Czech University of Life Sciences Prague

Faculty of Tropical AgriSciences

Climate Change Adaptation in Agriculture: The Case of Nepal, Czech Republic, and Nigeria

DISSERTATION THESIS

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Declaration

I hereby declare that I have completed this thesis entitled "Climate Change Adaptation in Agriculture: The Case of Nepal, Czech Republic, and Nigeria" independently, all texts in this thesis are original, and that all information sources have been quoted and acknowledged by means of complete references. I also confirm that this work has not been previously submitted, nor is it currently submitted, for any other degree, to this or any other university.

In Prague, March 2024

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Steffen Muench

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Abstract

Climate change has disastrous effects on agricultural production. Increased extreme weather events like droughts threaten global food security and farmers' subsistence. Appropriate adaptation is crucial for farmers to cope with climate change's ongoing and predicted impacts. A precondition for adaptation readiness is knowledge of the subject. This dissertation assessed the degree of adaptation to and knowledge of climate change via three case studies in Nepal (South Asia), the Czech Republic (Central- and Eastern Europe), and Nigeria (Sub-Saharan Africa). The selection of various geo-climatic regions allowed to capture the current situation from a broader perspective, following the global implications of climate change.

Quantitative data were collected individually through a semi-structured questionnaire survey in each study area. Case study 1 included 91 smallholder tea farmers in Nepal, case study 2 analyzed data gathered from 358 farmers throughout the Czech Republic, and case study 3 focused on farmers in Nigeria's dry and humid zones with a sample size of 1,080 respondents. While case studies 1 and 2 primarily concentrated on factors influencing the degree of climate change adaptation, the objectives of case study 3 centered on factors influencing farmers´ knowledge of climate change. The collected data was analyzed through basic descriptive statistics, multiple regression, and binary logit regression models.

Empirical results show that membership in a cooperative and access to extension services positively influenced the degree of climate change adaptation among Nepalese tea farmers and the level of climate change knowledge among Nigerian farmers. Maintaining profitability was a primary driver for Czech farmers to adapt to climate change. The case studies further revealed that the low dissemination of information on technological innovations in agriculture requires appropriate information provision through feasible channels. Communicating the merits of adaptation would support faster adoption rates and increase the farmers' resilience toward the impacts of climate change.

Another critical consideration is that regional differences can lead to significant variations in climate change knowledge among farmers. Policymakers are encouraged to base their interventions on regional conditions and tailor the provided information according to the specific needs of the target groups.

Keywords

Adaptation Strategies, Climate-Smart Agriculture, Diffusion of Innovations, Institutional Factors, Information Access

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List of abbreviations

AME	Average Marginal Effect
BLM	Binary Logit Model
CAP	Common Agricultural Policy
CEE	Central and Eastern Europe
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CGIAR	Consultancy Group of International Agricultural Research
CSA	Climate-smart Agriculture
DOI	Diffusion of Innovations
EGD	European Green Deal
EIP	European Innovation Partnership
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
IFPRI	International Food Policy Research Institute
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
ITC	International Trade Center
LDC	Least Developed Country
MR	Multiple Regression
NGO	Non-Governmental Organization

SAP	Sustainable Agricultural Practise
SDG	Sustainable Development Goal
SEA	South-East Asia
SSA	Sub-Saharan Africa
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
OR	Odds Ratio

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1. Introduction

1.1 Climate change adaptation in agriculture: Research gaps

The impacts of climate change on agriculture are palpable and expected to gain momentum in the coming decades (Mbow et al. 2019; Duncan et al. 2016). A shift in climatic conditions negatively affects crop production, livestock farming, fisheries, and forests (World Bank 2021). Ramifications of climate change are not only limited to global warming but include numerous climate events ranging from droughts to floods to extreme weather (GIZ 2022). Considering the potential implications of these occurrences on the world´s food supply, minimizing the adverse effects of climate change can only be dealt with through effective adaptation responses (Rosenzweig et al. 2020). Simultaneously, the rapid shift in biophysical conditions and the resulting global environmental changes require immediate action (Myers et al. 2017). However, the low dissemination of information on technological innovations in agriculture is a significant constraint because topic-related information on adaptation is only spread reluctantly (Fichter and Clausen 2021). While awareness of climate change adaptation is emerging, it remains low compared to the policy interest in mitigation frameworks (Frankhauser 2009). Effectively counteracting the combined effect of reluctant information exchange and the ongoing struggle to develop sustainable climate change adaptation pathways for agriculture requires scientific expertise. Despite the emergence of publications focusing on solutions for how agriculture can thrive in a rapidly changing climate, the current state of knowledge unveils numerous research gaps. A possible explanation for the low adaptation rates in many parts of the world may be rooted in the lack of knowledge on the effects of climate change and how to adapt to it accordingly.

As the Intergovernmental Panel on Climate Change (IPCC) pointed out, rapid adaptation is the key for the agricultural sector to thrive in these ongoing challenges (IPCC 2022). Offsetting climate change impacts by appropriate adaptation is a crucial requirement, allowing agriculture to cope with challenges posed by a higher variability and unpredictability of climatic patterns. According to the IPCC (2014), the term "*climate change adaptation*" can be defined as the "*process of adjustment to actual or expected climate and its effects*." Facilitating adjustments to climate change effects aims to transition farming systems by enhancing farmers' resilience to the natural disturbances caused by climatic changes. Concurrently, understanding the role of rural transformation in domestic agri-food systems is vital for targeting specified development strategies and allocating investments (Kruseman et al. 2020). The International Food Policy Research Institute (IFPRI) stresses the need for higher investments in agricultural infrastructure development and more agrarian research (Sulser et al. 2021). Without understanding the drivers behind climate change adaptation, policymakers struggle with formulating and implementing effective measures. In theory, what farmers should do to protect themselves from the devastating effects of climate change is well known. However, there is still little scientific evidence on the farmers' perspective and knowledge of climate change adaptation. This holds particularly for the relationship between the farmers' socio-economic characteristics, their institutional environment, and their adaptative capabilities. It is therefore not surprising that the present spending on this research field would have to increase by up to 118% to compensate for all projected losses induced by climate change (Baldos et al. 2020). This matter further underlines the necessity of shedding light on the current state of climate change adaptation in various agricultural fields.

Tackling climate change issues is not only relevant within agriculture but vital for safeguarding the well-being of humankind in its entirety. The overarching nature of climate change has broad implications for the livelihood of humans in practically all parts of the world. Unsurprisingly, "*climate action*" is one of the 17 sustainable development goals (SDGs) (UN 2022). The SDGs point out humanity's most significant ongoing challenges. The defined targets framed by the SDGs build the foundation for major global issues that governments must address accordingly. In addition, climate action is closely intertwined with other SDGs, such as "*zero hunger*," "*no poverty*," or "*life on land*". If climate action goals fail, other SDGs are at stake, too. Therefore, combating climate change impacts through urgent action is a critical factor in achieving the goals set by the UN. The effects of climate change on the environmental and socio-economic well-being of the global population are undeniable. Therefore, adaptation to and mitigation of climate change events can be defined as a prerequisite for most of humanities development issues.

The negative impacts of climate change on agriculture are wide-fold and a potential cause of food insecurity, particularly in regions with a low resilience towards natural disturbances (Morton 2007). Agriculture safeguards the global food supply and remains an essential source of income for the human population, particularly in developing countries. While the global average contribution of agriculture towards the gross domestic product (GDP) is approximately 4%, it currently accounts for close to 25% of the GDP in least-developed countries (LDCs) (World Bank 2022). Hence, agriculture is among the primary sources of livelihood for a significant share of the global population. Although regions with a high share of agriculture-dependent populations, such as Sub-Saharan Africa (SSA) and South-East Asia (SEA), are particularly affected by climate change, negative impacts are also expected to affect developed countries increasingly (FAO 2018). Despite raising awareness of governments towards responding to climate change by policy intervention, there is an urgent need to accelerate these ongoing initiatives regardless. Without an appropriate policy framework, the agricultural sector will struggle to develop sustainable pathways to climate change adaptation (Haden et al. 2012; Woods et al. 2017; Trinh et al. 2018). A fundamental prerequisite for suitable approaches to climate change adaptation is a profound understanding of its current state. Adaptation to climate change in agriculture depends on the specific regional conditions and the availability of information on the topic. Climate change is often too abstract for farmers to be perceived as an immediate threat (Findlater et al. 2018). The notional nature of climate change is one possible explanation of why adaptation often remains low (Amadu et al. 2020b). Extended knowledge of the topic, location, and farming experience are among the factors influencing the degree of applying sustainable agricultural practices (SAPs) (Liao et al. 2022). In addition, farmers often use SAPs traditionally; however, they do not particularly connect these practices to climate change adaptation. For instance, crop rotation, agroforestry, and soil conservation are commonly framed as adaptation strategies to climate change. Simultaneously, farmers often use these measures primarily to pursue other farming objectives such as higher yields, product diversification, or fulfilling specific environmental certification standards. When farmers apply specific SAPs with goals different from immediate adaptation, their adaptability to climate change becomes even more complicated to measure. This behavioral trait elevates the risk of inadequate adaptation and potentially further reduces a farmer's resilience toward climate change (Woods et al. 2017).

As a logical consequence, limited knowledge of the topic reduces the capability to adapt to such natural disturbances even more. Lower adaptive capabilities expose farmers to the disastrous effects of climatic shifts, threatening their livelihood. Because of this, stimulating information exchange and channeling support through feasible communication mechanisms are vital. Figure 1 visualizes the framework of this thesis. It contains the theoretical concepts applied in the case studies. This dissertation's research problem and basis was the increasingly palpable impact of climate change on agriculture. These disastrous effects require rapid adaptation schemes. Simultaneously, adaptation readiness among farmers remains low. Therefore, this dissertation identified factors based on previous research to determine which variables increase a farmer's likeliness to adapt to climatic changes.

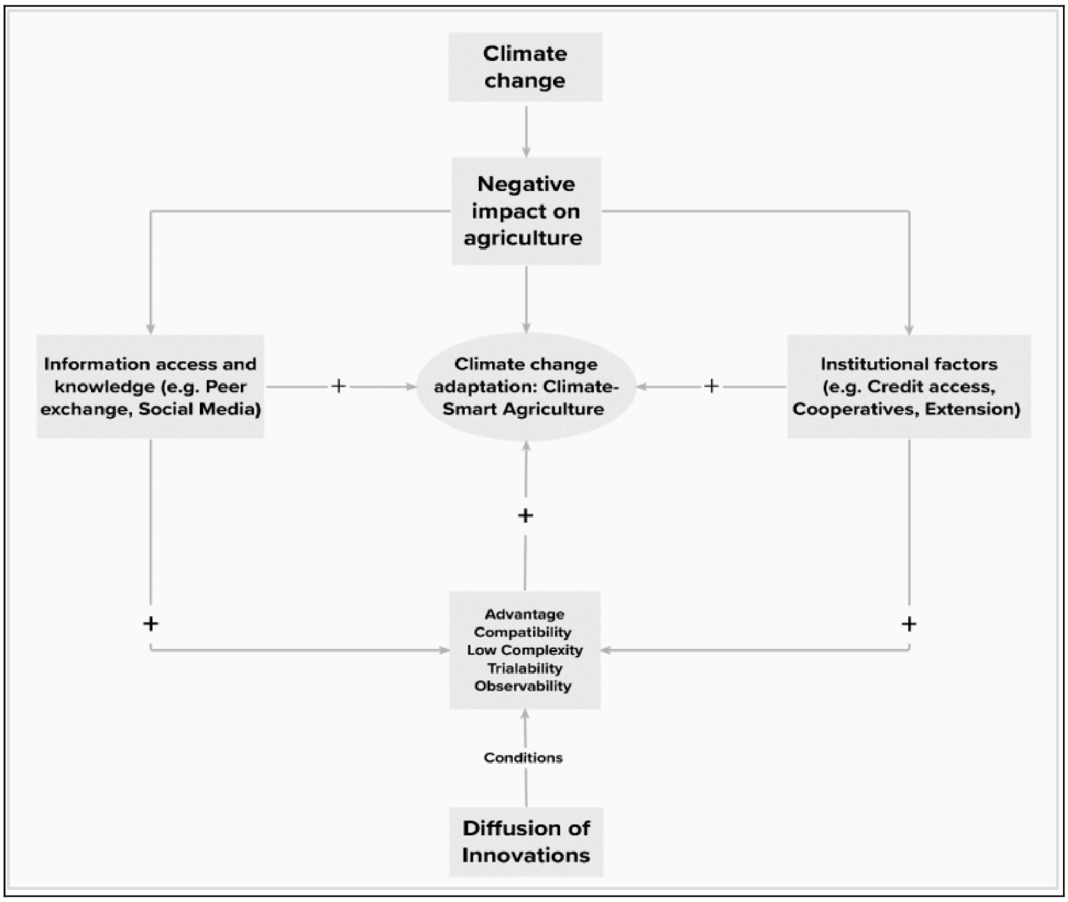

Figure 1: Thesis framework explaining the interconnectivity between information access, institutional setting, and climate change adaptation in agriculture

As pointed out in Figure 1, climate change adaptation is influenced predominantly by access to information and institutional factors such as cooperative membership, capacity building through extension service provision, and access to credits (Trinh et al. 2018; Menike & Arachchi 2016; De Sousa et al. 2018). Within the context of this dissertation, Climate-smart Agriculture (CSA) served as a framework for describing climate change adaptation and mitigation from a broader perspective. The term is closely intertwined with the SDGs and is often used globally to discuss climate change issues in agriculture (FAO 2020; CGIAR 2021; World Bank 2021). Within this study, CSA serves as an “umbrella term” for the adaptation to climate change among farmers (Chapter 1.2). CSA is based on the application of specific adaptation measures. These measures support farmers in coping with the adverse effects caused by climatic changes. However, the degree to which CSA-derived coping mechanisms are applied varies significantly and largely depends on the individual settings to which farmers are exposed. Previous literature frequently discussed the influence of the institutional environment on farming performance, including the adoption of SAPs (Masud et al. 2018). A robust institutional framework leads to higher efficiency in capacity building and, therefore, supports the process of climate change adaptation in agriculture. Concomitantly, being informed about climate change and its possible interventions is an equally important prerequisite within this context. How farmers access information shapes their perception of climate change and influences their knowledge of its causes and effects.

Existing studies are pointing at information sources and institutional settings being reliable indicators in the determination of adopting climate change adaptation strategies (Makate et al. 2019; Mahmood et al. 2021; Shi-yan et al. 2018; Muench et al. 2021). These revelations assert that better-informed farmers with sufficient access to institutional capacities are less vulnerable to climate change impacts due to higher adaptation capabilities. Creating a policy framework enabling farmers to quickly access related information and supporting them to thrive in the institutional environment are critical prerequisites to adoption.

The current state of scientific research on the farmers' perspective of climate change adaptation implies significant knowledge gaps. Firstly, there is an ever-increasing need for tailored adaptation schemes considering the specific situation of regional climate and farming systems. Secondly, smallholder farmers in developing countries are particularly affected by climate change, while their adaptive capacities remain low (Abdul-Razak and Kruse 2017). Affordable and accessible climate change action enhancing their resilience can only be developed hand in hand with scientific research focused on this field. Thirdly, many open questions remain about why policies often do not work as intended. Miscommunication and the lack of communication between farmers and policymakers require researchers to act as a “bridge” connecting the stakeholders. Considering this, insights into suitable information channels and farmers' current knowledge state are essential. This, however, requires continuous research on an ongoing basis. Fourthly, without user-friendly tools to share knowledge, policymakers remain struggling with the capacity-building process among farmers. Knowing the status quo in the field is necessary for such mechanisms to work.

These knowledge gaps served as a “backbone” to the framework of this dissertation. Providing comprehensive insights into the current state of climate change adaptation in various agricultural and geographical settings is a natural response to the ongoing situation in this academic field. The outcomes of this thesis intend to support policymakers in understanding the influence socio-demographic and institutional factors have on the degree of climate change adaptation. This understanding is of utmost importance because the proposed impacts of climate change on agriculture will only intensify over the following decades. In addition, this thesis uncovers the relevance of appropriate information channels in stakeholder communication. Knowledge of climate change is a precondition for adapting to it. Hence, the findings aim to shed light on the prerequisite of considering these aspects in formulating climate change action plans on a regional, national, supranational, and international level.

This research consisted of three case studies in different climatic regions, as shown in Figure 2. The case studies stretch from the South-Asian Subtropics (Nepal) over the humid and arid zones of tropical SSA (Nigeria) to the temperate areas of Central and Eastern Europe (Czech Republic).

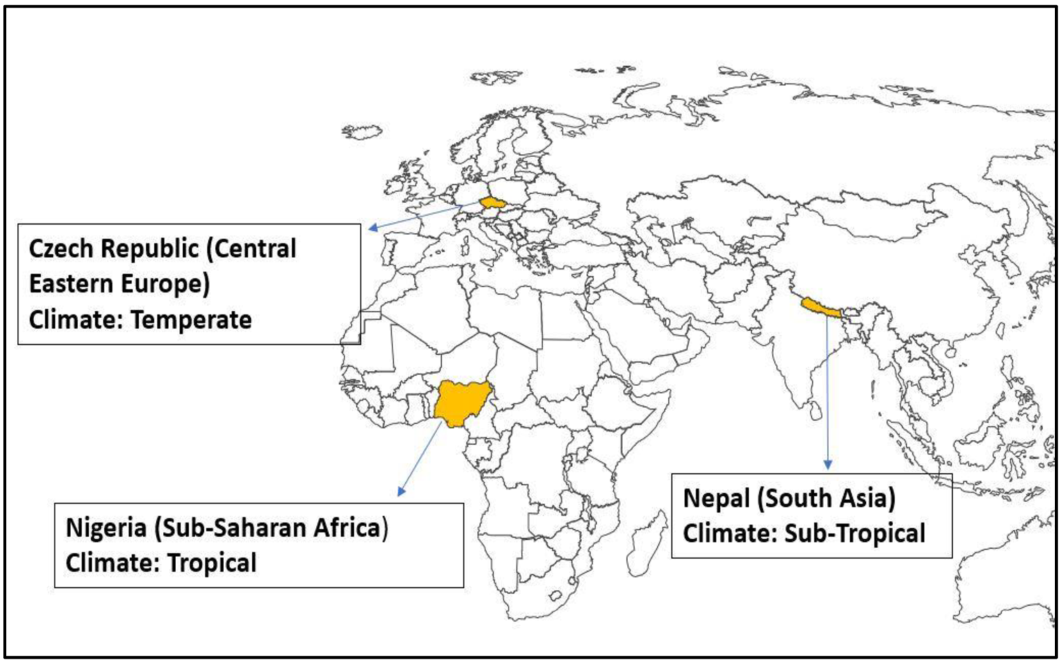

Figure 2: World map highlighting the three selected study areas

The differences in climatic conditions and the variation in farmer profiles derived from each data sample collected for the case studies allowed for capturing a broader image of climate change adaptation in agriculture based on the selected study areas. While the core objectives of this research were interwoven, a particular emphasis was drawn on diversifying the findings by applying a different set of survey instruments to the case studies. Understanding how these factors influence the adaptation process is not only necessary from a scientific perspective. It also stimulates stakeholders in agriculture to protect themselves from disastrous climate change impacts. This thesis aims to support current and future generations in safeguarding their livelihood and food security. Moreover, the results serve as a basis for further investigating these issues by applying the theoretical framework to other countries and various agricultural systems.

A general theory explaining the requirements for the adoption of innovative technologies in a society is the Diffusion of Innovations (DOI), according to Rogers (2003). This theoretical framework defined criteria that must be met for innovations (such as adaptation measures) to be adopted quickly (Chapter 1.3). While the DOI finds its place primarily in marketing, it can also be applied to other contexts. Appropriate information access and institutional enablement can positively influence the DOI. If farmers receive understandable and comprehensive information on the topic while being supported by their institutional environment, the extent and speed of adapting to climate change should naturally expedite. As effective climate change adaptation requires fast adoption rates, policy interventions must meet the conditions defined by the DOI. Therefore, this thesis focused on information access, knowledge perception, and institutional factors influencing climate change adaptation among farmers in various agricultural fields.

1.2 Climate-smart Agriculture

CSA aims to facilitate actions toward transforming agricultural systems to thrive in shifting climate patterns (FAO 2020). Due to climatic changes and the estimated human population growth, global agricultural production will have to increase by over 60% in the coming decades (CFAS 2022). The research program on climate change, agriculture, and food security (CCAFS) commissioned by the Consultancy Group of International Agricultural Research (CGIAR) emphasizes the positive effects of applying CSA principles (CGIAR 2021). Simultaneously, the Agricultural European Innovation Partnership (EIP) points to the necessity of integrating CSA approaches in European agriculture to achieve the goals set by the Common Agricultural Policy (EIP-AGRI 2021). The three core pillars of CSA are (i) sustainability in productivity and standard of living, (ii) a focus on climate change adaptation, and (iii) the reduction of greenhouse emissions. Although food security is a top priority within this context, one could argue that CSA is equally relevant to non-food agricultural systems. A more holistic approach to climate change adaptation can improve the economic outlook of farmers, regardless of the geographic location. That, again, positively affects society's overall well-being. These targets should be achieved by focusing on sustainability in the production process and emphasizing regionally adjusted adaptation measures.

Numerous studies have investigated factors that influence the degree of the adoption of CSA and the typical constraints among affected communities. Access to credit, information provision, and education in farming practices were crucial for successfully integrating CSA principles (Makate et al. 2019). Simultaneously, farmers in developing and developed countries often perceive these factors as significant constraints towards climate change adaptation (Tsige et al. 2020; Nalau et al. 2018). Therefore, the overall adoption rate of CSA on a global scale remains relatively low until now. At the same time, CSA is becoming an increasingly important concept in the face of climate change and its impacts on agriculture (Amadu et al. 2020b). The future of the agricultural sector is dependent on incorporating CSA approaches. CSA elevates resilience toward climate-induced disturbances while maintaining productivity (CGIAR 2017). This necessity applies to developing, transitional, and developed economies. These approaches include but are not limited to improving access to information. The CSA framework derived from CGIAR aims to encourage farmers worldwide to protect themselves from the negative impacts of climate change through appropriate adaptation and mitigation efforts. Adopting feasible coping mechanisms such as crop diversification, crop rotation, and minimal soil cultivation is thus not only desired but also factually indispensable. Transferring knowledge through appropriate information channels and institutional enablements, such as cooperative membership or credit access, was repeatedly proven to affect CSA integration among farmers (Makate et al. 2019). The included case studies have integrated the principles of CSA in consideration of factors potentially influencing the application among farmers in developing (case studies 1 and 3) and developed countries (case study 2).

