*I engage in daily labour work sometimes depending on the season. When there are farming activities, I do not involve in daily labour works*" [IND-M-18].

Farmers sub-optimal use of strategies is manifested through lower level investment, as vividly described in the following excerpts: "*I do not use the required amount of fertilizer due to lack of money. If I use sufficient amount of fertilizer, I know I can increase my production. However, as I cannot afford buying the required amount of fertilizer, I use the small amount I have managed to buy on the whole farmland*" [IND-H-3]. Another farmer similarly stated that "*we just use fertilizer based on the capacity to cover its cost. Our farmland could be 2 or 3 plots in different places. For these plots, 400–500 kg of fertilizer might be needed. We have no capacity to afford all these. We take 100 or 150 kg and use on few farmlands. We have no capacity to afford the cost to apply on the entire farmland we have*" [IND-H-6].

Desperate decision-making includes borrowing money with high interest rate, renting-out or sharecropping-out farmland and asset disposal. Sharecropping-out, mostly used by female-headed households, was a less-preferred strategy as it leads to lower yield due to sharing of outputs. The rental price of farmland was also claimed to be very small to cover subsistence requirements of households for the whole year. In the worst form of desperate decision-making, farmers opted for bad choices when they face decision dilemma. For instance, "*when the poor fails to pay back the credit because of the effect of climate change, they are accused by lending institutions and brought to court to face charges. It is better for the poor to work for the rich people [as a daily labourer] to cope with climate change as they have been doing before*" [FGD-L-10]. Climate problems might also lead to children's school drop-out. "*Our children are not able to go to school. They are engaged in daily labour works. That is how we live*" [FGD-M-8]. Selling oxen was another form of bad choice made under precarious living conditions. One informant disclosed his experience saying that "*we sold our ox to get some money as we have no land and we depend on sharecropping. It is difficult for our children to live without food and clothing. We sold it to solve household problems*" [IND-M-16].

5. Discussion

Promoting adaptation is a development issue of higher priority in developing countries to reduce the disproportionate impacts of CCV on smallholder farmers. Despite increase in awareness about the impacts of CCV and in the proportion of adapting households across time, there is noticeable difference between households in their adaptation decision-making logic and choice of strategies. The findings from both quantitative and qualitative study similarly suggest that path dependence, norms and values, financial constraint, institutional support mechanisms and climate and non-climate factors explain the heterogeneity in farmers' adaptation decisions.

There is strong path dependence in adaptation decision-making: Households that use a specific adaptation strategy in the previous year are more likely to use in the subsequent year. This finding suggests high persistence in adaptation and non-adaptation. Path dependence of adaptation decision-making works through economic and behavioural mechanisms. In the economic path, households using

adaptation strategies in the past are more likely to gain economic benefits that improve their adaptive capacity to make similar or additional investments in the following years, leading to virtuous circle of improvement. For instance, as shown by a study in Chile, crop income in the previous year positively affects farmers' adaptation decisions [11]. Conversely, for households that are unable to adapt in the past due to lack of resources, the likely consequent economic problems increase the risk of not adapting in the subsequent year, leading to vicious circle of poverty and vulnerability [47]. In the behavioural mechanism of path dependence, the possibility to observe the benefits of adaptation is motivating for adapting households to take actions in the following years. For non-adapting households, failure to adapt in the previous year and the associated economic problem might be translated to fatalistic attitude as well as loss of motivation and commitment to make use of even the tiny adaptation opportunity.

High risk perception does not necessarily translate to adaptation action: The result of this study shows that high perception significantly reduces the use of changing planting time, while it has insignificant effect on the use of the other strategies. It is consistent with a finding from Central America and Mexico that showed lower likelihood of engagement in adaptation actions among farmers with high risk perception [65]. Although risk perception is assumed to be a prerequisite for adaptation, farmers may not take action based on their perception of climate risks for various reasons. Adaptation action in response to uncertain climate condition might be associated with both gains or losses. In these situations, farmers refrain from taking adaptation action as their decision is dominated by the preference to avoid potential losses [24]. Farmers also do not intend to adapt when they perceive that the actions cannot protect them from the impacts of CCV [13,31]. As evident from fatalistic attitude of some farmers, they may also fail to act when they feel that they have little control over the problem of CCV [32]. For households with low adaptive capacity and conservative in taking risks, their level of perception does not also positively impact the use of adaptation strategies. Detailed understanding of the non-linear linkage between perception and adaptation is the subject of future investigation.

General knowledge about climate change may not be sufficient to prompt adaptation action: Raising knowledge is often considered as one means of boosting adaptation. However, as the unexpected result of this study shows, the effect of knowledge is negative for climate-sensitive adaptation strategies such as changing crop type but positive for land management activities that are less risky. A possible explanation for this might be lack of specificity of general climate knowledge to be used for household-level decisions. In this study, knowledge was measured focusing on factual questions about the general and widely acclaimed causes and consequences of CCV and possible responses. Since understanding and interpretation of scientific knowledge is mediated by socio-cultural contexts, factual scientific information is not sufficient for adaptation action [24]. Knowledge obtained from external sources are evaluated against one's own knowledge and integration of this knowledge is conditional on its fitness with the activities of farmers [48]. Unlike general knowledge about CCV, contextually specific and locally relevant knowledge helps farmers to know more about and be confident in their decision to use adaptation strategies. The consistently positive effect of farmers' trainings on adaptation found in this study signifies the decisive roles of knowledge obtained through extension services and tailored trainings in prompting adaptation. Persistent use of land management activities in the study areas might for instance be related to the effects of successive awareness raising activities. On the other hand, as evident from the negative effects of trust in local knowledge on changing crop type and land management, farmers' local knowledge does not suffice for adaptation. This entails the importance of integrating local knowledge with scientifically relevant information to build farmers' confidence on innovations and create better opportunities for adaptation [22]. Otherwise, factual knowledge alone may increase worry, resulting in inaction. Further research is needed to uncover the linkages between factual knowledge about CCV, local knowledge and farmers' choices of adaptation strategies.

Past experience translates to differing adaptation decisions: Past experience of climate risks and previous use of strategies increase adaptation, which suggests the learning and motivational effects of experience. In addition to one's own adaptation experience, farmers observe several normative adaptation behaviour in their surroundings that encourages them to comply with [37,38]. Another important

finding was that past experience also discourages adaptation. Unfavourable past experience as a cause for non-use or interrupted use of adaptation strategies works in two ways. It has behavioural effect in which trust of and confidence in the strategy is reduced due to its failure to meet the expectation of farmers. Ineffectiveness of the strategy also decreases farmers' economic capacity to use in the following year. The negative effect of past experience is most pronounced, the result of this study shows, when it is related to failure of newly introduced strategies. Since adoption of a new strategy requires time to gain farmers' confidence, introducing new methods of production at shorter time intervals without enhancing their in-depth theoretical understanding and practical demonstration reduces the likelihood of adoption. In relation to negative effect of peers' experience, it is not always compelling that a farmer positively conforms to what has been observed. Peer experience has beneficial impact only when the observed behaviour is positively framed [39]. Given that households implement adaptation strategies in different contexts, the outcome could be negative as a result of which observed behaviour may not translate to positive adaptation decision. The adaptation outcome of conformity might not also be positive due to underestimation of risk or misperception by the social referents (peers). In addition, the possibility to observe inconsistent behaviour and the tendency to evaluate the importance of conforming to certain normative behaviour based on personal expectations might result in negative effects of descriptive norm (peers' experience) on adaptation decisions.

Valuing change, individual responsibility and risk-taking positively affect adaptation decisions: Farmers who value tradition over change are less likely to adopt new practices and tend to accept the existing way of life acclaiming that the prevailing livelihood system is better than the newly introduced alternative [32]. The preference of some farmers in this study for conventional seeds and conventional method of sowing instead of improved seeds partly explains this tradition-based justification of existing farming system. Conversely, for farmers who are cognizant that the persistent problem of CCV requires change to new livelihood practices, the likelihood of adopting new technologies and innovative production practices is high. Decision to adopt a given strategy depends on farmers' risk preferences and the extent to which the strategies are risky. Risk-taking households are more likely to change planting time, whereas risk-averse households opt for crop diversification as also noted in another study [44]. Farmers are likely to take action when they believe that they are individually responsible for action than ascribing the roles to the government or non-governmental organisations. This might reflect the motivation of these farmers to determine their destiny by themselves than being passive victims of adverse climate conditions. Valuing knowledge/information obtained from institutional sources or knowledge obtained from both institutional and local sources is more important to prompt adaptation action than trusting local knowledge. One possible reason for this might be the difficulty of relying on local knowledge to understand dramatic shifts and unpredicted variabilities in weather conditions, and making changes to adaptation decisions.