1.3 Diffusion of Innovations

The DOI derived from Rogers (2003) was reviewed and used to conceptualize case studies 1 and 2 of this thesis. This theoretical framework explains why and at which rate specific ideas or innovations spread within society. Individuals do not adopt innovations all at the same time (Infante et al. 1997). According to the DOI, adopters can thus be categorized into several groups, indicating at which stage they tend to adapt to a new behavior/innovation: (i) innovators, (ii) early adopters, (ii) early majority, (iv) late majority, and (v) laggards. The categorization of an individual depends on the stage when innovations are adopted. There are several conditions an innovation must meet for it to be adopted quickly. As Figure 3 points out, innovations not only have to bring tangible advantages to the status quo and be consistent with the personal values of the adopter but must also be easy to implement and be triable in terms of proven effectiveness (Dearing and Cox 2018).

By applying this concept to climate change adaptation in agriculture, Long et al. (2019) identified particularly ineffective policies, alignment problems in agricultural supply chains, and naturally reluctant users (farmers) as barriers to fast adoption rates of technological innovations (adaptation strategies) in the farming sector. While policy frameworks in this field emphasize the critical conditions an innovation must meet, they simultaneously may cause delays and stagnation in the adoption process. Before farmers can evaluate an innovation according to the criteria stated in Figure 3, they must be aware of climate change and its impact on agriculture. This thesis investigated farmers' awareness of climate change to reveal the potential influence of climate change awareness on adopting adaptation strategies.

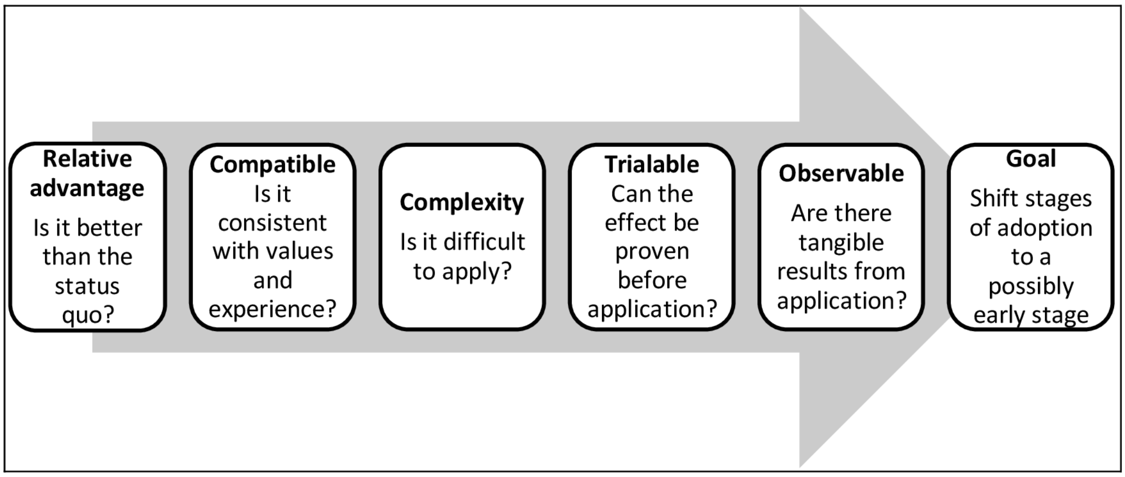

Figure 3: Enabling factors for the adoption of innovative technologies (derived from Rogers 2003)

Climate change challenges the applicability of theoretical models due to its unpredictability (Kipling et al. 2019). As a logical consequence, the expressive power and relevance of theoretical modeling to policymakers remain limited. Identifying knowledge gaps among farmers is thus critical and can be used as a foundation supporting them in building capacity toward adaptation. Based on this problem, this dissertation attempted to detect the awareness and other factors influencing climate change adaptation (case studies 1 and 2). Also, it looked at the differences between perception and knowledge among farmers regarding climate change (case study 3).

In the diffusion of climate-smart innovations in agriculture, several economic, institutional, behavioral, organizational, and market-related constraints act as barriers to adoption (Long et al. 2016). A lack of information, poor capital access, and low governmental support constrain the application of CSA principles. Insufficient information and a lack of knowledge are causing delays in adopting adaptation strategies, leaving only a minority adapting fast and the majority following slowly. By analyzing sectorial differences in the diffusion of environmental innovations, Fichter and Clausen (2021) revealed an additional constraint: Agriculture has particularly low dissemination of information on technological innovations.

Information on innovation spreads reluctantly and compared to other economic sectors at a much lower pace. However, a high degree of dissemination is crucial for adaptation readiness. Thus, adopting climate-smart concepts is impeded by inefficient policy planning and a generally slow spread of information in the agricultural sector. Before applying adaptation measures, farmers must first be aware of and knowledgeable about the subject matter. A condition of gaining knowledge on the topic is the appropriate access to information sources. Insufficient information access causes further issues in the adoption of innovations. For this reason, access to information on climate change adaptation among farmers is a research focus in all case studies of this thesis. The revelations aim to support policymakers by filling a knowledge gap in the perception of CSA application.

These stipulations should naturally support the conceptualization and implementation of effective adaptation plans for the agricultural sector. Case studies 1 and 2 used the DOI to make the results derived from the analysis less theoretical and more applicable.

1.4 Objectives of the dissertation

The study's overall goal was to identify the current degree of climate change adaptation in various agricultural sectors by conducting three case studies in research areas with different farming systems and climatic conditions. Although research on climate change and its effects on agriculture is rising, significant knowledge gaps still appear. These gaps are mainly centered around how aspects such as information access or the policy environment shape adaptive capacities among farmers in various agricultural, climatic, and socio-economic settings. To support filling parts of this scientific void, the dissertation was based on the following overarching and broadly defined research question:

How do agricultural systems in different parts of the world adapt to climate change, and which key factors influence the degree of adaptation readiness among farmers?

A second layer of more specified research questions has been formulated based on the overarching research question. Using these questions as a research basis allowed a more wide-angled approach to the case studies:

RQ1. Which common strategies do farmers adopt to adapt to climate change?

RQ2. How do information availability and the institutional environment influence climate change awareness, knowledge, and adaptation in agriculture?

RQ3. Do socio-demographic and farm-level characteristics affect climate change adaptation and knowledge among farmers under different climatic conditions?

Furthermore, the second layer of research questions served as a cornerstone in formulating context-specific research objectives for the three case studies. Table 1 indicates the primary objectives and methodology for composing each case study. A particular emphasis was drawn on the revelation of factors influencing the adaptive capabilities of farmers toward the impacts of climate change on their farms.

Each case study (CS1, CS2, and CS3) aimed to answer different research questions, thus comprising various objectives. Ultimately, this approach intended to facilitate a broader understanding of the topic. Simultaneously, the target was to allow the formulation of narrative conclusions, moving from the specific case study research questions back to the overarching research question. The interconnectivity between the overarching research question, the specific research questions (RQ1, RQ2, and RQ3), and the three case studies (CS1, CS2, and CS3) is shown in Figure 4.

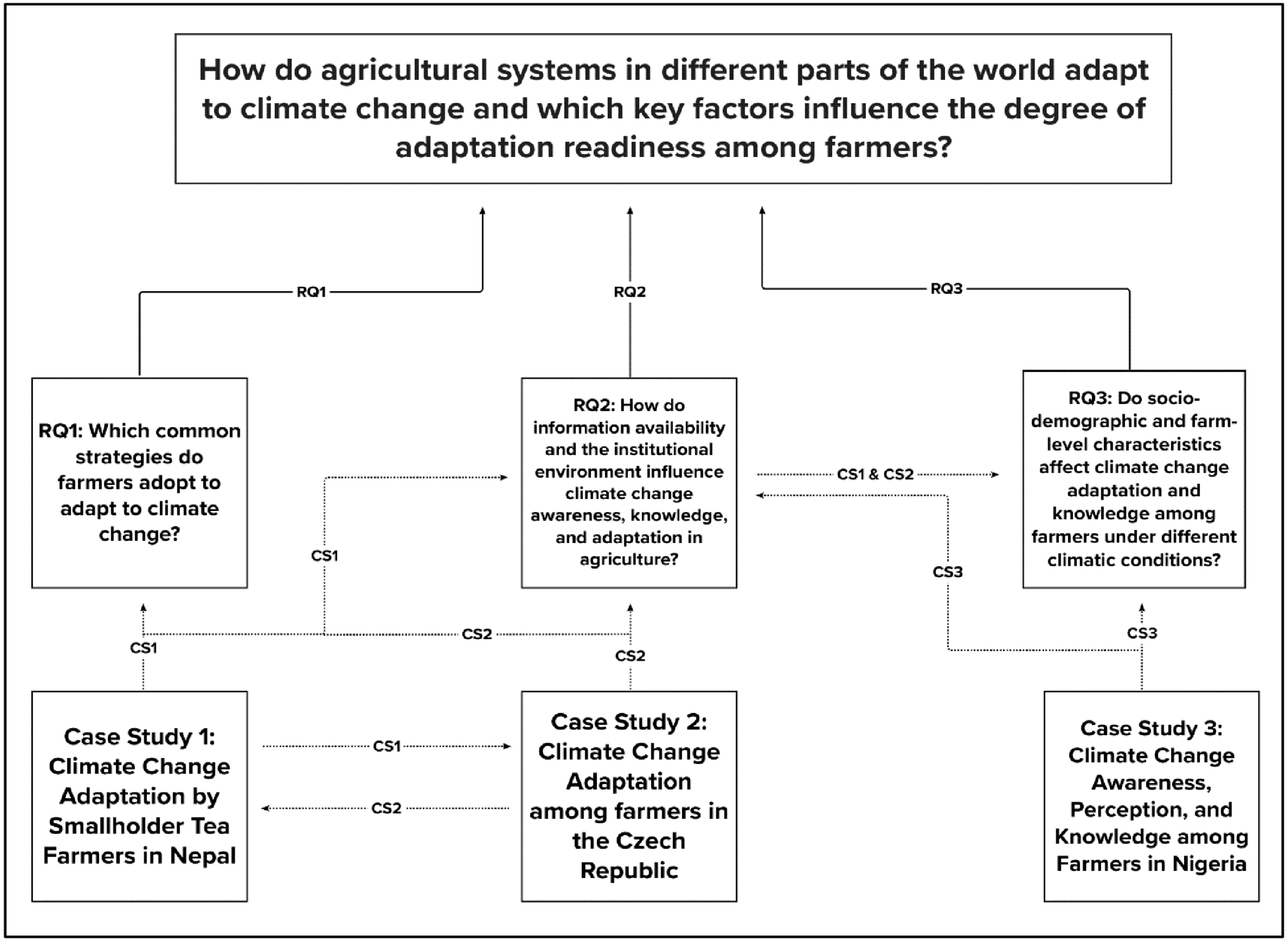

Figure 4: Interconnectivity between research questions and case studies (Note: CS=case study; RQ= research question)

Based on the overarching research question, each case study aimed to approach climate change adaptation in agriculture from a slightly different research angle. CS1 and CS2 followed a similar research layout and primarily focused on the specific adaptation strategies applied by farmers and factors influencing the adoption of these strategies (RQ1 and RQ2). CS3 used a different approach and aimed to uncover how the farmers´ information sources on climate change shape their knowledge of its causes (RQ2). According to recent scientific discussions, the negative impacts of climate change on agriculture can only be minimized by knowledge creation through the availability of appropriate information and the development of a supportive institutional framework.

This research was motivated by the need to support all involved stakeholders. Shedding light on the knowledge gap should help find answers to these pressing issues and eventually stimulate speedy climate actions in the agricultural sector.

Table 1: Title, objectives, keywords, and methods used for the three case studies

Title	Objectives	Keywords	Methods
Case Study 1: Climate Change Adaptation by Smallholder Tea Farmers in Neal	1. Awareness of climate change 2. Climate change adaptation strategies 3. Factors influencing the adoption of adaptation strategies	Climate Change; Adaptation Strategies; Smallholder Farmers; Tea Production; Nepal	• **Instrument:** Quantitative survey • **Sampling:** Non-discriminative snowball sampling • **Analysis:** Multiple binary logit regression
Case Study 2: Climate Change Adaptation among farmers in the Czech Republic	1. Agreement on the existence of climate change 2. Factors influencing the degree of adaptation 3. Adaptation barriers	Climate Change; Adaptation Strategies; Czech Republic; European Green Deal; Climate-Smart Agriculture	• **Instrument:** Quantitative survey • **Sampling:** Random sampling (through an agency) • **Analysis:** Binary logit regression
Case Study 3: Climate Change Awareness, Perception, and Knowledge among Farming Households in Nigeria	1. Climate change knowledge association with climate change perception 2. Factors affecting awareness of climate change 3. Factors affecting knowledge of climate change	Climate Change; Perception and Knowledge; Information Sources; Agro-Ecological Zones; Nigeria	• **Instrument**: Quantitative survey • **Sampling**: Multi-stage sampling (convenient and random) • **Analysis**: Chi-square test, T-test, Binary logit regression

1.5 Abstracts of the case studies

Abstract – Case Study 1

Climate change is threatening the livelihood of tea farmers in Nepal. Simultaneously, tea production is becoming an increasingly important economic sector for the country. This study aimed to reveal the adaptation behavior towards climate change among smallholder tea farmers, particularly focused on which demographic, institutional, and information source factors are likely to influence the degree of adaptation. Quantitative data in Ilam district were collected among 91 farmers through a questionnaire survey. Descriptive statistics, multiple regression, and binary logistic regression models were applied to analyze the collected data. The findings revealed that information sources (other tea farmers, the internet, and training) and institutional factors (membership in cooperative and credit access) positively influenced climate change adaptation among the respondents. Therefore, easier credit access and joining cooperatives could build the farmers' adaptative capacity. Improving the interaction between the Nepalese government and stakeholders in the domestic tea industry potentially stimulates economic development.

Keywords: Climate Change, Adaptation Strategies, Smallholder farmers, Tea Production, Nepal

Abstract – Case Study 2

Climate change threatens agriculture in the European Union and is a core issue discussed in the European Green Deal (EGD) within the Common Agricultural Policy (CAP). Central and Eastern European countries are prone to droughts and extreme weather, potentially leading to devastating effects on agriculture. This study examined the application of climate-smart agricultural principles among farmers in the Czech Republic by analyzing which farm-level and information source variables positively influence their adaptation behavior. 358 respondents were asked about climate change adaptation through a quantitative survey, and the data was analyzed via descriptive statistics and binary logit regression models. Findings revealed a high degree of climate change awareness and a diversified usage of climate change adaptation strategies among Czech farmers. The close linkage between perceived profitability and the willingness to adapt requires policymakers further to communicate the economic merits of climate change adaptation. As information sources, such as topic-specific journals, research institutions, and field training, positively influenced the adaptation rates, focusing on these channels to transfer knowledge within the EGD is recommended.

Keywords: Climate Change, Adaptation Strategies, Czech Republic, European Green Deal, Climate-Smart Agriculture

Abstract – Case Study 3

Nigeria commits itself to achieving a 20% unconditional and 45% conditional reduction of greenhouse gas (GHG) emissions by 2030 through a strong focus on awareness and preparedness for climate change impacts via the mobilization of local communities for climate change mitigation actions. As land use and forestry contribute 38% and agriculture contributes 13% of the country's GHGs, farmers are among the stakeholders who need to be aware of and prepare for climate change mitigation and adaptation. This study assessed the knowledge of agriculturally related practices associated with climate change and its relation to their climate change perception. 1,080 smallholder farmers were interviewed across six agroecological zones (AEZs) of Nigeria using a semi-structured questionnaire. Logit and linear regression models were used for the analysis. Results revealed that most farmers know deforestation and bush-burning land clearance contribute to climate change. However, many farmers did not know that methane emissions from livestock (enteric fermentation) can cause climate change. The results further show that the farmers' perception of climate change is associated with climate change knowledge. Factors affecting farmers' climate change knowledge include information received from government extension services and environmental NGOs, radio, and experiencing extreme weather events. Farmers of dry AEZs were more aware and knowledgeable of the agricultural practices contributing to the changing environment. Increased exposure to climate change events thus elevates knowledge on the topic. Using extension services, environmental NGOs, and radio to disseminate climate change information will help further guide and shape farmers' perceptions of scientific findings for appropriate actions.

Keywords: Climate Change Causes, Perception and Knowledge, Farm Practices, Knowledge Gap Theory, Agroecological Zones, Nigeria

2. Case Study 1: Climate Change Adaptation by Smallholder Tea Farmers in Nepal

2.1 Introduction

The impacts of climate change on the agricultural sector are increasing (Duncan et al. 2016), not only in staple crops but also in cash crops. Many high-value cash crops like wine, coffee, or tea are susceptible to a changing climate (Mozell & Tach 2014). Thus, climate change will impact the supply of many popular beverages and food security. For example, barley's climate-induced harvest losses would reduce the beer supply (Xie et. al 2018). Similarly, the future of global wine production might not be secured without appropriate climate change adaptation (Hannah et al. 2013). This need for adaptation also holds for non-alcoholic beverages. Increased extreme weather events due to climate change would lead to increased harvest losses in tea production in the future (Ahmed and Suphachalasai 2014).

The IPCC Special Report on Climate Change and Land highlights that climate change poses a global threat to food security with a high impact on the developing world (Mbow et al. 2019). Reduced crop yields and harvest losses due to climate change will mainly affect smallholder agriculture systems. These systems consist of smallholder farmers whose livelihood relies on agricultural production. Smallholder farmers face an exceptionally high risk of poverty and food insecurity (Morton 2007). Additionally, limited information and financial constraints contribute to smallholder farmers' socio-economic instability while facing the negative impacts of climate change

(Sietz et al. 2012). This observation holds both for smallholder staple and cash crop farmers.

Tea (*Camellia sinensis*) farming is one of the industries not directly connected to food production, yet it is a significant income generator for many farmers worldwide. In addition, the demand for tea is growing in various parts of the world. For example, Nepal's tea production increased by more than 60% between 2004 and 2014 (ITC 2016). This growth is proof of an increasing share of regional livelihood generated through tea production. The Nepalese tea sector primarily consists of smallholder farmers, who are often dependent on tea production as their primary source of income. However, as in most other agricultural fields, Nepal´s tea industry is also impacted by climate change (Chalise et al. 2017). While the government of Nepal aims to increase the production and export of tea, it should be a natural deliberation to gain insight into Nepalese tea farmers' climate change adaptation behavior (ITC 2016). This is important from an economic viewpoint and for developing effective policies.

A lack of awareness regarding climate-smart agriculture exposes farmers to potential losses. Besides, inappropriate adaptation lowers agricultural productivity (Woods et al. 2017). Therefore, many studies have investigated how the international tea industry adapts to climate change. These studies are, however, primarily focused on more significant players in the global tea trade, such as India (Biggs et al. 2018a), China (Ahmed et al. 2014), Vietnam (Nguyen & Mitsumasu 2017), Japan (Ashardiono & Cassim 2014), Kenya

(Ochieng et al. 2016), and Sri Lanka (Gunathilaka et al. 2018). Research focusing on the climate change adaptation behavior of smallholder tea farmers in Nepal is still missing. This empirical study among smallholder tea farmers in Nepal inspired us to fill this knowledge gap. Furthermore, by adding knowledge to the current understanding in this field, we intend to support the Nepalese government with its ambitious goals of making domestic tea farming a thriving economic sector with more international outreach. The aim thus was to provide insight into the current situation and the identification of factors that positively influence the adaptation behavior of the tea farmers by answering the following research questions:

1. How aware are Nepalese tea farmers of climate change?
2. Which strategies are applied by smallholder tea farmers in Nepal to adapt to climate change?
3. How do socio-demographic and institutional characteristics and information sources influence adopting climate change adaptation strategies?

2.2 Theoretical background

2.2.1 Climate change adaptation in tea farming

Different adaptation strategies are implemented in tea farming to build climate resilience (Figure 5). These factors were derived from research on climate change adaptation in various agricultural fields, including tea farming. In this study, the derived adaptation strategies were used to see which of them are applied by tea farmers in Nepal within the context of climate change. The most common methods include the usage of more climate-resilient tea cultivars (Biggs et al. 2018a; Fahad and Wang 2018) as well as soil conservation connected to adjustments in the use of fertilizers, pesticides, and irrigation (Deressa et al. 2009; De Sousa et al. 2018; Biggs et al. 2018a). Agroforestry is an equally standard adaptation measure in tea farming, protecting tea plantations from extreme weather and positively affecting yields and the living situation (Bedeke et al. 2018; Amadu et al. 2020a).

Creating awareness programs and intelligent control towards using pesticides and fertilizers can improve adaptive farming approaches (Biggs et al. 2018a; Shi-yan et al. 2018). Furthermore, irrigation, water conservation, and the prevention of deforestation are equally relevant coping strategies for farmers. Another standard measure to lower the risk of potentially harmful effects of climate change on tea farmers is crop diversification (Menike & Arachchi 2016; De Sousa et al. 2018; Fahad and Wang 2018, Shi-yan et al. 2018). Most farmers allocate their land not exclusively to tea but also to grow other crops for consumption or selling.