Lack of access to financial resources is a key constraint of adaptation: Congruent to previous studies [6,7], financial capital is a consistent predictor of adaptation. Financial capital (access to credit, savings and remittance) enhances farmers' adaptation investment which contributes to building their adaptive capacity. Farmers with higher financial resources tend to diversify livelihood strategies through engaging in high-return strategies such as irrigation, livestock fattening and use of improved seed varieties and other productivity-enhancing inputs. Conversely, the poor either do not use strategies at all, or focus on low-capital low-return strategies such as changing planting time and daily labour works. Financial constraint also compels them to take delayed action to respond to climate problems (e.g., late use of treatments). Lack of resources oblige poor farmers for sub-optimal use of strategies or to shift from adaptation to coping as, for instance, they may not have options except disposing the meagre assets they have to overcome food shortage. This not only incapacitates them not to undertake adaptation actions but also likely to increase their risk avoidance behaviour and vulnerability.

Climate variables, compounded by non-climate factors, influence adaptation decisions and choice of strategies: It is evident from the results of this study that climate variables play important roles in influencing farmers' adaptation decisions. Increase in the amount of *belg* rain reduces the need for changing

planting time as it provides options for farmers to produce more crops. The negative effect of *belg* failure on the use of various adaptation strategies suggests abandoning the production of *belg* crops in most of the study areas. As noted by farmers, it is only once in many years that they produce *belg* crops due to lack of rain during this season. Early onset of *belg* rain decreases the importance of changing planting time (mainly delaying planting time) and crop type. Early onset of *belg* rain, provided that it is not followed by extended period of consecutive dry days, helps farmers to plant long-duration crops of the season (maize and sorghum) in time without the need to delay planting time or change crop types. On the other hand, if *belg* rain comes late, farmers delay planting time to the later period of the season, a risk-taking decision made to avoid production only once a year. If *kiremt* rain comes late, it is highly unlikely that farmers change planting time due to shorter growth period unless late onset is compensated by late cessation which is less observed in the study areas. Engagement in non-farm activities was low during years of abundant *kiremt* rainfall, which suggests the possibility of extensively engaging in farming and harvesting activities, reducing the time available for non-farm activities. Non-climate factors such as landlessness, market failure, seasonality of employment opportunities and landslide interact with climate factors to limit farmers' adaptation space for actions.

Weakening of informal institutions and inefficient support of formal institutions hamper adaptation: As observed in many developing countries [22,50], informal institutions are assumed to provide viable support for farmers to adapt to CCV. Their roles in the study areas are mainly limited to facilitation, through social networks, of access to resources such as labour and oxen and mutual support in the case of emergencies. However, their support mechanism is largely based on reciprocity, which is less beneficial for the poor who are in dire need of support for adaptation. In such cases, the poor either decide not to take adaptation action or resort to nature-dependent and desperate adaptation decisions. Moreover, CCV is waning the roles of these institutions through, for instance, weakening of mutual support due to the effects of covariate climate risks on most farmers, consequently reducing the adaptation roles of these community-based institutions. It has been shown in many studies that formal institutions play an important role in facilitating adaptation [22,49,50]. They mobilise their resources (legitimacy, technical and human expertise, information and budget) to expedite farmers' adaptation by identifying and promoting the implementation of feasible and context-specific strategies. Nevertheless, without undermining their roles in facilitating access to inputs and building the capacity of farmers through trainings and other extension supports, these institutions are not effective in supporting adaptation with their full potential mainly because of implementation problems such as insufficient and delayed supply, as well as uneven distribution of farm inputs; and inadequate extension services. These problems are partly reflected in the low entry and high exit probability of using improved seeds. The problems of institutions are due in part to lack of adequate number of staff, shortage of budget and weak monitoring system.