Adaptation strategies in tea farming

- **Crop diversification** (Menike & Arachchi 2016; De Sousa et al. 2018; Fahad and Wang 2018, Shi-yan et al. 2018)
- **Rain water storage** (Menike & Arachchi 2016; Fahad and Wang 2018)
- **Water conservation with ponds** (Nguyen and Mitsumasu 2016; Fahad and Wang 2018, Shi-yan et al. 2018)
- **Soil conservation** (Deressa et al. 2009; De Sousa et al. 2018; Biggs et al. 2018a)
- **Less climate sensitive cultivars** (Biggs et al. 2018a; Fahad and Wang 2018)
- **Agroforestry** (Bedeke et al. 2018; Amadu et al. 2020a)

Factors influencing adaptation

- **Institutional characteristics: access to credit, cooperative membership** (Trinh et al. 2018;Menike & Arachchi 2016;De Sousa et al. 2018)
- **Socio-demographic aspects: age, gender, education** (Trinh et al. 2018;Shi-yan et al. 2018;Makuvaro et al. 2018;De Sousa et al. 2018;Arbuckle Jr. et al. 2013)
- **Farm characteristics: size, farm elevation**(Sahu and Mishra 2013;Ali and Erenstein 2017;Bedeke et al. 2018;Gunathilaka et al. 2018)
- **Information access: media sources, trainings** (Trinh et al. 2018;Shi-yan et al. 2018;Ali & Erenstein 2017;Gunathilaka et al. 2018)

Figure 5: Climate change adaptation strategies and factors influencing adaptation

2.2.2 Factors influencing climate change adaptation in agriculture

Various factors influence the adoption rate of different adaptation strategies. They can be grouped into institutional characteristics, socio-demographic aspects, farm characteristics, and information access (Figure 5). Based on previous literature, the most prevalent factors were identified and used as independent variables for further analysis in this study. Socio-demographic aspects are essential characteristics of the farmers, potentially influencing their adaptation behavior. These include household size, education, training participation, age, and gender (Trinh et al. 2018; Shi-yan et al. 2018; Makuvaro et al. 2018; De Sousa et al. 2018; Arbuckle Jr. et al. 2013). Similarly, farm characteristics such as farm size and the elevation of the farms affected the farmers' adaptive capabilities (Sahu and Mishra 2013; Ali and Erenstein 2017; Bedeke et al. 2018; Gunathilaka et al. 2018). In previous studies, institutional characteristics, particularly access to credit and cooperative membership, had positively influenced the farmer's adaptation behavior (Trinh et al. 2018; Menike & Arachchi 2016; De Sousa et al. 2018). This also holds for access to information via various media sources and training through the provision of extension services (Trinh et al. 2018; Shi-yan et al. 2018; Ali & Erenstein 2017; Gunathilaka et al. 2018).

2.3 Methodology

2.3.1 Study area

Jhapa, with 18.3 million kg, and Ilam, with 4.15 million kg, were Nepal's two central tea-producing districts in 2018 (Figure 6). Ilam has the highest number of smallholder farmers (6,985) (NTCDB 2018). As this study focused on smallholder tea farmers, Ilam constituted the most feasible district regarding accessibility and targeted research population. The research area is 1,703 $km^2$and is inhabited by around 303,000 people (City Population 2017). It is divided into a total of ten municipalities (Figure 7). Three of these ten municipalities were selected for this study: Ilam, Saryoday, and Deumai. The climate in the study area is subtropical. The elevation ranges between 1,000 to 2,000 meters. This zone covers approximately 40% of the total area of Ilam district (Lillesø et al. 2005). In Ilam, a large part of the annual precipitation occurs during the monsoon season from June to September (Climate Data 2019). Due to climate change, Nepal is experiencing a shift and higher unpredictability of the monsoon (Malla 2008). Thus, tea farmers increasingly struggle with the shifting climate patterns.

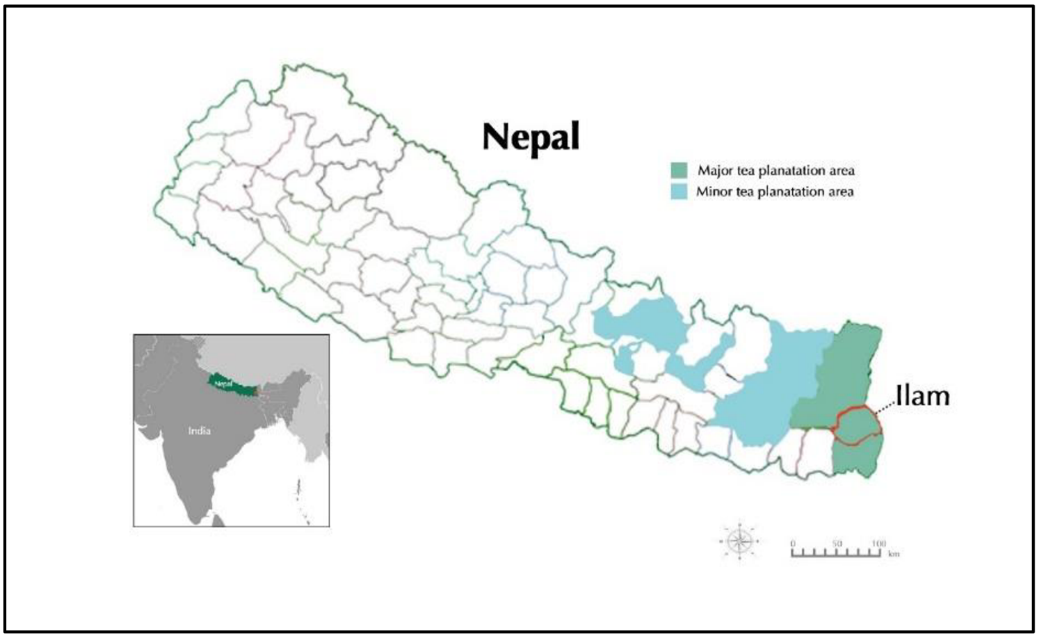

Figure 6: Map of Nepal with the position of minor and major tea producing areas

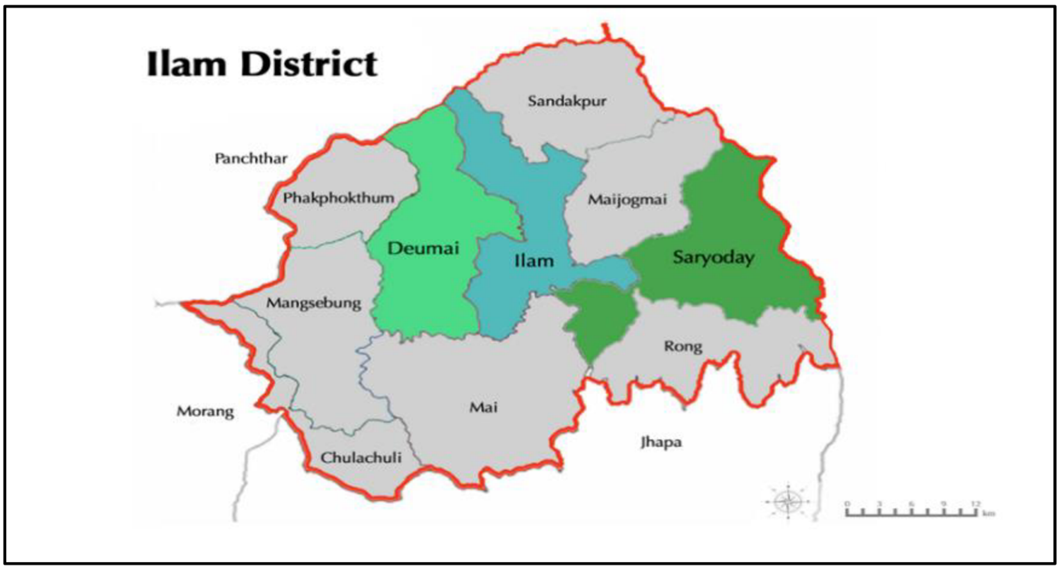

Figure 7: Detailed map of Ilam district with selected municipalities highlighted in colour

2.3.2 Data collection

Primary data was collected using a structured questionnaire (Appendix A1). It was developed based on the theoretical background presented in the previous section. The questionnaire was primarily designed to identify how many and which specific climate change adaptation measures were used by the farmers. Next to the socio-demographic characteristics of the respondents, the survey asked which specific information sources they use to educate themselves about tea cultivation practices and climate change. Knowing if credit access and cooperative membership positively influenced adaptation behavior was necessary for the analysis. Therefore, questions connected to institutional variables have been included as well. The questionnaire was divided into four major categories with a total of 41 questions:

1. Climate change perceptions and adaptation strategies (climate change awareness, perceived impact on farming performance, adaptation strategies, constraints of adaptation)

2. Financing and information access (use of loans, sources of weather and tea cultivation information, participation in training, awareness of tea export strategy, member of cooperatives, the relevance of information)

3. Economic performance (harvest quantity, average price, and perceived profitability for the past three years, usage of fertilizers/pesticides, certification according to international standards, harvest losses, further processing of the tea)

4. Sociodemographic characteristics (education, age, experience in tea farming, farm size, elevation, household size, workforce distribution, other crops on the farm)

Data was collected by using exponential, non-discriminative snowball sampling. This method provided access to hidden populations at a possible cost and was time efficient (Dudovsky 2018). We gained access to the farmers through several contacts in the district, who provided us with further references of tea farmers in Ilam. An assistant from a local university supported us in conducting the interviews and translating the conversations and responses to the posed questions. All questionnaires were completed on paper during individually appointed face-to-face interviews with each farmer. The questionnaire was translated from English to Nepali before the field stay. After piloting the survey among several field experts before the data collection, unclear questions and translation errors have been amended and adjusted accordingly. A total of 91 respondents were interviewed during the field research. 28 interviews took place in the Ilam municipality, 20 in Deumai, and 43 in Saryoday.

2.3.3 Data analysis

Table 2 includes all dependent and independent variables based on the theoretical background. The number of adaptation strategies the farmers used was the dependent variable. Furthermore, two of the six adaptation strategies (agroforestry and climate-resilient cultivars) for the analysis have been identified. The measures were taken from the questionnaire section, in which farmers had to indicate the climate change adaptation strategies they were already applying (Appendix A1). The share between farmers using/not using agroforestry and climate-resilient cultivars was relatively balanced. Therefore, further analysis was most feasible with these two options.

Table 2: Dependent and independent variables used for data analysis

Variables	Type/Label	Mean
Dependent Variables		
Nr. of adaptation strategies	continuous/ 1 – 6	3
Agroforestry	dichotomous/no, yes	.45
Climate resistant cultivars	dichotomous/no,yes	.42
Independent Variables		
Institutional variables		
Access to credit	dichotomous/no, yes	.26
Cooperative member	dichotomous/no, yes	.52
Socio-demographic variables		
Age	continuous/years	45.41
Gender	dichotomous/male,fem.	.82
Education	continuous/years	9.55
Farming experience	continuous/years	18.86
Farm characteristics		
Farm elevation	continuous/meters	1,553
Farm size	continuous/hectare	1.17
Information access variables		
Attendance in training	ordinal/never-frequently	2.84
Information source: Internet	ordinal/never-frequently	2.54
Information source: Other farmers	ordinal/never-frequently	3.30

Note: ordinal variables have a scale from 0=never – 4=frequently; dichotomous variables: 0=no,1=yes; 1=male,0=female; Mean= average values of the sample

A multiple regression (MR) model was used to identify potentially significant predictors of the number of adaptation strategies used among the respondents (Greene 2003; Cramer

2003). The basic equation for an MR can be formulated in the following way:

$$\boldsymbol{y} = \boldsymbol{x1\beta1} + \boldsymbol{x2\beta2} + \cdots + \boldsymbol{xK\beta K} + \boldsymbol{\varepsilon} \qquad (1)$$

y represents the number of adaptation strategies (min.=0, max.=6) as a dependent variable, where each x represents an independent variable noted in Table 2. Each β is the coefficient of an independent variable, and ε is the error term. The applied model was checked for multicollinearity by looking at the tolerance value and the variance inflation factor (VIF). Furthermore, Cook´s distance was checked to understand the model's predictive capabilities.

A Binary Logit Model (BLM) is a feasible analysis method when the dependent variable's outcome is binary (Hosmer & Lemeshow 2000; Greene 2003; Cramer 2003). The dependent variables agroforestry and less climate-sensitive cultivars can take only two results (using= yes or not using= no). These options were coded with 0 (=no) or 1 (=yes). The BLM reveals which of these factors affects the outcome of the dependent variable, assuming no multicollinearity among the independent variables (Cramer 2003). All independent variables have been checked by the VIF, which ranged between 1.5 and 3.2. Based on this outcome, we can assume no multicollinearity between the independent variables. The basic binary logit equation can be described in the following way:

$$\boldsymbol{log}\left(\frac{\boldsymbol{p}}{\boldsymbol{1-p}}\right) = \boldsymbol{\beta_0} + \boldsymbol{\beta x} \qquad (2)$$

The dependent variable y can have the outcome of 1 or 0 based on the logarithm (*log*) of probability p. Based on the selected variables, two models were developed with two selected adaptation strategies and whether they have been used. β_0 constitutes the intercept, while X is the vector of all independent variables included in the model. The coefficients of the independent variables were expressed through β. In addition to the original equation's intercept, coefficient, and variable vectors, e symbolizes the natural logarithm used for calculation. The probability of y=1 with a given value of the vector X of all independent variables can be calculated through the following formula:

$$\boldsymbol{p(y=1)=\frac{e\beta_0+\beta x}{1+e\beta_0+\beta x}} \qquad (3)$$

2.4 Results

2.4.1 Description of the sample

The sociodemographic characteristics of the sample varied from the average population of Nepal in terms of literacy, education, and family size (Table 3). The literacy rate of the respondents was 91.2 %, which is considerably higher than the current literacy rate average for Nepal at around 64% (Index Mundi 2018). The average family size in the sample equaled 5.14 people. This is more than the national average of 4.6 people per family (UNDP 2017). The youngest respondent was 25, while the oldest was 73, with an overall average of 45.41. Noteworthy is the average years of schooling, which equaled 9.55 years. This is higher than Nepal's average years of education, which is around 3.3 years (UNDP 2017). Table A2 contains further characteristics of the respondents.

Table 3: Sociodemographic characteristics of the respondents

Variable	Total (%)	Min.	Max.	Mean
Gender				
Male	75 (82.4%)	-	-	-
Female	16 (17.9%)	-	-	-
Literacy				
Literate	83 (91.2%)	-	-	-
Illiterate	8 (8.8%)	-	-	-
Marital status				
Single	2 (2.2%)	-	-	-
Married	87 (95.6%)	-	-	-
Divorced	0 (0.0%)	-	-	-
Widow	2 (2.2%)	-	-	-
Household members				
to 15 years	-	0	3	1.02
16-59 years	-	0	10	3.35
60+ years	-	0	3	0.77
Total average	-	-	-	5.14
Age (years)	-	25	73	45.41
Education (years)	-	0	15	9.55

2.4.2 Number of applied adaptation strategies

The average number of adaptation strategies used varied among the tea farmers (min.=1, max.=6) (Figure 8). The mean for all respondents in the application of adaptation strategies was 3.00.

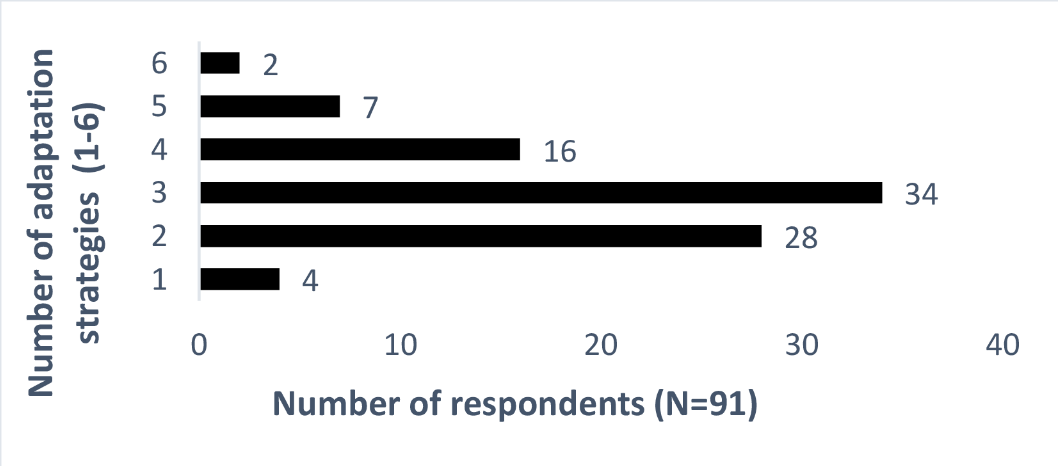

Figure 8: Number of adaptation strategies applied by respondents

The multiple regression shows that membership in a cooperative and attendance in training positively affected the number of adaptation strategies used (Table 4). Mainly, cooperative membership appears to notably increase the likeliness to apply a broader range of adaptation strategies towards climate change adaptation.

Table 4: Factors influencing the number of adaptation strategies used (min.=1, max.=6)

Variable	Coefficient	Std. Error	p-value
Access to credit	0.111	0.248	0.274
Membership Cooperative	**0.431**	**0.244**	**0.000**
Age	0.158	0.013	0.258
Gender	0.016	0.309	0.885
Education	0.098	0.033	0.415
Farming experience	0.129	0.019	0.317
Farm Elevation	0.024	0.001	0.815
Farm size	0.058	0.089	0.568
Attendance training	**0.242**	**0.102**	**0.035**
Info.Source: Internet	0.007	0.100	0.949
Info.Source: Other farmers	0.084	0.165	0.431

2.4.3 Usage of specific climate change adaptation strategies

Figure 9 shows all included adaptation strategies and their application rate among the sample. Agroforestry was applied by 50 respondents (54.9%), and less climate-sensitive cultivars by 38 respondents (41.8%). Thus, both strategies had a relatively balanced share between farmers who did and did not use them. Given the number of the overall sample size (N=91) and the frequencies of the usage of each adaptation strategy, we selected agroforestry and less climate-sensitive cultivars for further analysis. Ultimately, this study aimed to explain why some farmers and others are not using these strategies.

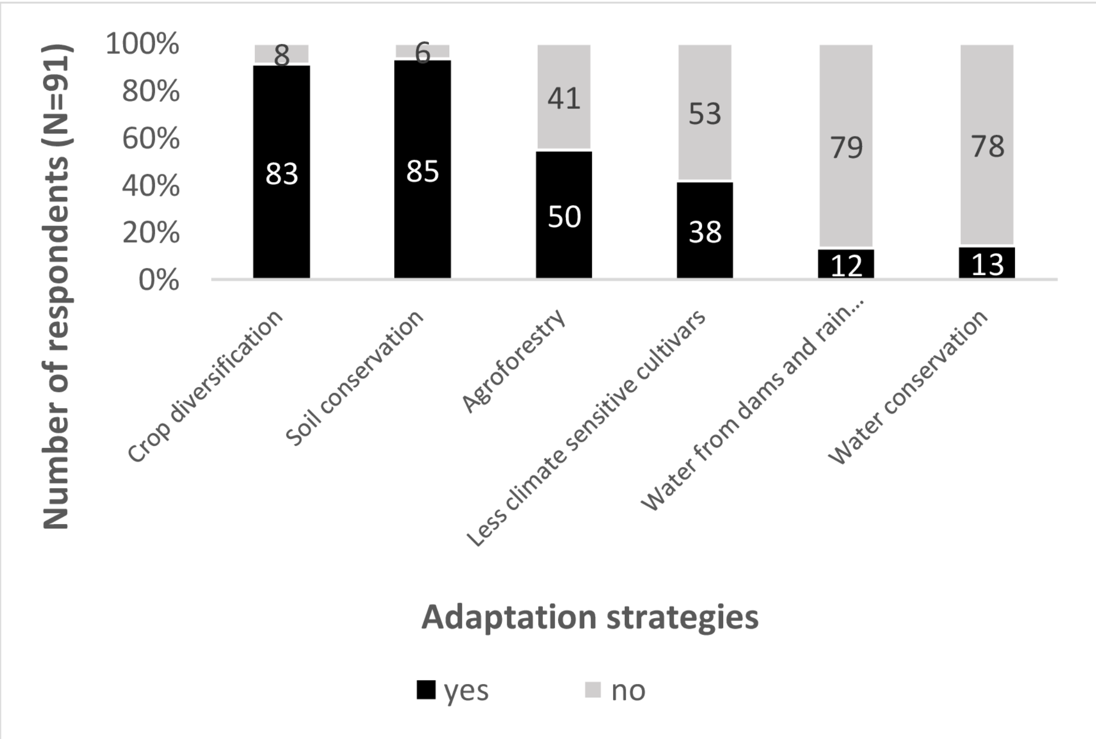

Figure 9: Application of specific adaptation strategies

Table 5 shows the results of the BLMs for the two selected adaptation strategies, agroforestry and using less climate-sensitive cultivars. If all other factors remain unchanged, the odds ratio (OR) indicates a more than eight times higher probability of using agroforestry than if no credit was utilized. Members of a cooperative were almost six times as likely to use agroforestry, and respondents who frequently use other tea farmers as information sources were over four times more likely to apply this strategy. Being a cooperative member positively influenced the usage of less climate-sensitive cultivars by almost five times. A higher frequency of internet use as an information source leads to a higher probability of switching to less climate-sensitive cultivars by around 1.7 times per scale unit (0=never-4=frequently). Both independent variables were significant at a 5% level. Based on these results, it becomes evident that institutional factors and information sources influence tea farmers' adaptation behavior.

Model 1 is significant at the 1% level and accurately predicts 78% of the values correctly compared to the observed values. In contrast, Model 2 is significant at the 5% level and accurately predicts 70% correctly. According to Greene (2003) these results allow the assumption that the values based on the models, including the predictors, are different from the observed values.

The VIF among the significant predictors was 1.372, thus lower than the commonly accepted limit of 10. The tolerance value of the model is at 0.777 and thus above the threshold of 0.100. It can, therefore, be assumed that the model is applicable and that there is no multicollinearity among the independent variables. One case with a residual of 3.099 was identified by looking at the case-wise diagnostics. However, checking the cook´s distance revealed no influence on the model's predictive capabilities. The adjusted R^2 is 0.297, meaning it explains around 30% of the variations. The p-value of this model is 0.000, so it is statistically significant.

Table 5: Factors affecting adoption of agroforestry and less climate-sensitive cultivars

	Agroforestry			Less climate-sensitive cultivars		
Variable	p-val.	odds ratio	S.E.	p-val.	odds ratio	S.E.
Access to credit	**0.008**	**8.104**	**0.783**	0.430	6.710	0.646
Membership cooperative	**0.012**	**5.804**	**0.700**	**0.012**	**4.923**	**0.632**
Age	0.830	0.992	0.039	0.158	1.050	0.034
Gender	0.237	3.602	1.085	0.620	0.681	0.775
Education	0.226	0.877	0.108	0.194	1.117	0.085
Farming experience	0.587	0.970	0.057	0.276	0.949	0.048
Farm size	0.492	0.980	0.279	0.797	0.946	0.217
Farm elevation	0.491	1.001	0.002	0.446	1.001	0.002
Attendance in training	0.197	0.959	0.321	**0.041**	**1.705**	**0.272**
Inf.source: Internet	0.166	1.659	0.365	0.170	0.638	0.328
Inf.source: Other farmers	**0.027**	**4.128**	**0.642**	0.194	0.590	0.406

2.5 Discussion

While there is an overlap with the findings of previously conducted research in this field, our study offers novel insights into the degree of climate change adaptation of smallholder tea farmers in Nepal. The results show that Nepalese tea farmers are highly aware of climate change and try to adapt to it accordingly. While most farmers applied crop diversification and soil conservation strategies, they only partially used coping options such as irrigation, agroforestry, and less climate-resilient cultivars. Despite a high degree of climate change awareness, adaptation readiness among smallholder tea farmers in Nepal appears to be limited. The analysis of the acquired data showed that farmers with credit access, frequent training participation, and a cooperative membership tend to adapt to climate change better than those who do not fall into those categories. The high degree of climate change awareness goes in line with the mean of previous findings among farmers in various countries such as Italy (Menapace et al. 2015), South Africa (Findlater et al. 2018), Sri Lanka (Menike & Arachchi 2016), China (Shi-yan et al. 2018) and India (Sahu & Mishra 2013). The most common adaptation strategies among tea farmers derived from Ashardiono and Cassim (2014) in Japan or Biggs et al. (2018a) in India were also applied by Nepalese farmers. However, these strategies are not always used intentionally with a direct link to CSA. Farming practices, such as crop diversification or agroforestry, were identified as helping farmers to adapt to climate change. However, farmers traditionally use such interventions with more than one goal. These include but are not limited to intentions such as profit maximization or adherence to certification standards. The design of this case study thus only provides a limited understanding of how Nepalese tea farmers' farming practices derived from previous literature are adopted solely to adapt to climate change. Another possible explanation for the deviance between awareness and adaptation is the lack of including climate change threats in the farmers' mental models of everyday risks (Findlater et al. 2018).

Previous studies suggest that smallholder tea farmers do not use the whole farm solely for tea production (Biggs et al. 2018b). In this case, the share of farm size dedicated to tea was, on average, 75.4%, indicating that farmland was also devoted to other crops. Despite the high perceived impact of droughts on the tea farms, the adoption of strategies related to irrigation was low among the sample. A possible explanation is a lack of knowledge of irrigation technologies and their application. Less climate-sensitive cultivars were used by less than half of the respondents. Perennial crops (such as tea) are challenging regarding appropriate adaptation due to their long lifecycles (Lobell et al. 2006). According to the farmers, more climate-resilient tea cultivars can only be introduced in the long term because it takes several years for a tea tree to mature. Adapting by protecting the tea from wind and sun exposure through agroforestry, next to other factors, also depends on the specific location of the tea farm. Socio-demographic characteristics and farm size did not play a statistically significant role in the adaptation behavior of smallholder tea farmers in Nepal. Menike and Arachchi (2016), Trinh et al. (2018), and Ali and Erenstein (2017) noted that a higher degree of education and gender (being male) leads to improved adaptation behavior. Previous studies argued about the impact of these factors (Sahu and Mishra 2013; Bedeke et al. 2018; Deressa et al. 2009). However, it is salient to consider that the targeted sample consisted of smallholder farmers. The size of most farms ranged between 0.5 and 1.5 hectares. A minor farm size variance could explain this factor's nominal effect size.

Other farmers and internet access were the most prevalent sources of information about weather and tea cultivation. Previous research (Menike and Arachchi 2016; Gunathilaka et al. 2018) also noted the importance of these channels. The lack of use of other sources of information would allow policymakers to diversify information access for farmers. If the sampled farmers attended training more frequently, they were more likely to apply more adaptation strategies and had a higher probability of using climate-resilient cultivars. Only a small share of the respondents never participated in any training, while many participated in training once per year (66%). 38.5% of the farmers even participated in training several times per year. Khanal et al. (2018) uncovered similar outcomes based on a study among Nepalese rice farmers, while Nguyen and Mitsumasu (2017) confirmed this among Vietnamese tea farmers. A lack of access to training is one of the main constraints towards adapting to climate change (Deressa et al. 2009). This shows the importance of training and extension services in climate change adaptation.

Nevertheless, the FAO (2010) pointed out the weaknesses of agricultural extension services in Nepal. Inappropriate technical expertise, weak motivation, and poor commercialization hinder the effectiveness of training provided to the domestic farming sector. Farmers should hence be encouraged to attend training if possible. Furthermore, the quality of extension should be improved overall with a focus on educating farmers on climate change. A majority of the respondents had never heard about the strategic plans in the National Tea Export Strategy 2017-2021 (ITC 2016). Only a minority was aware of its content. This revelation indicates a lack of dialogue between Nepal´s tea industry stakeholders.

The farmers' most prevalent information types were knowledge about farming techniques and the market situation (e.g., tea prices, competitors). Since the awareness rate of the export strategy (ITC 2016) is low, a lack of communication among the individual stakeholders in the regional tea industry can be suspected. Agricultural research on climate change adaptation behavior concluded that credit access is one of the main drivers of adaptation readiness (Sahu & Mishra 2013; Trinh et al. 2018; Khanal et al. 2018; Fahad & Wang 2018). The Nepal Rastra Bank (2014) analyzed the effect of microcredits on the Nepalese agricultural sector and came to the same conclusion: Improved credit access has a positive impact on agricultural efficiency. Nepalese credit institutions are, however, reluctant to provide loans, particularly to smallholder farmers. The conditions for granting loans can often not be fulfilled, and high-interest rates make it less appealing for farmers to apply for credit. Therefore, most of the respondents (73.6%) did not have credit access in the past five years, while simultaneously, farmers emphasized the importance of financial liquidity.

The sample size (N=91) was smaller than anticipated, so the applicability to the overall research population is limited. Due to the lack of farmers' address lists, collecting data based on random sampling was impossible. Being primarily dependent on an interpreter allowed only minor influence on discussions and explanations during data collection. Some tea farms were accessible only through challenging road conditions. Traveling to some of the farms in the research area thus took a substantial amount of time. This circumstance made the collection of field data a time-intensive and logistical challenge.

2.6 Policy implications

While the government of Nepal intends to increase tea exports significantly, most farmers were unaware of those strategic plans. The apparent lack of communication hinders the Nepalese tea sector from thriving at its full potential (Vij et al. 2018). Despite many tea farmers frequently attending training, the quality of these extension services remains questionable (FAO 2010). A lack of governmental support was perceived as one of the main barriers to appropriate adaptation from the farmers' point of view. Focusing on more efficient policy implementation and interaction between policymakers and tea farmers could support adaptation readiness (Ensor et al. 2019). Connected to that are the difficulties farmers face in accessing credits due to high barriers set by involved financial institutions.

Although Nepal dramatically increased its spending on climate change mitigation (Nepali Sansar 2017), outcomes indicate a need for further investments and improved communication with the tea farmers. As Nepal is prone to climate-induced disasters, it is not only the tea export strategy at stake. Economic dependency on agriculture frequently causes problems with domestic food security. Therefore, we recommend that the Nepalese government educate tea farmers about the national tea export strategy (ITC 2016) and any upcoming plans for the Nepalese tea sector. Increasing tea exports and product quality is practically impossible without close cooperation with the producers. Strengthening the tea sector could be achieved by preparing specific training and educating cooperative representatives, helping to transfer knowledge. In particular, cooperative memberships are vital in knowledge transfer among smallholder tea farmers in Nepal. Respondents who were cooperative members tended to use a greater variety of climate change adaptation strategies and better understand the benefits of CSA.

Furthermore, the facilitation of quality training and provision of topic-related information can aid continuous support for farmers. From the farmer's perspective, the restrictions and barriers to credit access are too high. As farmers with access to credits were more likely to adapt to climate change, we recommended that involved financing institutions review and possibly amend their current loan policies. As adaptation strategies related to irrigation were not applied frequently, yet increased droughts were perceived as a threat, it could help educate farmers regarding the irrigation of tea plantations within designated training programs. In this context, looking at existing irrigation schemes in tea farming areas with similar climatic, topographic, and socio-economic characteristics might be helpful. For instance, higher variability in rainfall patterns in neighboring Darjeeling (India) led tea farmers to focus much more on developing self-irrigation schemes (India Climate Dialogue 2018).

3. Case Study 2: Climate Change Adaptation among Farmers in the Czech Republic

3.1 Introduction

The European Green Deal (EGD) provides an action plan to make Europe climate-neutral by 2050 (EUR-Lex 2019). Within the EGD, the "Farm to Folk" strategy emphasizes the need to focus on sustainable food production and preventing food loss through appropriate climate change adaptation (European Commission 2021a). Although the Common Agricultural Policy (CAP) goals are clearly defined, Pe´er and Lakner (2020) criticize the inefficient budget allocation and emphasize the need for subsidizing adaptation to and mitigation of climate change in European agriculture. The sole focus on economic factors in policymaking could limit the effectiveness of farmer support within the CAP (Brown et al. 2021). Therefore, policymakers must consider farmers' motivations concerning environmental issues to achieve the goals set by the EGD. Research aims to address socio-economic indicators to minimize the adverse effects of climate change on agriculture. Such indicators could help understand how farmers would benefit from policy support as much as possible (Barry and Hoyne 2021). While the CAP aims to support the adaptation to and mitigation of climate change, the IPCC emphasizes climate change as a major threat to the agricultural sector (IPCC 2014). Climate scenarios project a global temperature increase of up to 6°C, more droughts, and other extreme weather events (Rahmstorf et al. 2007). The IPCC Special Report on Climate Change predicts dramatic impacts on the agricultural sector (Mbow et al. 2019). Despite the varying intensity of climate change effects in different geographic settings and climatic zones, agriculture remains one of the world's least climate-resilient economic sectors.

Climate change adaptation is thus a condition for agriculture to thrive in the face of future climatic events (Ewert et al. 2005; Haden et al. 2012; Woods et al. 2017; Trinh et al. 2018; Rosenzweig and Tubiello 2007). In addition, it is a critical factor in safeguarding humanity and the world´s ecosystem (Strezov 2019). Research on the degree of climate change adaptation in various settings showed that developing countries are more exposed to extreme climate change effects while having comparably low adaptive capabilities. Industrialized countries, including the Czech Republic, are seemingly less vulnerable to climate change due to better adaptive responsiveness and effective policy implementation. The Czech Republic lies in a region with a comparably low climate change vulnerability and an above-average adaptation readiness (Sarkodie and Strezov 2019). Nevertheless, food security is a core issue connected to climate change, and it is equally affecting agriculture in the European Union (EU) (FAO 2018). Reducing climate-induced harvest losses remains a challenge for the European agricultural sector, which is also a principal aim in supporting the goals set out in the “Farm to Folk” strategy within the CAP (European Commission 2021b).

Other studies, however, argue that increased temperatures and higher precipitation could lead to better farming conditions and higher yields in some climatic zones (Moriondo et al. 2010). For example, farmers in Denmark believe that climate change could increase their productivity (Woods et al. 2017). The geographic variation in the perception of these effects proves the complexity of the subject discussed. Crop types and the structure of agricultural systems thus require tailored approaches to protect them from the effects of climate change. In this context, productivity is mainly measured using crop models incorporating climate data (Easterling et al. 2007). However, climate change impacts are not exclusively influenced by biophysical factors but also by the characteristics of the farm and the farmers themselves (Reidsma et al. 2010). While climate change adaptation and mitigation in Czech agriculture have been discussed in recent scientific publications, there is no known study on farmers' climate change adaptation behavior in Central and Eastern Europe (CEE), including in the Czech Republic. At the same time, the Czech Ministry of the Environment (2015) emphasizes the crucial role of research regarding climate change adaptation. Bearing that in mind, this study aims to uncover factors that influence the degree of climate change adaptation among Czech farmers and to support targeted policies within the resource allocation of the CAP. The findings intend to support the goals set by the Czech government within the EGD by using targeted policy development. In addition, this study adds insights into how information sources and other drivers frame the willingness to adapt to climate change in agriculture. The following research questions aim to deepen the theoretical framework behind understanding the adaptation behavior of farmers in the Czech Republic:

1. Do Czech farmers agree on the existence of climate change, and which specific climate change effects are they experiencing?
2. Which climate change adaptation measures are commonly used among Czech farmers, and what factors influence the decision and degree of adaptation?
3. What are the main barriers keeping farmers from adapting to climate change in the Czech Republic?

3.2 Theoretical background

3.2.1 Importance of climate change adaptation in European agriculture

Although climate change effects on agriculture vary according to climatic conditions and cropping systems, adaptation measures follow the same application rule. The effects of climate change are likely to have a more dramatic impact on developing countries. However, agriculture in the EU will have to improve its adaptive capabilities, too (Reidsma et al. 2010; IPCC 2014). As climate change effects are experienced locally, regional specifications must be taken as essential determinants in adaptation (Aguiar et al. 2018). The impacts of climate change on agriculture include droughts, floods, soil erosion, and extreme weather events (Mbow et al. 2019). Simultaneously, agriculture contributes to climate change, for example, by causing GHG emissions (Anderson et al. 2020). Climate change induced harvest losses could increase the need for more agricultural land, leading to deforestation. This negatively impacts mitigation goals and thus leads to a pitfall in which agriculture contributes to its dilemma (Lungarska and Chakir 2018). Therefore, adaptation and mitigation within this context must go hand in hand. CSA incorporates and links agriculture adaptation measures, policy development, innovations, and ethical values (Gosnell et al. 2019). Land management practices, such as reduced soil cultivation and crop rotation, build the foundation of effective adaptative responses to climate change (Muench et al. 2021; Kipling et al. 2019; Makuvaro et al. 2018). Extended drought periods and uneven precipitation are expected to increase, so innovative irrigation technologies are considered equally critical key measures in adapting to climatic shifts (Iglesias and Garrote 2015).

Increasing temperatures will likely decrease natural water resources, making effective irrigation methods a pressing issue in agricultural adaptation (Huang et al. 2018). Besides, precipitation shifts and intensive agricultural activities influence the soil water balance (Muluneh 2020). Keeping soil cultivation to a minimum is a common strategy to reduce imbalances and counteract soil erosion. Complementary to irrigation is the usage of climate-resilient crop varieties (Fahad and Wang 2018). Climate change is already leading to crop substitution and dramatic changes in the global agricultural landscape, for example, in the United States (Cui 2020). Adaptive capabilities tend to be higher in areas with moderate climates and high economic strength than in areas prone to extreme weather with low economic well-being (Reidsma et al.

2010). Therefore, tailored adaptation according to regional conditions is essential. Farmers can lower their risk of harvest losses by applying various adaptation technologies (Aguiar et al. 2018). One of the most common adaptations in agriculture is the application of mixed crops (Ghahramani et al. 2020). Crop diversification creates more profit sources and lowers the risk of economic losses caused by climate change (Menike and Arachchi 2016; Fahad and Wang 2018). This holds for the utilization of different crop species simultaneously, for using several varieties of one specific crop type, and for rotating crops by the season (Piedra-Bonilla et al. 2020; Roesch-McNally et al. 2018; Labeyrie et al. 2021). Within the scope of this study, crop rotation is the process of growing various crops in succession to avoid soil erosion and land degradation. Applying mixed crops implies that a farmer generally has more than one crop at a given time. The Czech Ministry of the Environment (2015) continues to redefine climate change adaptation measures for agriculture. Reduced soil erosion, crop diversification, climate-resilient varieties, and the use of new crops are among the critical points in the adaptation targets for Czech agriculture. Nevertheless, policymakers in the Czech Republic and other countries are struggling with the data available to help them develop and elevate the accuracy of environmental models (Kipling et al. 2019). Adaptation plans cannot be communicated efficiently without the ability to predict specific impacts and their effects on agricultural performance indicators.

3.2.2 Climate change effects on agriculture in the Czech Republic

Climate change impact prognosis for the Czech Republic points towards a higher variability in precipitation and temperature with a tendency towards milder winters with more rain and warmer summers with drought periods (Papadimitriou et al. 2018). As a result, a shift in crop suitability and increased land degradation risk will be pressing issues for domestic agriculture. Early development of climate change adaptation pathways concerning regional specifics is crucial for effective policy planning (Zandvoort et al. 2017). Pietrapertosa et al. (2018) focused on climate change adaptation policies among countries in CEE. They revealed that the Czech Republic is on par with other European economies in climate change adaptation planning. Crop-specific models, such as CERES models (Otter-Nacke et al., 1991), can be applied to crops such as wheat or barley. These models include variables such as temperature, precipitation, and crop varieties and simulate potential yields according to climatic and topographic specifications. Simultaneously, agricultural land-use change and the shift in climatic conditions are leading to decreased availability of arable land and loss of grassland in the Czech Republic (Lorencová et al. 2013; Papadimitriou et al. 2018). Factors such as increased temperature or higher variability in precipitation change the turnover of organic matter, reducing soil fertility and eventually causing erosion. Predictions point toward these issues being key points in climate change adaptation among Czech farmers. Applying CSA principles reduces soil erosion risk (Vavra et al. 2019). Despite the lack of government efforts to strengthen soil conservation policies, many stakeholders favor enhancing adaptation measures by minimizing soil cultivation on farms.

Despite high climate change awareness in the Czech Republic, Kotecky (2015) criticizes national afforestation subsidies as contradicting climate change adaptation policies. Although there is no direct link between forestry and agriculture, it can be assumed that these policies need to complement each other. If climate change-induced harvest losses for staple crops, such as wheat, were to exceed a 20 % yield decline, the Czech Republic could also face food self-sufficiency issues. This threshold is even lower for fodder crops like maize (Pulkrábek et al. 2019). Domestic technical crops like hops are particularly vulnerable to climate change. As hops are grown only in a small country region, yields and quality are expected to suffer due to climate change (Mozny et al. 2009). Next to direct effects on the crops, climate change leads to higher variability in growing seasons and crop cycles (Potopová et al. 2015). Delays in harvesting and slower growth rates are threats that Czech farmers can only deal with by appropriate adaptation. To decrease climate change risks bound to one specific area, it is recommended to restructure the geographic distribution of crops grown in the Czech Republic. If yield losses want to be kept at a minimum, climate change adaptation must be looked at from a regional point of view. This holds even for a comparably small-sized country such as the Czech Republic (Eitzinger et al. 2013). Regional differences, for example, in a district or municipality, and the specific crops can be essential factors in determining climate change adaptation. An analysis of climate change effects on rapeseed oil production in the Czech Republic revealed variations in the effect on crop productivity based on regional climatic conditions (Pullens et al. 2019). The need to align and tailor the CAP by incorporating regionally specific factors, even for the same crop, becomes apparent. The complexity of domestic climate change adaptation in agriculture becomes evident from previous studies. Revealing the degree of adaptation and the measures used by farmers in the Czech Republic will allow a deeper understanding of the current situation.

3.2.3 Determining the effects influencing the degree of agricultural climate change adaptation

The scope of climate change effects is often perceived as too abstract, leading farmers to exclude this aspect from their mental model of perceived risks (Findlater et al. 2018). Previous research points to various factors influencing farmers' adaptation behavior. Socio-demographic characteristics, such as gender, age, educational level, and farming experience, were seen to influence the degree of adaptation among farmers (Arbuckle et al. 2013; De Sousa et al. 2018; Shi-yan et al. 2018; Zhang et al. 2020). Also, institutional variables such as credit access, training participation, and cooperative membership strongly influenced adaptation in developed and developing countries (Trinh et al. 2018; Menike and Arachi 2016; Masud et al. 2018). Institutional aspects and a lack of efficient policy planning are simultaneously perceived as the main barriers to adaptation to climate change (Masud et al. 2018). In addition, farm size was found to be significant in previous research, such as by Bedeke et al. (2018) or Ali and Erenstein (2017). Some studies point to small farms being more ready to adapt, while others derived a positive correlation between farm size and climate adaptation readiness (Sahu and Mishra 2013, Gunathilaka et al. 2018). Next to farm size, the legal form of agricultural businesses and their economic objectives can influence the degree of climate change adaptation in the Czech Republic (Špička et al. 2020). Financial goals often conflict with pro-environmental behavior, so economic reasons could also be decisive factors in using or not using specific adaptation strategies. The way farmers access information, for example, through mass media, extension services, or other farmers, was repeatedly identified as a factor in the willingness to adapt to climate change (Mahmood et al. 2021; Shi-yan et al. 2018; Trinh et al. 2018). Providing adequate information is crucial to increasing the likeliness of adopting sustainable agricultural practices, such as no-till farming (Bavorova et al. 2020). Therefore, the availability of specific information on climate change enables farmers to adapt appropriately. Nevertheless, farmers often only see the need to act on climate change effects when they feel it negatively impacts their operations (Gosnell et al. 2019). Zhang et al. (2020) argue that it is not only socio-demographic and institutional characteristics but also cultural norms and personal values shaping the willingness of farmers to adapt to climate change. This aligns with social theories, such as the theory of planned behavior.

3.3 Methodology

3.3.1 Climatic conditions in the Study area

Figure 10 shows the trend function for temperature development in the Czech Republic between 1961 and 2018. The trendline reveals an upward tendency, indicating an overall increase in yearly temperature averages for this period. The 10-year averages show a substantial temperature increase in the last decade, pointing to an elevated acceleration of this indicator. Annual precipitation averages with their standard deviation between 1961 and 2018 are shown in Figure 11. The values show variations in annual amounts of rainfall. However, the trendline for the period remained steady, not indicating tendencies towards higher or lower precipitation amounts up to this point.