6. Conclusions

The livelihood of smallholder farmers in Ethiopia is under increasing pressure due to the effects of unpredictable rainfall and non-climate factors being compounded by socio-economic and institutional problems. Path dependence noticeably explains continuous use or non-use of adaptation strategies, in which past history, success or failure, significantly explains current decisions and preferences [47]. The characteristics being rooted in their high adaptive capacity, rich households that are risk accepting, open to changes and individually responsible for actions to improve their lives utilise contesting and robust adaptation strategies (e.g., livestock fattening and irrigation-based production of cash crops) to build a livelihood that is resilient to the effects of climate and non-climate risks. On the other hand, poor households are highly heterogeneous (more than rich households) in terms of their decisions on the use and non-use of strategies as well as the type of strategies they use to respond to the problems. Common to all is that their adaptation history heavily relies on climate-sensitive strategies as well as sub-optimal investments. The livelihood system of poor households is constrained by limited options and lack of flexibility in decision-making. These households mostly follow responsive strategies that

accommodate unfavourable climatic conditions to meet their survival requirements. Path dependence in continuous non-use of adaptation strategies among these households is ingrained not only in their low adaptive capacity but also in their behavioural features involving risk-avoidance, externalisation of responsibilities to take action and fatalistic attitude. In the context of being locked in economic and behavioural constraints, raising knowledge and risk perception on CCV may not be a sufficient option to help the poor take adaptation measures [65]. Given the daunting challenges of CCV, the existing support of formal and informal institutions is not sufficient-enough to support poor farmers' adaptation efforts. The limited scope of the supports given by these institutions help only to build short-term adaptive capacity which is easily eroded by exposure to frequently occurring climate risks [50].

The study findings have significant scientific and practical implications. Climate, non-climate, economic, socio-cultural and institutional factors have non-linear and intertwined linkages to frame decision-making processes and choices of adaptation strategies. Hence, research on adaptation should take into account the complex interaction between these components of livelihood adaptation processes through a comprehensive system's approach to thoroughly understand the dynamics of farmers' livelihood vulnerability and their trajectories of dealing with multiple climate and non-climate risks. There is neither a linear approach to enhancing adaptation nor are there approaches or strategies that work in all contexts. For instance, raising farmers' risk perception may not be taken for granted to facilitate adaptation as perception does not remain intact due to the effects of knowledge, experience, norms and values. In addition, the extent of acceptance and utilisation of innovative adaptation strategies are evaluated based on pre-existing normative beliefs and value orientations. Hence, identification and implementation of adaptation strategies as well as monitoring and evaluation of adaptation actions require proper consideration of the local biophysical, socio-cultural and economic contexts. Particularly, persistence in non-use of adaptation demands effective institutional support to address the behavioural and economic barriers of these households, which, otherwise, would lead to limits to adaptation and thereby undermines overall community resilience.

Appendix A

Table A1. Descriptive statistics of the sampled households.

Variable	Categories	N	%	Highland	Midland	Lowland
Age of household head	Young	298	36.8	32.9	29.5	37.6
	Adult	313	38.6	31.3	32.6	36.1
	Old	199	24.6	37.2	40.2	22.6
Sex of household head	Male	702	86.7	34.3	32.8	32.9
	Female	108	13.3	26.9	37.0	36.1
Household size	Mean	810	4.96	4.80	4.80	5.28
Education of household head	No education	547	67.5	36.0	30.2	33.8
	Primary +	263	32.5	27.8	39.9	32.3
Land size	Mean	810	1.82	2.34	1.31	1.81
Number of oxen	Mean	810	1.37	1.66	1.28	1.16
Received farmers' training	No	312	38.5	26.0	32.7	41.3
	Yes	498	61.5	38.0	33.7	28.3