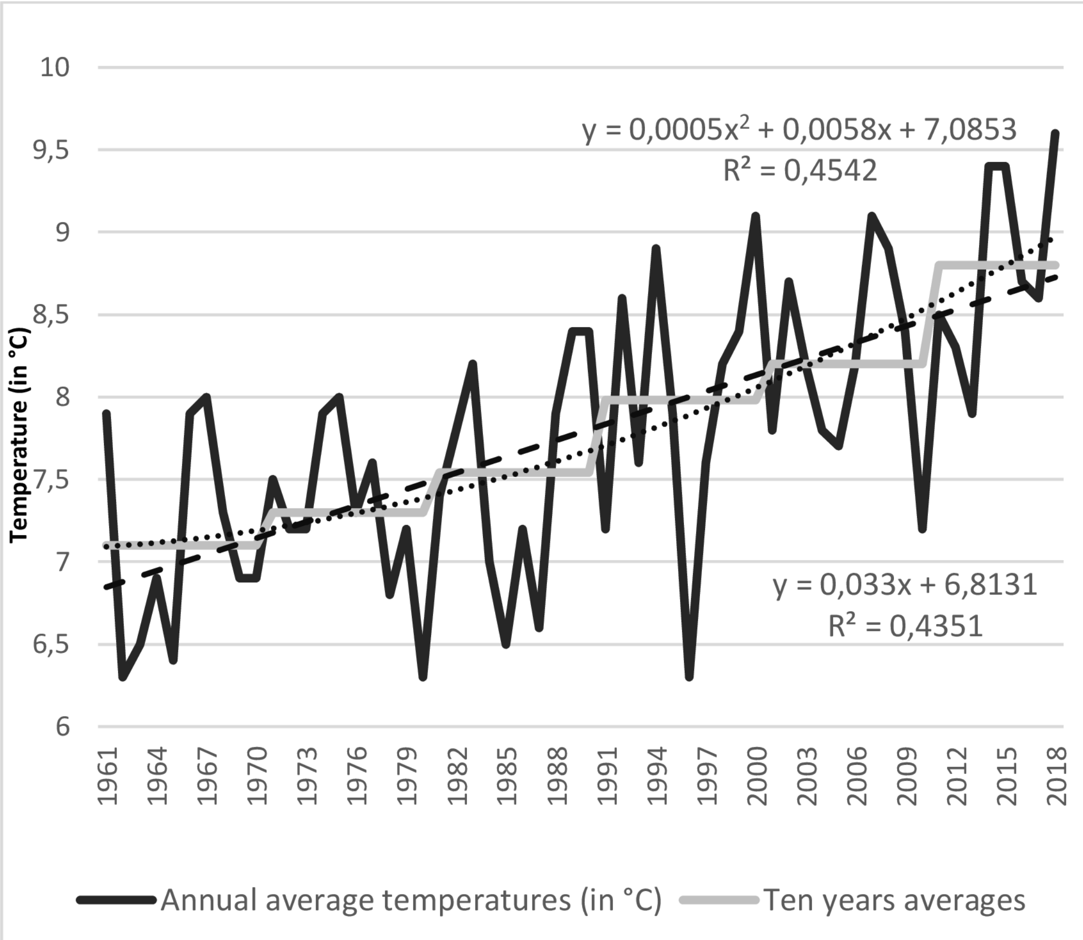

Figure 10: Annual average temperature in the Czech Republic from 1961-2018
(Composed with data from the Czech Hydrometeorological Institute)

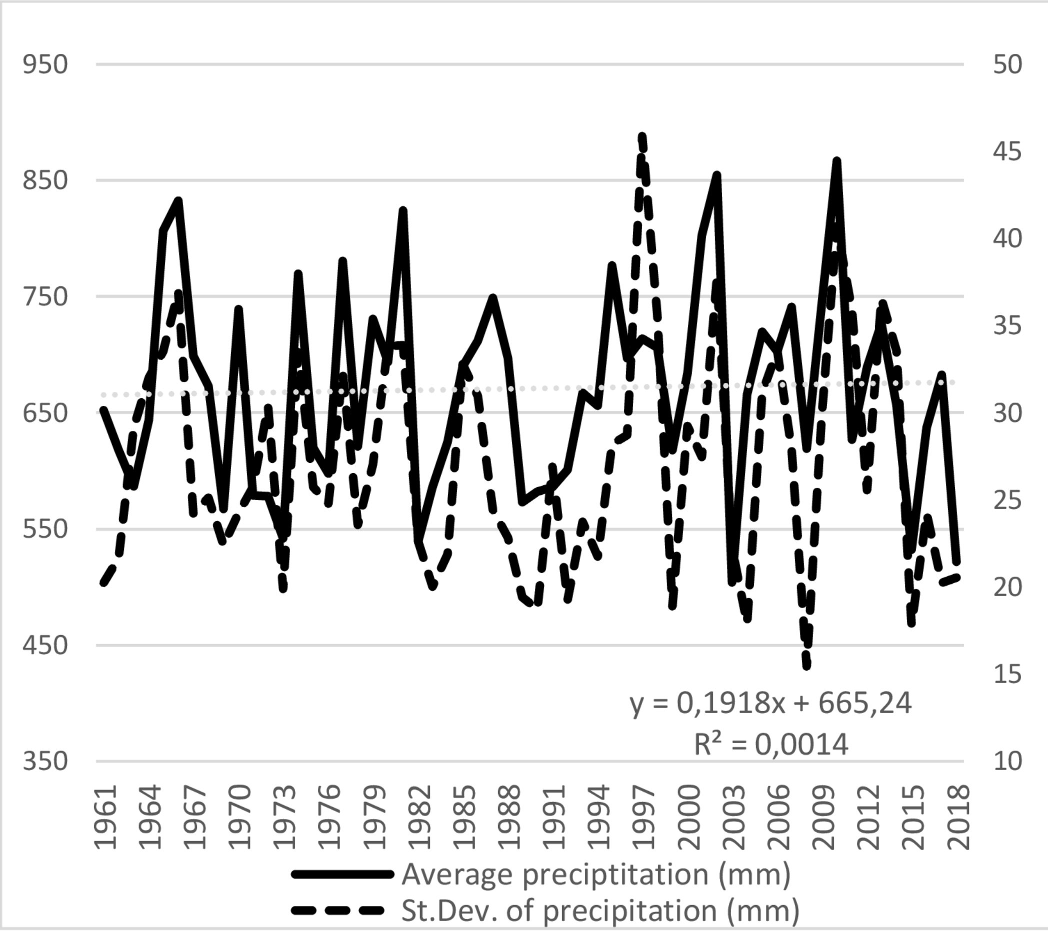

Figure 11: Annual average precipitation in the Czech Republic from 1961-2018 (Composed with data from the Czech Hydrometeorological Institute)

3.3.2 Data collection

All data used in this study were collected through a structured questionnaire (Appendix B1). The data collection was delegated to the professional social research agency FOCUS to ensure the quality of responses. The first step in data collection consisted of a pilot survey carried out in February 2020 among five farmers. The pilot survey allowed minor improvements and adjustments to the questionnaire by removing or rephrasing unclear expressions. The survey was carried out between March and April 2020, and 358 complete responses were obtained. The research sample was selected to correspond to the size structure of agricultural holdings in the Czech Republic (small-size farms up to 50 hectares (ha), average-size farms from 51 to 500 ha, and large-size farms over 500 ha). The respondents were randomly selected from the Czech Farm Accountancy Data Network (FADN) database provided by the Institute of Agricultural Economics and Information. Firstly, the trained operator called the potential responder, explained the purpose of the research, and asked them to fill in the questionnaire. The operator went through the screening process with the respondent to ensure that the appropriate person filled in the questionnaire. The questionnaires were completed via phone or computer-assisted web interview through the secure link provided by the operator.

3.3.3 Data analysis

Table 6 includes all variables used for analyzing the data. The dependent variables are the most relevant climate change adaptation measures derived from the questionnaire. The regressors used for the analysis can be found in the independent variable section of Table 6. The variables have been categorized according to their topical affiliation. Next to variables directly connected to the respondent's characteristics, several farm-level variables and a range of information sources have been included in the analysis. The aim was to be as elaborate as possible and follow this study's theoretical background.

Table 6: Dependent and independent variables used for data analysis

Variables	Type/Label	Mean	Std. Dev.	Min.	Max.
Dependent variables					
Minimal soil cultivation	binary/yes, no	-		0	1
Mixed crops	binary/yes, no	-	-	0	1
Climate-resilient varieties	binary/yes, no	-	-	0	1
New crops	binary/yes, no	-	-	0	1
Permanent soil cover	binary/yes, no	-	-	0	1
Crop rotation	binary/yes, no	-	-	0	1
Independent variables					
Climate change awareness	binary/yes, no	0.407	0.492	0	1
Gender	binary/male(1),female (0)	0.893	0.308	0	1
Age	categorical/5 categories	3.335	1.201	1	5
Education	categorical/4 categories	3.128	0.795	1	4
Land area	continuous/hectare	219.497	677.404	1	10160
OSVC	binary/yes(1),no(0)	0.840	0.366	0	1
Rented Land (Ratio)	ratio/from total land area	56.812	118.285	0	1789
Farm target-profit	categorical/0-4	3.234	0.914	0	4
Farm target-rural employment	categorical/0-4	1.994	1.359	0	4
Farm target-soil protection	categorical/0-4	3.503	0.721	0	4
Wheat production	binary/yes(1),no(0)	0.737	0.441	0	1
Agricultural associations	ordinal/1-4	2.374	1.139	1	4
Ministry of Agriculture	ordinal/1-4	2.935	0.875	1	4
Research institutions	ordinal/1-4	2.192	0.992	1	4
Other farmers	ordinal/1-4	3.101	0.792	1	4
Commercial companies	ordinal/1-4	2.851	0.832	1	4

Agricultural journals	ordinal/1-4	2.751	0.994	1	4
Mass media (TV, radio)	ordinal/1-4	2.072	0.892	1	4
Internet	ordinal/1-4	3.245	0.817	1	4
Field days	ordinal/1-4	2.522	0.966	1	4
Training	ordinal/1-4	1.911	0.896	1	4
Importance strategy (CC)	ordinal/1-5	-	-	1	5
Importance strategy (profit)	ordinal/1-5	-	-	1	5

Note: Values of ordinal information source variables: 1=Not at all – 4=very often; Farm level: 0=not important – 4=very important

Binary Logit Regression Models (BLM) were applied as a suitable method for dealing with binary dependent variables. A BLM allows the analytical interpretation of factors influencing one specific event's likeliness (Cramer 2003). The general formulation of the BLM can be described as follows (Hosmer & Lemeshow 2000; Greene 2003; Cramer 2003):

$$\boldsymbol{p}(\boldsymbol{y} = \mathbf{1}|\boldsymbol{x}) = \frac{\boldsymbol{e}^{\boldsymbol{x}'\boldsymbol{\beta}}}{\mathbf{1}+\boldsymbol{e}^{\boldsymbol{x}'\boldsymbol{\beta}}} = \boldsymbol{\Lambda}(\boldsymbol{x}'\boldsymbol{\beta}) \qquad \textbf{\textit{(1)}}$$

In equation 1, $\boldsymbol{p}$ is the probability of one event occurring, where $\boldsymbol{y}$ = 1 means the event occurs and $\boldsymbol{y}$ = 0 means the event does not happen. As a basis for each BLM, one of the six climate change adaptation measures defined as dependent variables in Table 6 has been selected. $\boldsymbol{x}$ represents the vector of the independent variables, including a unit vector to introduce the intercept in the model estimate, and $\boldsymbol{\beta}$ the vector of coefficients of $\boldsymbol{x}$. $\boldsymbol{e}$ symbolizes an irrational number being used for calculation. Λ(.) stands for the logistic cumulative distribution function. The equation shows how the probability of $\boldsymbol{y}$= 1 with a specific value of $\boldsymbol{x}$ is calculated. In addition, the results were interpreted by looking at the marginal effects. According to Greene (2003), the formula for determining the marginal effects of a BLM is defined in the following way:

$$\boldsymbol{ME} = \frac{\partial \boldsymbol{\Lambda}(\boldsymbol{x\beta})}{\partial \boldsymbol{x}} = \boldsymbol{\Lambda}(\boldsymbol{x\beta})[\mathbf{1} - \boldsymbol{\Lambda}(\boldsymbol{x\beta})]\boldsymbol{\beta} \qquad \textbf{\textit{(2)}}$$

In this equation, the marginal effects are formulated through $\boldsymbol{x}$ being the specified independent variable and $\boldsymbol{\beta}$ being the parameter of each BLM applied in this study. With the BLM for each adaptation measure, the independent variables posed in Table 6 were derived. These predictors influence the likeliness of applying the specified adaptation measure. Through looking at the marginal effects of the BLM, further assumptions on the influence of a specific independent variable on the dependent variable could be drawn. All marginal effects in Table B2 have been calculated based on the averages.

3.4 Results

3.4.1 Description of the sample

Table 7 shows the socio-demographic characteristics of the respondents as well as the legal form and specialization of their operations. Most respondents were male (89.4%). The largest share of farmers was between 41 and 50 years old (27.7%), while only a minority was younger than 30 years old (6.1%). A considerable proportion of the respondents have at least a higher secondary education or a university degree (75.1%). It can also be observed that the majority work under the term "OSVC", meaning they are registered as self-employed. While a small share of the farmers worked in mixed production (8.4%), such as a combination of animal and crop farming, crop production was the predominant type of specialization (88.2%).

Table 7: Characteristics of respondents and farm business (N=358)

Variables (Categories)	Total (%)	Mean	St. Dev	Median
Gender		**0.90**	**0.31**	**1**
Male (1)	320 (89.4%)	-	-	-
Female (0)	38 (10.6%)	-	-	-
Age		**3.34**	**1.2**	**3**
less than 30 (1)	22 (6.1%)	-	-	-
30-40 (2)	75 (21.0%)	-	-	-
41-50 (3)	99 (27.7%)	-	-	-
51-60 (4)	85 (23.7%)	-	-	-
60+ (5)	77 (21.5%)	-	-	-
Education		**3.13**	**0.79**	**3**
Elementary (1)	2 (0.6%)	-	-	-
Secondary/no leaving exam (2)	87 (24.3%)	-	-	-
Secondary/ leaving exam (3)	132 (36.8%)	-	-	-
University (4)	137 (38.3%)	-	-	-
Legal form		**3.76**	**0.71**	**4**
Cooperative (1)	4 (1.1%)	-	-	-
Limited liability company (2)	37 (10.3%)	-	-	-
Joint stock company (3)	8 (2.2%)	-	-	-
OSVC (4)	301 (84.2%)	-	-	-
Other (5)	8 (2.2%)	-	-	-
Specialization		**1.26**	**0.73**	**1**
Crop production (1)	316 (88.2%)	-	-	-
Animal production (2)	2 (0.6%)	-	-	-
Mixed production (3)	30 (8.4%)	-	-	-
Other (4)	10 (2.8%)	-	-	-

3.4.2 Climate change awareness among Czech farmers

Figure 12 shows whether the respondents agree with the existence of climate change. 47.2% of the farmers agreed, and 40.8% strongly agreed with the presence of climate change. Given the total number of respondents, only a small proportion did not agree with the existence of climate change. Climate change awareness among farmers in the Czech Republic is thus similar to other research conducted on this matter (Menapace et al. 2015, Shi-yan et al. 2018). In addition, almost 85% of the farmers believe that humans are responsible for this development, while only 15.4% disagree. These findings align with study outcomes in various ethnic and geographical settings (Findlater et al. 2018; Menike and Arachi 2016; Sahu and Mishra 2013). As climate change awareness is crucial for proactively adapting to it, these results could indicate high climate change adaptation in the Czech agricultural sector.

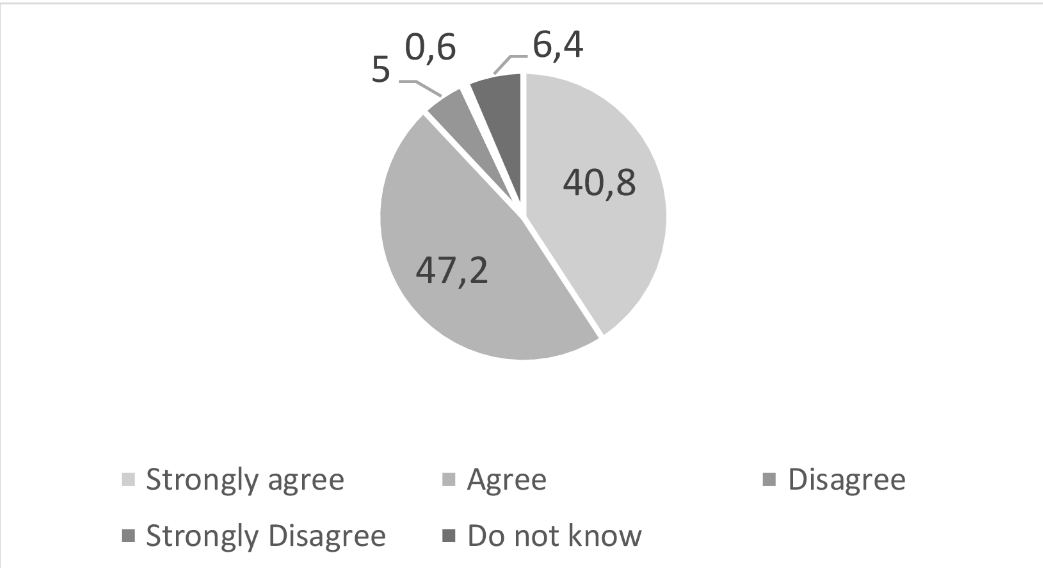

Figure 12: Degree of agreement on the existence of climate change among Czech farmers (in %)

3.4.3 Factors influencing the degree of climate change adaptation

The fit of each model has been evaluated by looking at the outcomes of the likelihood ratio Chi2 – Test (Table 8). This helped to determine if the models with the selected variables have improved goodness of fit compared to a model with none of the selected independent variables. All p-values are at 0.0000, so the models are statistically significant at the 1% significance level and thus applicable. The Pseudo-R2 provides insights into the extent to which the independent variables of each model explain whether the respondents were applying one of the adaptation strategies. The values for this statistic were between 0.3484 and 0.6063, meaning that the predictors in the models explain between 34.8% and 60.6% of the likeliness to apply an adaptation measure.

Table 8: Fit of the BLMs

Characteristics/Model	**Min.Soil Cult.**	**Mixed crops**	**New varieties**	**New crops**	**Soil cover**	**Crop rotation**
LR Chi^2	300.67	238.21	210.60	137.53	211.48	103.55
Prob>Chi^2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.6063	0.5000	0.4290	0.3484	0.4578	0.5023

The presence of high multicollinearity would deem it necessary to remove causal variables. According to Hosmer and Lemeshow (2000), the VIF allows the interpretation of whether high multicollinearity among independent variables is present. Table B3 shows the VIF values for each BLM. Ideally, the VIF would remain below the value of 3. However, the commonly accepted maximum should not exceed 10. Most of the variables in this study had a VIF below 2. Only the variables “Importance for climate change” and “Importance for profitability” showed a VIF between 7 and 9. As no VIF exceeds the threshold of 10, high multicollinearity among the independent variables for each BLM can be ruled out.

The results of the BLM for each of the six selected adaptation strategies are found in Table B2. These strategies have been selected based on the results presented in Table B4. The included measures were chosen based on the application rate. Another criterion was the intended use of the measures by farmers within three years to provide policymakers with insights into adaptation measures. To interpret the relationship between the independent variables and each adaptation strategy, the average marginal effects (AME) were calculated. Only AMEs with a statistical significance between 1% and 10% were used for interpretation. The subjective importance of each adaptation strategy towards climate change adaptation and profitability showed a statistically significant positive effect on all proposed measures. The more important that farmers considered each strategy to be in terms of adaptation and profitability, the more likely it was for them to apply this measure. The increase in likeliness was between 2.3% and 10.5% per unit in this category. Also, the likelihood of using minimal soil cultivation in the context of climate change adaptation was influenced by climate change awareness, age, information sources, mass media, and the internet. While the awareness of climate change and mass media consumption negatively influenced the application rate of minimal soil cultivation between 4.3% and 5.7% per scale unit, other highlighted factors positively influenced the likeliness to apply this strategy between 2.7% and 6.7% per unit increase. Information sources, such as commercial companies and agricultural journals, negatively affected the degree of use of mixed crops.

Interestingly, farmers primarily focused on wheat production showed an almost 9% lower likeliness of using this measure. If respondents agreed on climate change, they had a 6.8% lower likeliness of applying climate-resilient varieties. A similar observation was made for respondents using mass media more frequently. Farmers focusing on wheat production seem likelier to use climate-resilient varieties than their peers. Accessing information through research institutions and attending field days also increased the likeliness of applying climate-resilient varieties. The likeliness of using new crops decreased by 3.2% per age category of the respondents. Also, the bigger the ratio between the total land and the rented land, the less likely farmers were to plant new crops. However, sourcing information from agricultural journals and the importance of soil protection as a farm target positively influenced the application rate of ensuring a permanent soil cover. An OSVC corporate structure increased the likeliness of applying crop rotation by 6.2%. Farmers focusing on wheat production are also more likely to use this measure. The overall analysis revealed that information access, farm characteristics, such as the specialization of wheat production, and corporate structure, influence the degree of climate change adaptation among farmers in the Czech Republic. Different drivers predominantly induce the probability of adopting various measures.

3.4.4 Adaptation barriers in Czech agriculture

In combination with a lack of appropriate information, economic and market-related reasons are among the main barriers to applying CSA concepts in agriculture (Long et al. 2016). Several factors were identified to explain why respondents refrain from adapting to climate change.