Table A1. *Cont.*

Variable	Categories	N	%	Highland	Midland	Lowland
Member of farmer group	No	623	76.9	30.3	35.2	34.5
	Yes	187	23.1	43.3	27.3	29.4
Financial capital	No	366	45.2	22.7	36.1	41.3
	Yes	444	54.8	42.1	31.1	26.8
Risk perception	Low	173	21.4	88.4	4.0	7.5
	Moderate	312	38.5	32.1	30.4	37.5
	High	325	40.1	5.2	51.7	43.1
Knowledge about climate change	Low	137	16.9	39.4	23.4	37.2
	Medium	292	36.0	34.6	36.3	29.1
	High	381	47.0	30.2	34.6	35.2
Descriptive norm	Low	354	43.7	38.4	29.1	32.5
	Medium	222	27.4	24.3	40.5	35.1
	High	234	28.9	34.2	32.9	32.9
Past experience	Low	234	28.9	26.9	22.6	50.4
	Medium	216	26.7	38.9	22.2	38.9
	High	360	44.4	34.2	46.9	18.9
Change vs. Tradition	Change	284	35.1	30.6	36.6	32.7
	Both	205	25.3	38.5	36.1	25.4
	Tradition	321	39.6	32.4	28.7	38.9
Responsibility	Social	199	24.6	33.2	37.2	29.6
	Both	397	49.0	34.0	31.0	35.0
	Individual	214	26.4	32.2	34.1	33.6
Risk preference	Risk avoidance	429	53.0	31.9	35.9	32.2
	Both	154	19.0	31.8	48.1	20.1
	Risk taking	227	28.0	37.0	18.5	44.5
Trusted source of knowledge	Institutional	350	43.2	30.0	30.0	40.0
	Both	312	38.5	35.6	35.6	28.8
	Local knowledge	148	18.3	36.5	36.5	27.0

Table A2. Summary of climate measures (2003–2017).

Variable	Category	Boset	Kimbibit	Kuyu
Belg rainfall (mean)	–	87.5	67.1	212.7
Kiremt rainfall (mean)	–	385.2	680.5	962.9
CDD (mean)	–	116.8	161.4	77.1
CWD (mean)	–	9.7	14.4	19.9
Belg onset (% of years)	Failure	53.3	53.3	20.0
	Early	6.7	6.7	33.3
	Normal	20.0	20.0	26.7
	Late	20.0	20.0	20.0
Kiremt onset (% of years)	Early	13.3	26.7	20.0
	Normal	66.7	40.0	66.7
	Late	20.0	33.3	13.3

References

1. Dilling, L.; Daly, M.E.; Travis, W.R.; Wilhelmi, O.V.; Klein, R.A. The dynamics of vulnerability: Why adapting to climate variability will not always prepare us for climate change. *Wiley Interdiscip. Rev. Clim. Chang.* **2015**, *6*, 413–425. [CrossRef]
2. Eisenack, K.; Moser, S.C.; Hoffmann, E.; Klein, R.J.T.; Oberlack, C.; Pechan, A.; Rotter, M.; Termeer, C. Explaining and overcoming barriers to climate change adaptation. *Nat. Clim. Chang.* **2014**, *4*, 867–872. [CrossRef]
3. Moser, S.C.; Ekstrom, J.A. A framework to diagnose barriers to climate change adaptation. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 22026–22031. [CrossRef]
4. Wise, R.M.; Fazey, I.; Stafford Smith, M.; Park, S.E.; Eakin, H.C.; Van Garderen, E.A.; Campbell, B. Reconceptualising adaptation to climate change as part of pathways of change and response. *Glob. Environ. Chang.* **2014**, *28*, 325–336. [CrossRef]
5. Below, T.B.; Mutabazi, K.D.; Kirschke, D.; Franke, C.; Sieber, S.; Siebert, R.; Tscherning, K. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Glob. Environ. Chang.* **2012**, *22*, 223–235. [CrossRef]
6. Bryan, E.; Deressa, T.T.; Gbetibouo, G.A.; Ringler, C. Adaptation to climate change in Ethiopia and South Africa: Options and constraints. *Environ. Sci. Policy* **2009**, *12*, 413–426. [CrossRef]
7. Deressa, T.T.; Hassan, R.M.; Ringler, C. Perception of Adaptation to Climate Change in Ethiopia. *J. Agric. Sci.* **2011**, *149*, 23–31. [CrossRef]
8. Di Falco, S. Adaptation to climate change in Sub-Saharan agriculture: Assessing the evidence and rethinking the drivers. *Eur. Rev. Agric. Econ.* **2014**, *41*, 405–430. [CrossRef]
9. Di Falco, S.; Veronesi, M.; Yesuf, M. Does Adaptation to Climate Change Provide Food Security—A Micro Perspective from Ethiopia.pdf. *Am. J. Agric. Econ.* **2011**, *93*, 825–842. [CrossRef]
10. Jianjun, J.; Yiwei, G.; Xiaomin, W.; Nam, P.K. Farmers' risk preferences and their climate change adaptation strategies in the Yongqiao District, China. *Land Use Policy* **2015**, *47*, 365–372. [CrossRef]
11. Roco, L.; Engler, A.; Bravo-Ureta, B.; Jara-Rojas, R. Farm level adaptation decisions to face climatic change and variability: Evidence from Central Chile. *Environ. Sci. Policy* **2014**, *44*, 86–96. [CrossRef]
12. Campos, M.; Velazquez, A.; McCall, M. Adaptation strategies to climatic variability: A case study of small-scale farmers in rural Mexico. *Land Use Policy* **2014**, *38*, 533–540. [CrossRef]
13. Grothmann, T.; Patt, A. Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Glob. Environ. Chang.* **2005**, *15*, 199–213. [CrossRef]
14. Price, J.C.; Walker, I.A.; Boschetti, F. Measuring cultural values and beliefs about environment to identify their role in climate change responses. *J. Environ. Psychol.* **2014**, *37*, 8–20. [CrossRef]
15. Adger, W.N.; Barnett, J.; Brown, K.; Marshall, N.; O'brien, K. Cultural dimensions of climate change impacts and adaptation. *Nat. Clim. Chang.* **2013**, *3*, 112. [CrossRef]
16. Jones, L.; Boyd, E. Exploring social barriers to adaptation: Insights from Western Nepal. *Glob. Environ. Chang. Hum. Policy Dimens.* **2011**, *21*, 1262–1274. [CrossRef]
17. Nielsen, J.O.; Reenberg, A. Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. *Glob. Environ. Chang. Hum. Policy Dimens.* **2010**, *20*, 142–152. [CrossRef]
18. Etana, D.; van Wesenbeeck, C.F.; de Cock Buning, T. Socio-cultural aspects of farmers' perception of the risk of climate change and variability in Central Ethiopia. *Clim. Dev.* **2020**, 1–13. [CrossRef]
19. Adger, W.N.; Dessai, S.; Goulden, M.; Hulme, M.; Lorenzoni, I.; Nelson, D.R.; Naess, L.O.; Wolf, J.; Wreford, A. Are there social limits to adaptation to climate change? *Clim. Chang.* **2009**, *93*, 335–354. [CrossRef]
20. O'brien, K. Do values subjectively define the limits to climate change adaptation? In *Adapting to Climate Change: Thresholds, Values, Governance*; Adger, W.N., Lorenzoni, I., O'Brien, K., Eds.; Cambridge University Press: New York, NY, USA, 2009; pp. 164–180.
21. Nightingale, A.J. Adaptive scholarship and situated knowledges? Hybrid methodologies and plural epistemologies in climate change adaptation research. *Area* **2016**, *48*, 41–47. [CrossRef]
22. Osbahr, H.; Twyman, C.; Adger, W.N.; Thomas, D.S.G. Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. *Geoforum* **2008**, *39*, 1951–1964. [CrossRef]

23. Schwartz, S.H. National culture as value orientations: Consequences of value differences and cultural distance. In *Handbook of the Economics of Art and Culture*; Elsevier: Amsterdam, The Netherlands, 2014; Volume 2, pp. 547–586.