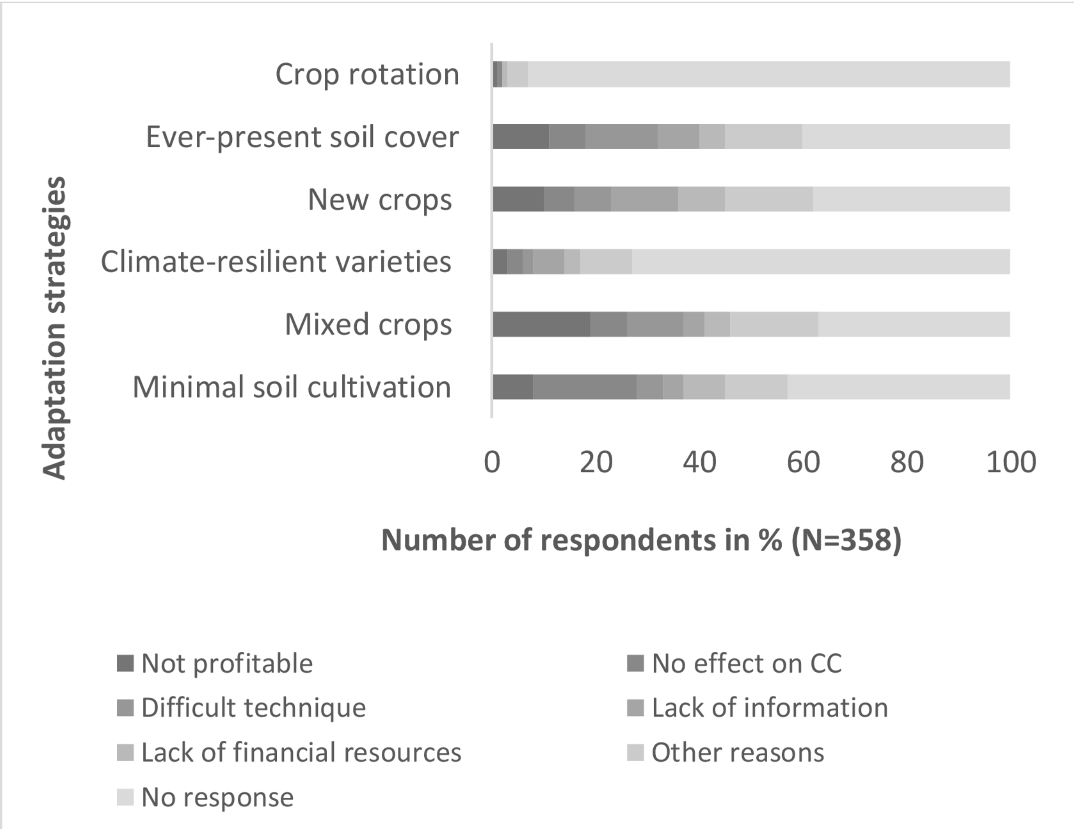

Figure 13: Perceived barriers in the application of specific climate change adaptation strategies

Figure 13 shows the perceived adaptation barriers according to each selected adaptation strategy. Only a few respondents pointed out barriers to applying crop rotation. However, mixed crops, new crops, permanent soil cover, and minimal soil cultivation are not being used to their full potential due to the high share of farmers pointing out adaptation barriers. Difficulties applying the technique and lacking information regarding the topic are the barriers to ensuring a permanent soil cover. At the same time, the barriers to applying new crops and mixed crop farming were connected to them being difficult to carry out. Using mixed crops was not perceived as economically feasible. Many respondents believe minimal soil cultivation would not support mitigation and adaptation efforts. While credit access and the qualifications of employees play a minor role, farmers defined the provision of financial and technical information, as well as higher subsidies from the government, as the most critical drivers towards encouraging them to adapt to climate change appropriately.

Table B5 reveals that farmers perceive the increased incidence of extreme weather events as a particularly relevant impact of climate change on their farming operations. Changes in precipitation patterns, as well as decreasing water availability, variation in temperature, and an overall temperature increase in the vegetative phase, were categorized as climate change effects with a high or very high impact on the farms. Otherwise, most farmers do not perceive a shorter vegetative period, changes in the time of out-planting, or a shift in the harvest period. Most farmers agreed with specific statements on climate change (Table B6). “Changes in precipitation distribution affect crop production” and “Drought has become a more serious problem in the last five years” evoked peculiarly strong responses among the farmers. These findings align with previous studies, where the increasing variability of the climate in the Czech Republic has been discussed (Potopová et al. 2015; Eitzinger et al. 2013; Mozny et al. 2009).

3.5 Discussion

The findings of this study add new context to the ongoing debate on climate change adaptation among farmers in the Czech Republic. 88% of the respondents agree that climate change is real, and over 75% believe human activity contributes to its effects. This high rate aligns with climate change awareness among farmers in other countries (Findlater et al. 2018; Menike and Arachi 2016; Sahu and Mishra 2013). Looking at factors influencing the degree of adaptation as well as the perceived barriers and impacts, however, we can assume that the agricultural sector in the Czech Republic has not reached its full potential in climate change adaptation. The adaptation measures used by Czech farmers follow the recommendations set out by the EIT Climate-KIC (2021) and the Czech Ministry of the Environment (2015). As agriculture in CEE is prone to soil erosion, strategies such as crop diversification, crop rotation, and minimized soil cultivation constitute crucial CSA practices complementing the goals set in the CAP. In this study, crop rotation, the usage of more climate-resilient varieties, and soil protection had the highest application rate. These measures help to counteract decreasing arable land usage in the Czech Republic, as pointed out by Lorencová et al. (2013) and Papadimitriou et al. (2018). The threat of reduced soil fertility and erosion requires local farmers to increase the application of CSA principles proactively. These results indicate that Czech farmers are aware of this necessity. As in this case study, land management practices and a focus on more resilient crop varieties were identified as key measures in various geographical and topographical settings (Ghahramani et al. 2020; Muench et al. 2021; Kipling et al. 2019; Makuvaro et al. 2018). We can, therefore, assume that farmers in the Czech Republic apply the concepts of CSA as described by the CGIAR (2021), FAO (2021), or World Bank (2021). These additionally align with the critical adaptation measures defined by the Czech Ministry of the Environment (2015), e.g., aiming to reduce soil erosion and diversify domestic agriculture. However, to minimize soil erosion, farmers are encouraged to use these measures even more (Vavra et al. 2019). While adaptation readiness in the Czech Republic appears to be high, the findings reveal that farmers perceive numerous adaptation barriers. A lack of information on the topic, difficulty applying specific measures, and financial constraints were perceived as the most significant barriers. Many farmers believed that particular measures would not be helpful for climate change adaptation. As the measures addressed are even recognized by institutions such as the CGIAR or the FAO, the results of this case study suggest a certain degree of misinformation on the topic. Also, the Czech government does not always align climate change adaptation policies with other fields, such as afforestation policies (Kotecky 2015). A lack of policy support and the resulting consequences are vital constraints in climate change adaptation (Masud et al. 2018). One reason for the deviance between climate change awareness and the inchoate degree of adaptation could lie in the cognitive isolation of climate change. Farmers do not tend to include abstract climate threats in their mental model of risks, which decreases the readiness to adapt accordingly (Findlater et al. 2018).

By opposing the theoretical findings with the results, we identified respondent characteristics and access to information as significant predictors in measuring the likelihood of applying adaptation strategies. Low dissemination of information on technological innovations in agriculture causes delays in the DOI concerning CSA concepts (Fichter and Clausen 2021), which is why providing information is crucial in this context. Accessing information from research institutions, agricultural journals, the internet, or field training increased the likelihood of applying more adaptation strategies among Czech farmers. Simultaneously, mass media and commercial companies decreased the likelihood of using specified adaptation strategies. Mahmood et al. (2021), Shi-yan et al. (2018), and Trinh et al. (2018) emphasized the importance of providing farmers with in-depth information on sustainable farming techniques through extension services. As Makate et al. (2019) pointed out, information provision is critical in increasing the application of CSA principles. To achieve the targets set in the EGD, incorporating CSA is of the utmost necessity. However, the privatization of agricultural extension services in the EU causes smaller agricultural businesses to struggle to access quality knowledge (Labarthe and Laurent 2013). The need for close interaction between academic research institutions, topic-specific journals, practical field training, and climate change adaptation in Czech agriculture becomes apparent. Equally important is the availability of information for all agricultural businesses in the Czech Republic. As the applicability of climate change prediction models remains limited (Kipling et al. 2019), policymakers are encouraged to collaborate more closely with the stakeholders involved in agricultural production. In addition, results indicate a positive relationship between economic profitability and climate change adaptation. Špička et al. (2020) emphasize that Czech farms focusing on crop production were more economically driven than livestock farms. Also, higher economic objectives could negatively influence adaptation behavior. Nevertheless, further findings indicate that financial goals and climate change adaptation do not necessarily need to be negatively correlated.

Socio-demographic predictors did not strongly affect the likelihood of applying specific adaptation strategies. While education and gender did not influence the measures' application rate, age positively affected minimal soil application. In contrast, it negatively affected the usage of new crops. These findings deviate from studies such as Arbuckle et al. (2013), De Sousa et al. (2018), Shi-yan et al. (2018), or Zhang et al. (2020), where socio-demographic characteristics were more robust predictors of the likelihood to adapt to climate change. Although farm size had varying effects on climate change adaptation in other studies (Sahu and Mishra 2013; Gunathilaka et al. 2018), it was not statistically relevant in this sample. OSVC farmers were more likely to use crop rotation compared to other legal forms of the farm. This indicates a need to investigate further how legal structures in the agricultural sector might deviate in their adaptation behavior. Furthermore, farmers solely focusing on wheat production were less likely to apply mixed crops simultaneously but more likely to use more climate-resilient varieties and crop rotation. So, it is not only the broader agricultural specialization playing a role in adaptation but also the specific crops grown on the farm. As more diversified farming systems generally reduce harvest losses, farmers focusing on only one crop should be encouraged to diversify their farming operations (Mozny et al. 2009). Crop diversification lowers the threshold of substantial harvest losses and strengthens the farmers' resilience and ability to cope with climatic variations.

3.6 Policy implications

The results of this study stress the exigency for a close collaboration between policymakers, research institutions, topic-specific journals, and training institutions to support Czech farmers in adapting to climate change efficiently. The need to further integrate CSA in the CAP suggests ambitiously unifying social, environmental, and economic sustainability in Europe´s agricultural sector (European Commission 2021c). Simultaneously, the EGD targets not only appropriate climate change adaptation but also the mitigation of the human contribution to its effects. As a considerable share of respondents had economic motives for adapting to climate change, the focus on communicating the connectivity between profitability and climate change adaptation remains a vital factor in elevating adaptation readiness. Therefore, it could be helpful to investigate further the effect of climate change adaptation on the economic performance of agricultural operations. Proof of higher adaptation rates leading to an improved economic outlook, particularly in the long term, could be a strong argument for encouraging farmers to adapt. The targeted provision of financial incentives for farms that already show a high degree of adaptation could encourage other farmers to adapt better to climate change. The outcomes revealed a perceived high impact of droughts and uneven precipitation, but the application rate of measures connected to irrigation was low (Table B4). Also, only a minority of the respondents used intercropping, no-tillage or agroforestry. It is, therefore, worthwhile to investigate why these measures were not applied to a higher degree and how farmers could be encouraged to use such strategies. Attendance at practical field days with specific information provision positively influenced the adaptation behavior. Using this knowledge source as an efficient channel to educate farmers about the benefits of climate change adaptation is recommended. Domestic technical crops, like hops and wine, are grown in specific regions. Because different agricultural systems require an individualistic adaptation approach, it is indispensable to consider regional conditions in policy planning. As the CAP oversees agriculture for the whole EU, there is a danger of formulating adaptation goals without considering specific crops grown, regional climatic conditions, and the current degree of climate change adaptation in the area. Targeted policy interventions must be based on accurate data and an understanding of farmers' behavioral drivers.

4. Case study 3: Climate Change Awareness, Perception and Knowledge among Farming Households in Nigeria

4.1 Introduction

Nigeria is committed to reducing GHG emissions as the country has been identified as a climate change hotspot (UN 2018). Africa´s most populated country faces the deleterious effects of climate change, such as changes in rainfall patterns, desertification, flooding, and drought (IPCC 2014). These will negatively impact the environment and result in a loss to Nigeria's GDP of 1.27% by 2027 and 3.42% by 2037 (Kompas et al., 2018). As a condition of the Paris Agreement, Nigeria formulated an Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) to achieve a 20% unconditional and 45% conditional reduction of GHG emissions by 2030. This includes a strong focus on awareness and preparedness for climate change impacts via the mobilization of local communities for climate change adaptation action (Li et al. 2017). In addition, it is intended to integrate climate change mitigation and adaptation into national, sectoral, state, and local government planning as well as into the plans of universities, research and educational organizations, civil society organizations, the private sector, and the media (UNFCCC 2015).

Experience demonstrates that small-scale farmers are not very concerned with questions related to causes and effects but rely more on their perception and awareness of changes (FAO 2012). Farmers respond to climate change according to their perception of the causes of the environmental changes rather than scientific facts and evidence, as conventional media trust is not guaranteed among farmers (Hyland et al. 2015; Arbuckle et al. 2015). The actions taken towards climate change adaptation thus imply that the farmers experience the adverse effects of climate change on their farm operations. Awareness of climate change among farmers has been a focus of interest in recent scientific discussions (Bryan et al. 2013; Ibrahim et al. 2015; Kutir et al. 2015; Keneilwe et al. 2018; Oduniyi and Tekana 2019; Abdullah et al. 2019 and Mahamadou et al. 2019). However, studies investigating how knowledge of climate change is associated with farmers' perceptions of climate change are scanty. Understanding this issue can guide and shape the farmers' climate change mitigation and adaptation decisions. This research gap served as motivation for this study.

While the global food production system causes up to 37% of global GHG emissions (Mbow et al. 2019), almost 24% of the total global greenhouse gas emissions were caused by the agricultural sector in 2010 alone (EPA 2018). In Nigeria, land use and forestry contribute 38.2%, and agriculture contributes 13% of the total emissions. These values increased by 25% between 1990 and 2014 (USAID 2019). Investigating farmer awareness and knowledge of the causes of climate change in the context of the need for appropriate mitigations is of the utmost relevance. The knowledge gap theory hypothesizes that when information is disseminated to a social system increase, the population with higher socioeconomic status will acquire this information faster than the lower status segments. The gap in knowledge between these segments tends to increase rather than decrease (Tichenor et al. 1970). In this way, farmers with high social status will likely be more knowledgeable on climate change as they can access various information sources/channels that broadcast or publish governmental and non-governmental programs on climate change. This indicates the effect of socio-economic variables such as education or income and the role of information sources and channels on farmers' knowledge of climate change. However, some authors found that people with low socioeconomic status are more knowledgeable about local issues that affect them directly than their counterparts (Hwang and Jeong 2009). Therefore, farmers experiencing climate risk events firsthand are assumed to be more knowledgeable about climate change.

Poor coping strategies and financial shock absorbers depict the effect of climate risk experience in climate risk-prone agroecological zones (AEZs) (e.g., in arid, semi-arid savannah zones). Local observations of climate change knowledge among populations in various AEZs are crucial to understanding the regional conditions supporting adaptation planning on a national level (Reyes-Garcia et al. 2016, Wilbanks and Kates 1999). This assumption holds particularly for countries with several climate zones, like Nigeria. It is, therefore, vital to look at the actual climatic conditions and the perception and knowledge of local populations based on specific climate zones (Kieslinger et al. 2019). By using AEZs as a factor, we aim to create a bridge between regional perspectives and policy making on a national level.

Based on these previous findings, this study analyzed the climate change knowledge of farmers and its association with their perception and provided answers to the following research questions:

1. Is the climate change knowledge of farmers associated with their climate change perception?
2. Which factors affect the awareness and knowledge of climate change among farmers in Nigeria?

4.2 Methodology

4.2.1 Study area

Nigeria has a total land area of 910,768km^2 and a water area of approximately 13,000km^2 (World Bank 2016). The country is characterized by a tropical climate, with six distinctive AEZs. These AEZs can be categorized into *i. the Semi-arid zone, ii. the Sudan savanna, iii. the Guinea savanna, iv. the Swamp forest, v. the Mangroves, and vi. the Rainforest*. Rainfall is bimodal in the humid/southern (freshwater swamp, mangroves, and rainforest) part while unimodal in the dry/northern part (the Semi-arid zone, the Guinea and Sudan savannas) of Nigeria (World Climate Guide 2019). Annual rainfall varies significantly from about 500mm/year in the north (the Semi-arid zone) to 3,000mm/year in the extreme south (the Mangrove and

Rainforest ecological zones). The humid climate results from the proximity to the Gulf of Guinea.

Seasonal temperature differences range from 40˚C in the extreme north (the Semi-arid zone) around April and May to only 12˚C in the central part of the country around December and January (World Climate Guide 2019). The drought occurrences are more pronounced in the dry AEZs (Eze 2018), and floods affect almost all of the country to a great extent in the humid AEZs (Usigbe 2021). Multi-stage sampling was used to select the respondents for this study. In the first stage, convenient sampling of one state from each AEZ was used (Figure 14), followed by the random sampling method (a lottery), which was used to select 12 local government areas. Based on these specifications, two wards were chosen randomly from each local government area, making up 24 wards. Lastly, 45 farming households were drawn randomly (again using a lottery) from each selected ward, reaching a total of 1,080 farming households for the study (Table 9). In cases where random sampling was not possible because of missing lists of farmers (about 20% of wards), snowball sampling was used.

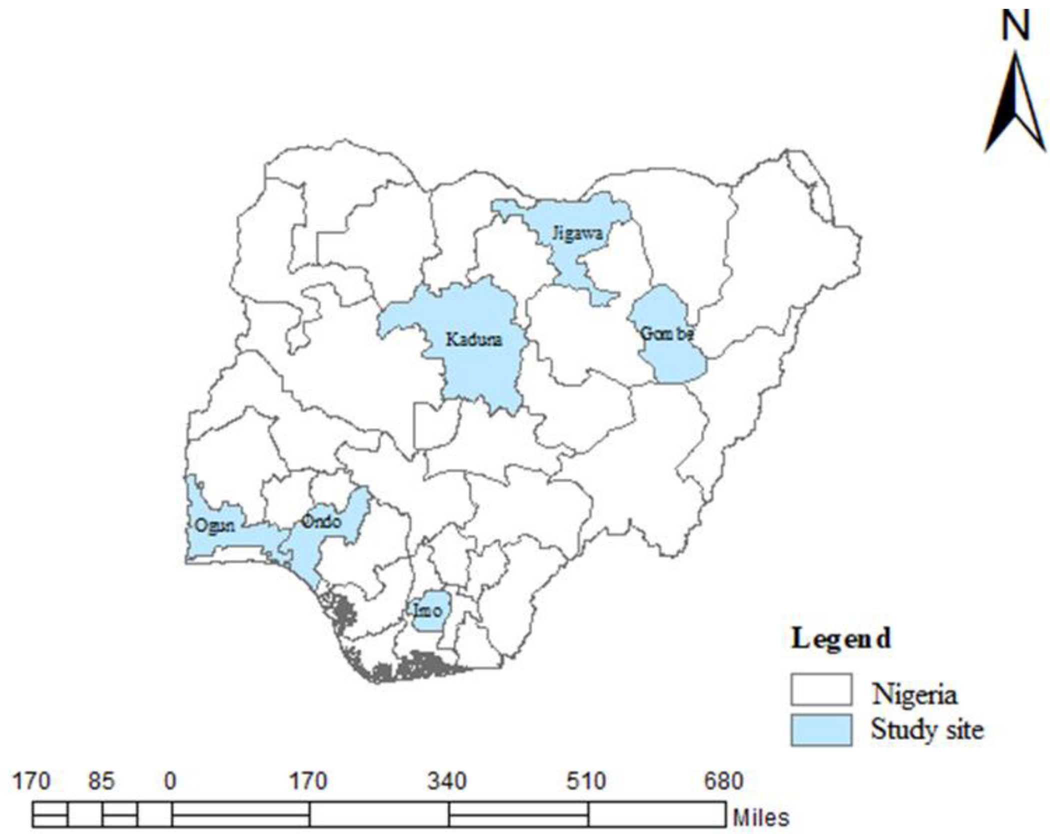

Figure 14: Map of Nigeria showing the study sites

Table 9: Sampling and sample size

Area	Agro-ecological zone	State	No. of farming households
Dry part	Semi-arid	Jigawa	180
	Sudan savannah	Gombe	180
	Guinea savannah	Kaduna	180
Humid part	Mangrove	Ondo	180
	Freshwater swamp	Imo	180
	Rainforest	Ogun	180
		Total	**1,080**

4.2.2 Data collection

Primary data were collected with the help of 12 trained enumerators using a questionnaire/pen and paper survey between October 2020 and February 2021. Household heads or their representatives (less than 10% of respondents) were interviewed. Most of the interviews were made in native languages (Hausa, Yoruba, and Igbo), and responses were translated into English on the spot.

A pre-test survey was conducted with 40 farmers, and modifications were made based on the pre-test outcome before data collection. A semi-structured questionnaire was used, in which most questions were derived from the knowledge-gap theory as used in the literature (Abdullah et al. 2019; Keneilwe et al. 2018; Oluwaseun et al. 2019 and Sonam et al. 2017) and adjusted to suit regional differences accordingly. The questions included respondents' weather information sources (e.g., extension agents, NGOs, research institutions, farmers' colleagues), information channels (e.g., radio, television, newspapers, internet), their climate risk event experience (e.g., drought, flooding) and their socio-economic characteristics (e.g., household, farm, and institutional characteristics), climate change awareness/knowledge of causes and indicators of climate change such as increases in temperature and evaporation, or rainfall variability.