24. Patt, A.G.; Schroter, D. Perceptions of climate risk in Mozambique—Implication for the success of adaptation strategies. *Glob. Environ. Chang.* **2008**, *18*, 458–467. [CrossRef]

25. Kasperson, R.E.; Renn, O.; Slovic, P.; Brown, H.S.; Emel, J.; Goble, R.; Kasperson, J.X.; Ratick, S. The social amplification of risk: A conceptual framework. *Risk Anal.* **1988**, *8*, 177–187. [CrossRef]

26. Renn, O. The social amplification/attenuation of risk framework: Application to climate change. *Wiley Interdiscip. Rev. Clim. Chang.* **2011**, *2*, 154–169. [CrossRef]

27. Haden, V.R.; Niles, M.T.; Lubell, M.; Perlman, J.; Jackson, L.E. Global and local concerns: What attitudes and beliefs motivate farmers to mitigate and adapt to climate change? *PLoS ONE* **2012**, *7*, e52882. [CrossRef]

28. Lo, A.Y. The role of social norms in climate adaptation: Mediating risk perception and flood insurance purchase. *Glob. Environ. Chang.* **2013**, *23*, 1249–1257. [CrossRef]

29. Spence, A.; Poortinga, W.; Butler, C.; Pidgeon, N.F. Perceptions of climate change and willingness to save energy related to flood experience. *Nat. Clim. Chang.* **2011**, *1*, 46–49. [CrossRef]

30. Bubeck, P.; Botzen, W.J.; Aerts, J.C. A review of risk perceptions and other factors that influence flood mitigation behavior. *Risk Anal. Int. J.* **2012**, *32*, 1481–1495. [CrossRef]

31. Frank, E.; Eakin, H.; López-Carr, D. Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Glob. Environ. Chang.* **2011**, *21*, 66–76. [CrossRef]

32. Gifford, R.; Kormos, C.; McIntyre, A. Behavioral dimensions of climate change: Drivers, responses, barriers, and interventions. *Wiley Interdiscip. Rev. Clim. Chang.* **2011**, *2*, 801–827. [CrossRef]

33. Van der Linden, S. The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. *J. Environ. Psychol.* **2015**, *41*, 112–124. [CrossRef]

34. Pothitou, M.; Hanna, R.F.; Chalvatzis, K.J. Environmental knowledge, pro-environmental behaviour and energy savings in households: An empirical study. *Appl. Energy* **2016**, *184*, 1217–1229. [CrossRef]

35. Whitmarsh, L. Are flood victims more concerned about climate change than other people? The role of direct experience in risk perception and behavioural response. *J. Risk Res.* **2008**, *11*, 351–374. [CrossRef]

36. Deng, Y.; Wang, M.; Yousefpour, R. How do people's perceptions and climatic disaster experiences influence their daily behaviors regarding adaptation to climate change? A case study among young generations. *Sci. Total Environ.* **2017**, *581*, 840–847. [CrossRef] [PubMed]

37. Elgaaied-Gambier, L.; Monnot, E.; Reniou, F. Using descriptive norm appeals effectively to promote green behavior. *J. Bus. Res.* **2018**, *82*, 179–191. [CrossRef]

38. Farrow, K.; Grolleau, G.; Ibanez, L. Social norms and pro-environmental behavior: A review of the evidence. *Ecol. Econ.* **2017**, *140*, 1–13. [CrossRef]

39. Cialdini, R.B. Crafting normative messages to protect the environment. *Curr. Dir. Psychol. Sci.* **2003**, *12*, 105–109. [CrossRef]

40. Kallgren, C.A.; Reno, R.R.; Cialdini, R.B. A focus theory of normative conduct: When norms do and do not affect behavior. *Personal. Soc. Psychol. Bull.* **2000**, *26*, 1002–1012. [CrossRef]

41. Kahan, D.M. Cultural Cognition as a Conception of the Cultural Theory of Risk. In *Handbook of Risk Theory: Epistemology, Decision Theory, Ethics, and Social Implications of Risk*; Roeser, S., Hillerbrand, R., Sandin, P., Peterson, M., Eds.; Springer Netherlands: Dordrecht, The Netherlands, 2012; pp. 725–759. [CrossRef]

42. Heyd, T. Climate change, individual responsibilities and cultural frameworks. *Hum. Ecol. Rev.* **2010**, *17*, 86–95.

43. Reser, J.P.; Swim, J.K. Adapting to and coping with the threat and impacts of climate change. *Am. Psychol.* **2011**, *66*, 277. [CrossRef]

44. Asravor, R.K. Farmers' risk preference and the adoption of risk management strategies in Northern Ghana. *J. Environ. Plan. Manag.* **2019**, *62*, 881–900. [CrossRef]

45. Kahan, D.M.; Braman, D. Cultural cognition and public policy. *Yale L. & Pol'y Rev.* **2006**, *24*, 149.

46. Hisali, E.; Birungi, P.; Buyinza, F. Adaptation to climate change in Uganda: Evidence from micro level data. *Glob. Environ. Chang.* **2011**, *21*, 1245–1261. [CrossRef]

47. Yesuf, M.; Bluffstone, R.A. Poverty, risk aversion, and path dependence in low-income countries: Experimental evidence from Ethiopia. *Am. J. Agric. Econ.* **2009**, *91*, 1022–1037. [CrossRef]

48. Naess, L.O. The role of local knowledge in adaptation to climate change. *Wiley Interdiscip. Rev. Clim. Chang.* **2013**, *4*, 99–106. [CrossRef]

49. Islam, M.; Nursey-Bray, M. Adaptation to climate change in agriculture in Bangladesh: The role of formal institutions. *J. Environ. Manag.* **2017**, *200*, 347–358. [CrossRef]

50. Yaro, J.A.; Teye, J.; Bawakyillenuo, S. Local institutions and adaptive capacity to climate change/variability in the northern savannah of Ghana. *Clim. Dev.* **2015**, *7*, 235–245. [CrossRef]

51. Leech, N.L.; Onwuegbuzie, A.J. A typology of mixed methods research designs. *Qual. Quant.* **2009**, *43*, 265–275. [CrossRef]

52. Creswell, J.W.; Creswell, J.D. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*; Sage Publications: Thousand Oaks, CA, USA, 2018.

53. Johnson, R.B.; Onwuegbuzie, A.J. Mixed methods research: A research paradigm whose time has come. *Educ. Res.* **2004**, *33*, 14–26. [CrossRef]

54. Creswell, J.W.; Plano Clark, V.L. *Designing and Conducting Mixed Methods Research*, 3rd ed.; Sage Publications, Inc.: Thousand Oaks, CA, USA, 2018.

55. Kothari, C.R. *Research Methodology: Methods and Techniques*; New Age International: New Delhi, India, 2004.

56. Axinn, W.G.; Pearce, L.D.; Ghimire, D. Innovations in life history calendar applications. *Soc. Sci. Res.* **1999**, *28*, 243–264. [CrossRef]

57. Scoones, I. *Sustainable Rural Livelihoods: A Framework for Analysis*; Institute of Development Studies: Brighton, UK, 1999.

58. Alexander, L.; Herold, N. *ClimPACT2: Indices and Software. A Document Prepared on Behalf of the The Commission for Climatology (CCI) Expert Team on Sector-Specific Climate Indices (ET-SCI)*; World Meteorological Organization: Geneva, Switzerland, 2016.

59. Raes, D.; Willems, P.; Baguidi, F. RAINBOW—A software package for analyzing data and testing the homogeneity of historical data sets. In Proceedings of the 4th International Workshop on 'Sustainable management of marginal drylands', Islamabad, Pakistan, 27–31 January 2006.

60. Grotti, R.; Cutuli, G. xtpdyn: A community-contributed command for fitting dynamic random-effects probit models with unobserved heterogeneity. *Stata J.* **2018**, *18*, 844–862. [CrossRef]

61. Wooldridge, J.M. Simple solutions to the initial conditions problem in dynamic, nonlinear panel data models with unobserved heterogeneity. *J. Appl. Econom.* **2005**, *20*, 39–54. [CrossRef]

62. Hill, T.D.; Davis, A.P.; Roos, J.M.; French, M.T. Limitations of fixed-effects models for panel data. *Sociol. Perspect.* **2019**, 1–13. [CrossRef]

63. Rabe-Hesketh, S.; Skrondal, A. Avoiding biased versions of Wooldridge's simple solution to the initial conditions problem. *Econ. Lett.* **2013**, *120*, 346–349. [CrossRef]

64. Braun, V.; Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. [CrossRef]

65. Tucker, C.M.; Eakin, H.; Castellanos, E.J. Perceptions of risk and adaptation: Coffee producers, market shocks, and extreme weather in Central America and Mexico. *Glob. Environ. Chang.* **2010**, *20*, 23–32. [CrossRef]