4.2.3 Data analysis

A binary response (Logit) model was used to examine the factors influencing climate change awareness. Following previous studies, this study considered that a farming household head was aware of climate change if he heard the word climate change from information sources and channels or if the farmer experienced changes in their farming operations due to climatic variations (Oduniyi and Tekana 2019; Abdullah et al. 2019 and Mahamadou et al. 2019).

$$\boldsymbol{y_{i1}} = \boldsymbol{\alpha} + \boldsymbol{\beta_1 X_1} + \boldsymbol{\beta_2 X_2} + \ldots + \boldsymbol{\beta_n X_n} + \boldsymbol{\varepsilon} \quad \ldots (1)$$

In the equation, $\boldsymbol{y_{i1}}$ is the probability that the farming household head *i* will be aware of climate change by getting climate information or climate variability experience is more significant than zero ($\boldsymbol{y_i}$> 0). $\boldsymbol{\alpha}$ is a constant, $\boldsymbol{\beta_1 \beta_n}$ are the regression coefficients, $\boldsymbol{X_i}$-$\boldsymbol{X_n}$ denotes the explanatory variables or factors influencing climate change awareness, $\boldsymbol{\varepsilon}$ is the error term.

$$\boldsymbol{y_{i2}} = \boldsymbol{\alpha} + \boldsymbol{\beta_1 X_1} + \boldsymbol{\beta_2 X_2} + \ldots + \boldsymbol{\beta_n X_n} + \boldsymbol{\varepsilon} \quad \ldots (2)$$

In the second formula $\boldsymbol{y_{i2}}$ is the number of questions a farmer answered correctly. A correct answer attracted 1 point, and a wrong answer earned 0 points, resulting in a total score ranging from 0 to 7 points. $\boldsymbol{\alpha}$ is a constant, $\boldsymbol{\beta_1 \beta_n}$ is the regression coefficient, $\boldsymbol{X_i}$ -$\boldsymbol{X_n}$ represents the explanatory variables, $\boldsymbol{\varepsilon}$ is the error term. Logit and the Multiple linear models were tested for multicollinearity and homogeneity using the Variation Inflation Factor (VIF). No signs of homogeneity and multicollinearity were found. No VIF value exceeded the threshold of 10, which would indicate multicollinearity among the explanatory variables (Akinwande et al. 2015).

According to the reviewed literature, factors that affect climate change awareness were identified in Table 10. Gender, farming experience, and information usage showed varying effects in previous research, indicating the importance of considering regional differences within this context (Bryan et al. 2013; Ajuang et al. 2016). Education and farming experience influence farmers' climate change awareness (Ajuang et al. 2016; Oduniyi and Tekana 2019; Bryan et al. 2013; Oduniyi and Tekana 2019). However, extension services show mixed effects on the degree of climate change awareness among farmers (Bryan et al. 2013; Oduniyi and Tekana 2019; Mahmood et al. 2021; Shi-yan et al. 2018; Trinh et al. 2018). Access to credit is associated with awareness of the causes of climate change (Ibrahim et al. 2015; Menike and Arachi 2016; Masud et al. 2018). The most reliable sources of farmers' climate change awareness were extension agents, radio, the internet, magazines, newspapers, and television (Agwu and Adeniran 2009; Junsheng et al. 2019; Ali et al. 2021; Mudombi et al. 2014).

Table 10: Description of variables imported into the models (N=1,080)

Variable	Description	Mean and standard deviation
Dependent variables		
Climate change awareness	Yes= 1, otherwise= 0	0.72 (0.44)
Knowledge of climate change causes	Farmer's quiz score 0-7	2.62 (1.56)
Independent variables		
Socio-demographic characteristics		
Gender	Male= 1, female= 0	0.78 (0.41)
Age	Years	48.15 (13.30)
Years of education	Years of formal education	8.24 (5.59)
Farming experience	Years of being in farming	22.61 (12.18)
Farmers group membership	Yes= 1, no= 0	0.82 (0.37)
Farm size	In hectare	3.44 (3.45)
Credit	Access to credit (Yes= 1, No= 0)	0.32 (0.46)
Livestock ownership	Yes= 1, No=0	0.56 (0.49)
Agricultural income	Annual agricultural income (Naira)	7,563.60 (5,249.34)
Non-agricultural income	Annual non-agricultural income (Naira)	86.99 (96.78)
Dependency ratio	Number dependent/number of active laborers	1.13 (1.70)
Climate change information sources		
Government extension agent (GEA)	Receiving weather information from GEA (Yes= 1, No=0)	0.69 (0.45)
Environmental NGOs	Receiving weather information from NGOs (Yes= 1, No=0)	0.22 (0.42)
Farmers' cooperatives	Receiving weather information from farmers' cooperatives (Yes= 1, No=0)	0.37 (0.48)
University and research institution (URI)	Receiving weather information from URI (Yes= 1, No=0)	0.10 (0.31)

Farmers' friends	Receiving weather information from farmers' friends (Yes= 1, No=0)	0.40 (0.49)
Climate change information channels		
Radio	Number of times receiving climate-related information via radio in a month	9.84 (9.37)
Television	Number of times receiving climate-related information via television in a month	1.63 (4.75)
Newspaper	Number of times receiving climate-related information via newspapers in a month	0.49 (2.37)
Internet	Number of times receiving climate-related information via the internet in a month	1.10 (4.46)
Climate change experience		
Extreme temperature	Number of extreme temperature experiences by farmer in the last ten years	0.71 (0.45)
Flooding	Number of flood experiences by farmer in the last ten years	0.73 (0.43)
Drought	Number of drought experiences by farmer in the last ten years	2.15 (2.23)
Dry agroecological zones	If a farmer is from one of the three dry zones = 1 otherwise= 0	0.5 (0.50)

Furthermore, multiple linear regression was used to analyze the factors affecting knowledge of agricultural practices contributing to climate change. Farmers were asked seven quiz questions to indicate their level of climate change knowledge. Table 11 shows the score distribution of farmers in the following seven dimensions:

i. Deforestation: Process of cutting down plants and crops. This breaks the carbon cycle by stopping the CO_2 absorption function of plants. Between 2015-2017, the global loss of tropical forests contributed to about 4.8 billion tonnes of CO_2 per year (or about 8-10% of annual human carbon dioxide emissions) (Climate Council 2018).

ii. Land clearance by bush burning: Farmers clear their farmlands using fire to prepare for the rainy season. Bush burning can deplete topsoil nutrients, potentially causing crop yields to decrease (Hassan et al. 2019). Furthermore, it changes organic nitrogen into mobile nitrates, which makes it very volatile and causes air pollution by releasing carbon stored in plant leaves, stems, and branches into the atmosphere (Sciencing 2017).

iii. Fossil fuel use: Primary source of CO_2 emitted directly from human-induced impacts. The total CO_2 contribution from fossil fuel use and other industrial processes alone contributes to 65% of global GHG emissions (EPA 2018).

iv. Methane (CH_4) from livestock production: Methane makes up the majority of emissions from farmed livestock, such as sheep and cattle; animals naturally produce methane as a by-product of their digestive processes and release it into the air (NIWA 2018). Between 1970 and 2010, emissions of CH_4 from enteric fermentation and rice cultivation increased by 20 % (IPCC 2014).

v. Use of manure: Inappropriate manure handling and application lead to CH4 and Nitrous Oxide (N2O) emission. This agricultural activity significantly contributes to climate change (EPA 2018).

vi and vii. Use of chemical fertilizer and other agrochemicals: Agricultural activities contribute to GHG emissions, partially due to the intensive use of chemical fertilizers and other agrochemicals (IAEA, 2020).

Table 11: Farmers' scores on quiz questions of causes of climate change (N=1,080)

Quiz mark	Score distribution of farmers (%)	Cumulative frequency
0	10.11	10.11
1	9.46	19.57
2	29.13	48.70
3	25.88	74.58
4	14.01	88.59
5	6.40	94.99
6	2.88	97.87
7	2.13	100.00

4.3 Results and Discussion

4.3.1 Socio-economic characteristics of the sample

Table 12 presents the Chi-square result of the discrete socio-economic characteristics of the farmers. Most (88.89%) farmers in dry and humid AEZs were male. There is a statistically significant difference between the two AEZs, as females constituted 32.22% of respondents in humid AEZs, while in dry AEZs, females represented only 11.11%. Generally, farmers with secondary school education constituted 31.1% of the respondents, while 29.6% had primary education. Furthermore, a significant difference between the two zones regarding education could be derived. Farmers with non-formal education in dry AEZs constituted 36.11% and only 7.59% in humid AEZs. This could partially be attributed to the fact that political unrest and insurgency in the dry zones in northern Nigeria led to the destruction of schools and displaced people from their hometowns (UNICEF 2021).

The majority (88.2%) of the farmers in this study possessed farmland. The differences between the AEZs are significant. Only 0.93% of farmers from dry AEZs had no farmland, as opposed to 22.59% from humid AEZs. Most farmers (82.4%) had access to extension services with no significant difference between the AEZs. 82.68% of the farmers were members of farmers' groups/cooperatives, with a significant difference between the two AEZs. 85.19% of farmers from the dry AEZ were members of farmers’ groups, as opposed to 80.19% of farmers of humid AEZs. In addition, a significant difference in livestock ownership between the dry and humid AEZs was identified. 73.70% of farmers of dry AEZs reared animals, while only 39.07% had livestock in humid AEZs.

Table 12: Socioeconomic characteristics of farmers (N=1,080) [categorical variables]

Variables	***Category***	***Dry part (%) N=540***	***Humid part (%) N=540***	***Sig[1]***	***Total sample (%)***
Sex	Female	11.11	32.22	**0.000**	21.7
	Male	88.89	67.78		78.3
Level education	Non-formal	36.11	7.59	**0.000**	21.9
	Primary	27.96	31.30		29.6
	Secondary	21.67	40.56		31.1
	NCE/Diploma	9.82	10.00		9.9
	Graduate	3.89	9.81		6.9
	Postgraduate	0.56	0.74		0.6
Land ownership	No	0.93	22.59	**0.000**	11.8
	Yes	99.07	77.41		88.2
Extension contacts	No	16.11	19.07	0.201	17.6
	Yes	83.89	80.93		82.4
Farmers' group membership	No	14.81	19.81	**0.030**	17.32
	Yes	85.19	80.19		82.68
Livestock ownership	No	26.30	60.93	**0.000**	43.69
	Yes	73.70	39.07		56.31

[1] **Significant level of X^2 result**

Table 13 presents the t-test result of the continuous socio-economic characteristics of the farmers. There is a significant difference in farmers' age between the two AEZs. The mean age of farmers in the dry AEZs is 42.66, while the mean age in the humid AEZs is 53.63. Farmers in the dry AEZs have a larger family size than in the humid AEZs. Eleven members is the average household size of farmers in the dry AEZs, while the average family size is six members in the humid AEZs. This may be attributed to the polygamous family setting of dry AEZs (northern part) of the country compared to the dominant monogamous family setting of the humid AEZs (southern part) of the country (Kramer 2020).

Table 13: Socio-economic characteristics (N=1,080) (continuous variables)

Variable	***Dry part*[1]**	***Humid part*[1]**	***Sig***	***Total*[1]**
Age	42.66 (11.85)	53.63 (12.38)	**0.000**	48.15 (0.40)
Household size	11.44 (6.97)	6.38 (2.64)	**0.000**	8.89 (0.17)
Farm size	3.93 (3.97)	2.87 (2.60)	**0.000**	3.44 (3.45)
Farming experience	23.98 (12.11)	22.61 (12.18)	**0.000**	22.61 (12.18)
Agric income ($)[2]	1,493.28(127.83)	1,350.90 (708.66)	**0.000**	7,563.60 (5,249.34)
Non-agric income ($)[2]	76.63 (61.80)	97.32 (5.24)	**0.000**	86.99 (96.78)

[1] Mean and standard deviation (in parenthesis) are reported. [2]original value was in Naira ($1=381 Naira)

The average farming experience in the dry AEZs was 24 years and was thus significantly higher than that of the humid AEZs at 22.61. This is because agricultural activities in the dry AEZs are more predominant as an occupation than in the humid AEZs. Farmers in the dry AEZs earn more than the farmers of the humid AEZs from agriculture. The agricultural income varies significantly, with an average of $1,493 in dry AEZs in contrast to an average of $1,350 in humid AEZs. However, regarding non-agricultural income, farmers in humid AEZs earn more than those in dry AEZs. The average non-agricultural earnings of farmers in the humid AEZs is $97.32, and $76.63 for the dry AEZs. This result is not surprising, as agricultural activities are the main occupation in the dry AEZs, while business activities are more predominant in the humid AEZs of Nigeria. In addition, the level of investment is higher in the country's humid AEZs (southern part) (World Bank 2016).

4.3.2 Climate change perception in dry and humid zones

Table 14 presents the farmers' climate change perceptions based on indicators of climate change and risk occurrences (from strongly disagree to agree strongly on a 1-5 scale). Perceived increases in temperature have a mean of 4.03, indicating that most farmers perceived some temperature increases in the last ten years. These findings agree with NiMet (2020) and BNRCC (2011). Farmers also perceived a decrease in rainfall and a delay in the onset of rains. The perception values of the dry AEZs farmers were 3.82, while the mean perception of the humid AEZs farmers was 3.72.

Table 14: Climate change perception of indicators and risk occurrences in last 10 years

Indicator[1]	***Dry AEZs***[2]	***Humid AEZs***[2]	***Sig***	***Mean and standard deviation***[1]
Climate change indicators perception				
Increase in temperature	4.02 (0.98)	4.04 (0.77)	0.647	4.03 (0.88)
Decrease in rainfall (amount)	3.9 (1.07)	3.85 (1.00)	0.241	3.77 (1.10)
Delay in coming of rainfall	3.81 (1.22)	3.72 (1.07)	**0.083**	3.88 (1.04)
Climate risk occurrence perception				
Increase in frequency of drought	3.83 (1.07)	3.88 (0.87)	0.780	3.85 (0.98)
Increase in frequency of flooding	3.84 (0.99)	3.87 (1.04)	0.715	3.86 (1.01)
Increase in evaporation/rapid dry of soil	3.82 (1.02)	3.89 (0.84)	0.857	3.86 (0.93)
Increase in crop pest and disease outbreak	4.18 (0.91)	3.95 (0.84)	**0.000**	4.07 (0.88)

[1] From strongly disagree to strongly agree (1-5) scale. [2]Mean (Std Dev.)

Furthermore, farmers perceived increased drought, evaporation, and frequent floods in the last ten years. These perceptions conform with BNRCC (2011). In addition to climatic conditions, farmers perceived increased crop pest and disease outbreaks in the previous ten years. A significant difference between the zones is observed, as 4.18 was the mean perception of farmers of increases in crop pest and disease outbreaks in the dry AEZs. At the same time, 3.95 was the mean perception of farmers of increases in crop pest and disease outbreaks in the humid AEZs.

Further results revealed no significant differences between the two AEZs on the perceptions of climate change indicators except for the delay in coming rainfall. Within the climate risk occurrence perception, a significant difference was only observed in the increase in crop pest and disease outbreaks. These findings clearly show that the farmers in this study strongly perceive adverse climate change effects despite the varying climatic conditions in the selected AEZs of Nigeria.

4.3.3 Knowledge of farming practices regarding climate change

Table 15 reports a chi-square test of farmers' knowledge of causes of climate change comparing dry and humid AEZs. Farmers in dry AEZs are more aware of deforestation being a cause of climate change than farmers of humid AEZs. In the dry AEZs 78.70% of farmers knew deforestation could cause climate change, while 52.89% of farmers in humid AEZs were aware of this. Although many farmers were aware, it did not stop them from deforestation because they considered it a drought-coping strategy (Hassan et al., 2019; Asfaw et al., 2019). 72.96% of the farmers in dry AEZs were aware of land clearance by bush burning causing climate change, as opposed to 47.41% of the farmers in the humid AEZs. This corroborates with Hassan et al. (2019), who reported that farmers did not know the negative impacts of bush burning. Also, they believe this traditionally used method is the most cost-effective way of land clearance (Hassan et al. 2019).

Table 15: Farmers' knowledge of farming practices causes climate change (N=1,080)

Causes	***Item***	***Dry AEZs (%) N=540***	***Humid AEZs (%) N=540***	***Sig***	***Total % (of knew)***
Deforestation	No	21.30	47.11	**0.000**	69.67
	Yes	78.70	52.89		
Land clearance by bush burning	No	27.04	52.59	**0.000**	60.1
	Yes	72.96	47.41		
Fossil fuel emissions	No	56.48	65.37	**0.000**	39.0
	Yes	43.52	24.62		
Methane from livestock	No	79.26	89.44	**0.000**	15.57
	Yes	20.74	10.56		
Inappropriate manure management	No	78.15	87.04	**0.000**	17.41
	Yes	21.85	12.96		
Excessive use of chemical fertilizer	No	63.52	88.52	**0.000**	24.0
	Yes	36.48	11.48		
Use of chemical plant protection and pesticides	No	58.34	61.67	0.264	40.0
	Yes	41.66	38.33		

Simultaneously, 39% of respondents knew that agricultural machinery's fossil fuel emissions could cause climate change. However, there is a significant difference between the farmers of the two AEZs. In dry AEZs, 43.52% of farmers knew fossil fuel emissions could cause climate change. In humid AEZs, only 24.62% were aware of this. Farmers thus appear to have relatively little knowledge of this issue. Previous research in Malaysia showed that 85% of the public identified fossil fuel emission as a major cause of climate change, and its converse with the knowledge in “developed” countries, where most farmers know about the effect of fossil fuel emissions on global warming (McCright et al. 2013).

The results further indicate that farmers know little about the methane emissions from livestock production that contribute to climate change. On average, only 15% of the farmers knew about this, with 20.74% in dry AEZs and 10.56% in humid AEZs, knowing that livestock production's methane emissions contribute to climate change. This differs from developed countries, such as New Zealand, where many farmers were not only aware of this but also looking for feed management from different types of plants with low impacts on the amount of methane produced by animals (NIWA 2018).

Only 17% of farmers knew that inappropriate manure management could cause climate change because of methane and nitrous oxide emissions. The differences between farmers in dry AEZs were significant, with 21.85% being aware and only 12.96% being aware in humid AEZs. 24% of farmers knew about the intensive and indiscriminate use of chemical fertilizers contributing to climate change. Again, a significant difference between the dry and humid AEZs could be observed. 36.48% of the dry AEZs farmers knew that excessive use of chemical fertilizer could cause climate change, while only 11.48% of humid AEZs were aware of this issue. These results align with previous research, where many respondents were unaware that N_2O is included in the list of harmful GHGs. 40% of the farmers knew that chemical plant protection and pesticides contributed to climate change, with no significant difference between the two AEZs. In a related study, Bhandari (2014) reported that farmers generally tend to be unaware of the negative effect of agrochemicals on the environment. The result depicted the farmers' deficient knowledge that livestock methane and inappropriate manure management contributed to climate change, irrespective of their AEZs. Although the respondents in the dry AEZs had a lower level of education than their counterparts in the humid AEZs, this study uncovered that the farmers in the dry AEZs had significantly more knowledge of climate change causes in almost all dimensions. This would also align with previous findings indicating that social status and education might not necessarily lead to more knowledge on a specific subject (Hwang and Jeong 2009).

4.3.4 Climate change knowledge vs. climate change perception

There is a relationship between farmers’ knowledge of the causes of climate change and their perceptions of several climate indicators (Table 16). Farmers who perceived an increase in temperature (yes) also achieved a higher knowledge score (average score of 2.85 on a scale from 0-7). This is significantly higher than the 1.84 mean knowledge score of farmers who did not perceive an increase in temperature. Similarly, farmers perceiving a decrease in rainfall had a higher knowledge mean score of 2.80 than farmers who did not perceive a decrease (score of 2.3). If farmers perceive a delay in the coming of the rains, they have a higher knowledge mean score (2.77) than farmers who do not perceive this delay (2.31). Similar observations were made with the perceived increase in the frequency of drought and flooding. If farmers perceived an increase, they had a higher knowledge mean score than farmers who did not perceive it. Overall, these findings show that perception and knowledge of the effects of climate change seem to be positively correlated. This indicates that knowledge about climate change can guide and shape farmers' perceptions of climate change, potentially supporting appropriate climate mitigation and adaptation decisions.

Table 16: Relationship between the perception of climate indicators and knowledge of causes (N=1,080)

Perception	**Yes**	**No**	**Sig.**
	Knowledge Mean and Std.	Knowledge Mean and Std.	
Increase in temperature	2.85[1] (1.45)	1.84 (1.73)	**0.000**
Decrease in rainfall (amount)	2.80 (1.46)	2.32 (1.73)	**0.000**
Delay in coming of rainfall	2.77 (1.46)	2.31 (1.79)	**0.000**
Increase in frequency of drought	2.89 (1.49)	2.31 (1.66)	**0.008**
Increase in frequency of flooding	2.77 (1.38)	2.39 (1.89)	**0.000**
Increase in evaporation	2.89 (1.49)	2.17 (1.60)	0.173
Increase in crop pest and disease outbreaks	2.85 (1.52)	2.17 (1.50)	0.629

[1] **knowledge score in a range from 0-7**

4.3.5 Factors influencing awareness of climate change and knowledge on causes

The factors that influence general climate change awareness and the knowledge of agricultural practices contributed to climate change are shown in Table 17. Members of farmers' groups are significantly more likely to be aware of climate change ($p<0.05$) and are more knowledgeable about the causes of climate change compared to farmers not members of such a group (Table 8). Similar observations have been made by Hasan and Kumar (2021), Huong et al. (2017), Mango et al. (2017), and Mudombi et al. (2014). A farmer's higher share of non-agricultural incomes significantly increased the probability of climate change awareness and knowledge of climate change causes ($p<0.01$). Ibrahim et al. (2015) also recorded a positive influence of non-agricultural income on the causes and effects of climate change in southwestern Nigeria. Farmers who received weather information from government extension agents were likelier to be aware of climate change. While this is in line with some studies (Ali et al. 2021; Ibrahim et al. 2015), it contrasts with the findings of other researchers (Bryan et al. 2013; Elum et al. 2017; Oduniyi and Tekana 2019) in which extension contact affected climate change awareness negatively. The varying effects of extension service provision and the influence of the quality of these facilities become apparent. Farmers receiving weather information from environmental NGOs are significantly more likely to be aware of climate change and have more knowledge of the causes of climate change. Similar results were reported in Mali and South Africa, where environmental NGOs were identified as farmers' most important sources of climate change information (Mahamadou et al. 2019; Mudombi et al. 2014). These findings indicate the need for closer collaboration between the public and private sectors concerning providing information on climate change issues.

Table 17: Double hurdle model of drivers of climate awareness and knowledge (N=1080)

Variable	*Logistic regression[1] (Awareness)*	*Linear regression[2] (Knowledge)*	*VIF[3]*	*1/VIF*
Socioeconomics				
Sex	0.0818 (0.128)	0.0957 (0.119)	1.15	0.867
Age	0.0050 (0.006)	0.0057 (0.005)	2.94	0.340
Years of education	0.0132 (0.009)	0.0137 (0.009)	1.46	0.686
Farming experience	0.0094 (0.006)	0.0069 (0.005)	2.55	0.392
Farmers group membership	0.3322 (0.136)**	0.2471 (0.125)**	1.16	0.865
Farm size	0.0113 (0.015)	0.0093 (0.0141)	1.23	0.813
Credit	-0.1516 (0.118)	-0.1373 (0.109)	1.38	0.726
Livestock ownership	0.0505 (0.111)	0.1055 (0.104)	1.33	0.750
Agricultural income	-0.0003 (0.00)	-0.0014 (0.007)	1.05	0.953
Non-agricultural income	0.0834 (0.028)***	0.0748 (0.026)***	1.16	0.864
Dependency ratio	0.0349 (0.028)	-0.009 (0.026)	1.10	0.908
Weather information sources				
Government extension agent	0.5744 (0.118)***	0.4713 (0.108)***	1.26	0.794
Environmental NGOs	0.2465 (0.124)**	0.2332 (0.115)**	1.20	0.834
Farmers' cooperatives	0.1913 (0.109)*	0.2464 (0.100)**	1.25	0.799
University and research institution	-0.0295 (0.171)	-0.0467 (0.157)	1.21	0.824
Farmers friends	0.6389 (0.108)***	0.6136 (0.100)***	1.22	0.820
Weather information channels				
Radio	0.0255 (0.005)***	0.0273 (0.005)***	1.36	0.736

Television	0.0091 (0.010)***	0.0054 (0.009)	1.22	0.823
Newspaper	-0.0030 (0.020)	-0.0098 (0.018)	1.15	0.867
Internet	0.01165 (0.011)**	0.0119 (0.010)	1.22	0.817
Climate risk experience in the last 10 years				
Extreme temperature	0.1679 (0.130)**	0.0517 (0.025)**	1.58	0.633
Flooding	0.0420 (0.123)	0.0499 (0.023)**	1.25	0.801
Drought	0.6640 (0.117)***	0.0802 (0.024)***	1.37	0.727
Windstorm	0.4384 (0.107)***	0.0656 (0.024)***	1.24	0.804
Dry agro-ecological zones	0.7535 (0.158)***	0.6309 (0.147)***	2.69	0.371
F-value	***0.000***	***0.000***		
Pseudo R^2/R^2	***0.1915***	***0.5231***		

[1]Marginal effect and standard error are reported. [2]Regression coefficient and std error is reported, *p<0.10, **p<0.05 and ***p<0.01, VIF= variance inflation factors.

Farmers receiving weather information from farmers' cooperatives were significantly more likely to be aware of climate change and more knowledgeable of the causes of climate change. Other studies, such as those from Muench et al. (2021), De Sousa et al. (2018), and Menike and Arachchi (2016), uncovered the positive effects agricultural cooperatives have on information access and awareness of climate change among farmers. Cooperatives serve as a common communication platform to stimulate information exchange among farmers. Therefore, weather information from fellow farmers significantly increased the likelihood of a respondent being aware of climate change. In addition, an increase in knowledge of the causes of climate change due to access to information from other farmers was observed. Farmer-to-farmer interaction was also identified as an essential source of climate change information in Mali (Mahamadou et al. 2019) and Nepal (Muench et al. 2021). This finding indicates a generally close peer interaction in smallholder farming systems, regardless of location. As local farmer cooperatives encourage peer exchange, farmers in the study area should be motivated to join cooperatives. The importance of cooperatives, informal farmer groups, and peer exchange as information sources among Nigerian farmers is evident. This revelation is particularly crucial because the dissemination of information on technological innovations in agriculture is comparably low (Fichter and Clausen 2021).

An increase in receiving weather information via radio significantly increased the likelihood of a farmer's awareness of climate change and knowledge of the causes of climate change. Similar findings were reported in the United States and South Africa (Dorothee et al. 2011; Mudombi et al. 2014). Using television to access weather information significantly affected the likelihood of farmers being aware of climate change. This corroborated the findings of Junsheng et al. (2019), who reported the substantial contribution of television to climate change awareness. However, mass media, such as television and radio, have a more negligible effect on climate change awareness than the institutional factors reported in this study. Nevertheless, they can still serve as relevant information sources, particularly in light of the need to access weather information in rural areas and communicate with farmers during emergencies (e.g., pest and disease outbreaks, expected flooding, windstorms, or wildfires).

Receiving and searching for weather information primarily from the internet positively influenced the likelihood of farmers being aware of climate change. This effect of internet usage on climate change awareness agrees with the findings of Dorothee et al. (2011). Experiencing extreme temperatures more often increased both the perception and knowledge of the causes of climate change among the sample of this study. An increase in experiencing floods and droughts also enhanced their knowledge of the causes of climate change. Experiencing windstorms made farmers significantly more likely to be aware of climate change and simultaneously increased the farmers' knowledge of the causes of climate change.

Another revelation of this study was that farmers in the dry AEZs were more likely to be aware of climate change and have more knowledge of climate change than farmers in the humid AEZs. This result can be attributed to farmers living in vulnerable climate-risk areas experiencing the effects of climate change more than those not living in climate-risk regions, as depicted by the second argument of the knowledge gap theory (Hwang and Jeong 2009). The location has been found to affect climate change knowledge, such as perceived changes in drought, flooding, temperature, and rainfall patterns, as proxies (Huong et al. 2017). Similar findings from Kenya and Bangladesh, respectively, reported that farmers in arid and semi-arid areas perceived a decrease in rainfall and an increase in its variability, as well as an increase in temperature, more than their humid AEZs counterparts (Bryan et al. 2013;

Ajuang et al. 2016; Abdullah et al. 2019). As in case studies 1 (Nepal) and 2 (Czech Republic), this result emphasizes the importance of considering regional differences in climate change awareness campaigns, policy formulation, and agricultural mitigation efforts.

4.4 Policy implications

This study aimed to assess farmers' knowledge of farming practices related to climate change and how it is associated with the perception of climate change. In addition, the factors influencing awareness and understanding of climate change were analyzed. Furthermore, this research uncovered varying degrees of knowledge on the causes of climate change. Most respondents know deforestation and bush-burning land clearance contributes to climate change. Nevertheless, many farmers did not know that methane emissions from livestock (enteric fermentation) can cause climate change despite it being a major GHG contributor. This also holds for the inappropriate use of manure, fossil fuel emissions from agricultural machinery, and the excessive and indiscriminate use of agrochemicals.

Farmers' climate knowledge was positively associated with their climate perception. This finding proves that wrong or missing information can lead to distorted perceptions. Critical knowledge gaps consequently lower farmers' mitigation preparedness towards climate change. Given the mixed results in the level of knowledge about the agricultural causes of climate change among the respondents, focusing on educating farmers more about the effects of farm practices on the environment is recommended. A well-planned knowledge transfer process would positively influence understanding of the subject matter.

Contrary to the first aspect of the knowledge-gap theory, socio-economic factors did not affect farmers' climate change awareness and knowledge of farm practices that mitigate climate change. This may happen because the smallholder farmers seem to be socio-economically homogenous. However, farmers' weather information sources, channels, and climate risk experience significantly influence the farmers' awareness and knowledge of farm practices to mitigate climate change. Furthermore, cooperative members, government extension agents, environmental NGOs, and farmer-to-farmer climate change information sources shaped the farmers' awareness and knowledge of farming practices that mitigate climate change. This indicates the importance of using subject information sources in teaching farmers how farming practices, such as methane from livestock and improper manure management, can affect the climate. Radio usage as an information source affected farmers' awareness of climate change, highlighting the importance of radio in raising climate change awareness within the study area.

Experiencing extreme temperatures, drought, flooding, and windstorms were identified as positive drivers of climate change awareness and knowledge. Farmers of humid AEZs were less knowledgeable about the farm practices that mitigate climate change than their peers in dry AEZs. Living in areas prone to a higher climate risk thus also increases the level of climate change knowledge. This holds particularly true when there is no significant difference in income or education and access to information sources and channels among the respondents. Therefore, framing the perception and knowledge of climate change according to specific locations is essential. The findings indicate that farmers of climate risk-prone areas are already ahead of their counterparts in terms of climate change perception and understanding of farming practices that mitigate climate change.

Climate change awareness and education schemes should be available through farmers' cooperatives, radio, television, and the Internet. The better the farmers understand the complexity of climate change issues, the more they will be ready to adapt accordingly. Increased organizational involvement with farm-related associations and encouraging farmers to participate in farmer-to-farmer extension and "best practices networks" could strengthen their knowledge of climate change and shape their perceptions.

5. Discussion

5.1 General elaboration on the case study results

The effects of climate change threaten agricultural production worldwide. Simultaneously, the climate varies significantly in different geographical regions. Farmers are forced to adapt to the specific impacts of climate change under local conditions. Consequently, the variability requires governmental and non-governmental organizations to consider the specific location in developing farmers' support frameworks. Therefore, this dissertation investigated and assessed farmers' awareness, knowledge, and adaptation toward climate change in three study areas with different climatic conditions. Each case study's findings provide insights into the current degree of knowledge of and adaptation to climate change in a broad spectrum of geo-climatic settings (temperate/sub-tropical/tropical). Conclusions have been drawn for each case study individually in the respective chapters. In addition, the results of the case studies have been used to answer each of the research questions specified in chapter 1.4. The following section intends to synthesize and interpret the findings within the overarching context of this study by highlighting the interconnectivity of the case study results in light of the overall research questions.

RQ1. Which common strategies do farmers adopt to adapt to climate change?

All case studies reported a high awareness of climate change among the respondents. Most respondents agreed that human activities significantly contribute to climate change. In addition, farmers in each study area experienced various effects of climate change in the previous years. These effects range from droughts and floods to more extreme temperatures. This revelation is in line with previous research conducted on this matter.

By asking respondents in Nepal (case study 1) and the Czech Republic (case study 2) about the measures they use to adapt to climate change, it became evident that farmers in both study areas utilized the coping mechanisms derived from the CSA framework at least partially. Crop diversification, crop rotation, soil conservation, and climate-resilient crop varieties were applied by a significant share of farmers in each case study. The application rates of crop diversification and soil conversation techniques were exceptionally high among tea farmers in Nepal. Soil conservation through minimal cultivation, cover crops, and permanent soil coverage were also found to be commonly adopted adaptation strategies among farmers in the Czech Republic. On the contrary, the application rates of additional irrigation techniques were low in both samples. This was a surprise because respondents from both case studies reported severe concerns about the negative impact of drought and unpredictable rainfall patterns on their farming activities. RQ1 aimed to see if farmers in different geographic and climatic settings generally use a similar approach to climate change adaptation. Although case studies 1 and 2 are far from being globally representative, the results still indicate that adaptation mechanisms derived from the CSA framework are generally applicable even in highly different agricultural environments. This claim holds at least in the cases of smallholder tea farmers in Nepal and commercial crop farmers in the Czech Republic. Therefore, researchers could use the CSA framework as a “blueprint” for conducting similar studies in regions with different climates and farming systems.

RQ2. How do information availability and the institutional environment influence climate change awareness, knowledge, and adaptation in agriculture?

Compared to other industries, agriculture is subjected to a meager dissemination of information on technological innovations (Fichter and Claussen 2021). This leads to slow transmission of information and knowledge among the many stakeholders involved in agriculture. Therefore, access to appropriate information sources is crucial for building knowledge on climate change. Easily accessible and comprehendible information on climate change causes, and impacts can positively influence adaptive capacities. The findings of the case studies confirmed this assumption. Results of the Nepal and Czech Republic case studies reveal a lack of information access as a primary barrier to appropriate adaptation. Information provision through frequent training and peers increased the likeliness of using specified adaptation strategies in Nepal. This revelation is supported by the findings in the Czech Republic, where field training and information provided by research institutions positively influenced adaptive capabilities among farmers. The need to stimulate information exchange among stakeholders in the agricultural sector has become apparent. Easily accessible and comprehendible information supports adopting innovations. These outcomes are in line with how information access supports the stages of adoption according to the DOI (Rogers 2003). This consideration evokes the assumption, as shown in Figure 15.

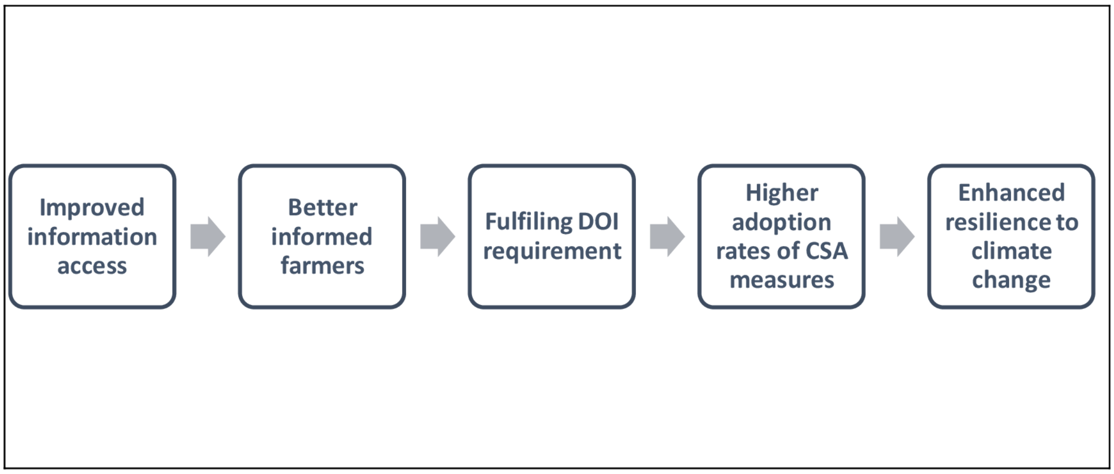

Figure 15: Information access as a requirement to enhanced climate change resilience

Farmers who receive easily comprehendible information through appropriate channels could raise their knowledge of adaptation to climate change. Improved knowledge access would allow farmers to evaluate the measures appropriately according to the DOI requirements. This includes, for example, if the measure offers a relative advantage compared to the status quo or if its effectiveness has already been proven. If the benefits convince farmers of a specific adaptation measure, they will likely use it. Naturally, higher adaptation rates leave farmers less exposed to the negative impacts of climate change.

While case studies 1 and 2 (Nepal and Czech Republic) looked at factors affecting climate change adaptation, case study 3 (Nigeria) focused on the relationship between the awareness and knowledge of climate change causes in consideration of the information sources used by the farmers. A noteworthy observation from case study 3 was the farmers' relatively low knowledge of the causes of climate change. For instance, less than half of the respondents knew that agricultural fossil fuel emissions contribute to climate change. Simultaneously, farmers who were aware of the adverse effects of deforestation even perceived this activity as an adaptation strategy to drought. Again, these concerning revelations stress the need for appropriate information provision. Results of case study 3 highlight that membership in a farmer cooperative, provision of well-functioning extension services, and peer-to-peer information exchange among farmers positively influenced the respondents' knowledge of the causes of climate change. Although the objectives of case studies 1 and 2 deviated from case study 3, the outcomes of all included case studies in this dissertation highlight the importance of stressing policy allocations further toward information provision. While case studies 1 and 2 directly show the effect of climate change adaptation, case study 3 provides valuable insights into factors shaping the knowledge of the causes of climate change. Naturally, if farmers are not knowledgeable about this subject matter, their adaptive capabilities remain low.

Each case study's findings further show that the farm location, even within a geographically confined area, can largely influence climate change awareness, knowledge, and adaptation behavior. For example, farmers in the dry AEZs of Nigeria were significantly more knowledgeable on climate change causes than their counterparts in the humid AEZs. Despite the global implications of climate change, it is consequently of utmost importance to simultaneously look at this topic from an international, supranational, national, and regional perspective.

Moreover, case study 2 uncovered economic motives as an essential driver for climate change adaptation. Maintaining profitability positively affected the application rates of all proposed adaptation strategies among farmers in the Czech Republic. If the exposed farmers are educated on the economic benefits of incorporating climate change adaptation measures, they are more likely to apply these concepts. Thus, profitability often remains a crucial motivator in adopting climate change adaptation strategies.

RQ3. Do socio-demographic and farm-level characteristics affect climate change adaptation and knowledge among farmers in different climatic regions?

Previous scientific literature argues whether socio-demographic characteristics such as age, gender, and educational level influence the adaptative capabilities of farmers towards climate change. Socio-demographic characteristics and farm-level variables showed mixed effects on climate change knowledge and adaptation in all three case studies. The case among farmers in Nepal did not reveal any socio-demographic factors as statistically significant. Age positively and negatively impacted the adaptation behavior among Czech farmers, depending on the specific adaptation measure. Only the case study in Nigeria revealed the respondents' age, education, and farming experience as positive drivers toward enhanced climate change knowledge. These non-homogenous results suggest that it is challenging to generalize implications derived from socio-demographic or farm-level factors when conducting behavioral studies on climate change in agriculture. Contradicting findings in previously reviewed literature further undermine this assumption. Although these variables did influence the degree of climate change adaptation and knowledge in other research settings, the results of the case studies in this dissertation showed that the socio-demographic profile of a farmer was not particularly relevant. Based on the findings, accessibility of information and the institutional environment had a more significant effect on climate change knowledge and adaptive capabilities.

How do agricultural systems in different parts of the world adapt to climate change, and which key factors influence the degree of adaptation readiness among farmers?

RQ1, RQ2, and RQ3 were conceptualized considering the specific objectives of the individual case studies. Therefore, the overarching research question can be considered the sum of these elements. Despite the climatic, institutional, and socio-demographic differences, farmers in case studies 1 and 2 used similar strategies to adapt to climate change. Empirical results further indicate that several institutional factors positively impact climate change knowledge and adaptation among study farmers. For instance, access to credits and extension services positively influenced the adaptation behavior among tea farmers in Nepal. Access to extension services was further identified as a positive driver toward enhancing climate change knowledge among farmers in Nigeria. Being a member of an agricultural cooperative has elevated the adaptive capabilities of the farmers in Nepal and the understanding of climate change among Nigerian farmers. Numerous studies support the hypothesis that cooperative memberships improve farmers' welfare. This revelation holds especially true for the agricultural sector in transitional and developing countries.

Nevertheless, it is noteworthy that the popularity of agricultural cooperatives varies vastly in different parts of the world. While cooperatives are becoming an increasingly important link in agricultural value chains, they are sometimes still looked upon with a critical eye by farmers, particularly in post-soviet countries and developed economies (Luo et al. 2020; Wolz et al. 2020). Given the versatility of the study sites and respondent characteristics, it can be argued that socio-demographic and farm-level characteristics did not play a significant role in determining adaptation readiness among farmers within the frame of this dissertation. Although previous studies with similar objectives suggest a solid explanatory power of socio-demographic variables, the findings of this research could not confirm this assumption. Despite the versatile selection of the study areas and the sector-specific results, the overall findings of this dissertation aim to stipulate a broader perspective of how these factors shape climate change knowledge and adaptation to climate change effects in agriculture.

5.2 Limitations of the study

This dissertation intended to provide new perspectives on the awareness of and adaptation to climate change in different agricultural systems. Nevertheless, the results are subject to several limitations. One drawback in the representativeness of the findings is the different survey layouts for each case study. This approach made it possible to investigate the topic from a broader perspective but simultaneously made the results less comparable. Consequently, the case study's findings are only generalizable to a limited extent. Since the case studies were conducted in various cultural and linguistic settings, misunderstandings in the survey interpretation could have potentially distorted the results. Another potential drawback is the data type used for the analysis. Each case study collected cross-sectional data. This type of data allowed the interpretation of the results for the given timeframe. Given the long-term nature of climatic changes, panel data would facilitate a more elaborate analysis of how perception and knowledge of climate change shift over time.

The econometric analysis methods for each case study were chosen based on the suitability of the data type and inspired by previous research. However, potentially more suitable statistical approaches could have been used to analyze farmers' adoption of adaptation strategies. For example, the analysis could have been enhanced by using multivariate probit models, allowing the investigation of the adoption rate of multiple climate change adaptation strategies. Analytical approaches such as structural equation models could have supported a more in-depth analysis of the main drivers for adopting specific climate change adaptation strategies. A considerable limitation of case study 1 is the small sample size (N=91) and the specific target group (tea farmers). The small sample size is partially due to the study design's implied data collection without external support and limited time. The original target was to interview at least 265 farmers. According to a sample size calculator, 265 respondents would amount to a representative sample size based on the population size of smallholder tea farmers in the study area (N= approximately 7,000). Unfortunately, logistical challenges on-site did not allow data collection among more tea farmers in the study area. Due to the small number of respondents, the findings of this case study cannot be generalized to Nepal's tea farming sector. Furthermore, perennial crops like tea require a specific farming approach. Therefore, results from this case study should not be directly compared to farming systems with annual crops, including most staple food crops (e.g., rice, wheat, and corn). In addition, obtaining a comprehensive list of all the farmers in the study area was impossible. Data for case study 1 could not be collected on a randomized base. The lack of administrative information is a general issue in collecting data for research focused on farmers in developing countries. While a professional data-collection company compiled the data for case study 2, the selected sample was not restricted by specific agricultural fields. Although this is not a limitation per se, it limits the opportunity to analyze the data according to specified agrarian fields.

6. Conclusions

6.1 Policy implications of the study

Policy implications have been presented in the subsequent sections for each case study (Chapters 2.6, 3.6, and 4.4). This sub-chapter aims to provide general policy implications derived from the overall conclusions of this study.

Although marketers extensively use the theory of DOI (Rogers 2003) to promote the adoption of specific goods, it can support the structure and primary focus of information campaigns addressed to farmers. If information regarding climate change adaptation incorporates the requirements for fast adoption rates, as shown in Figure 3, farmers are more likely to use these measures accordingly. For example, farmers must be informed about the advantages of adopting a climate change adaptation strategy by providing compatible, observable, and trialable information on the effectiveness of the proposed measure.

The overall results showed that peer-to-peer interaction in cooperatives plays a vital role in knowledge transfer among farmers. Therefore, farmers could benefit from specific training on climate change adaptation measures. Cooperatives and farmer associations could serve as suitable institutional bodies for knowledge transfer. This approach would also counteract the low dissemination of information on technological innovations in agriculture, as stated by Fichter and Clausen (2021). While farmers in various parts of the world already benefit from such training, many have limited access to up-to-date knowledge on climate change adaptation.

Regional specifications are crucial in developing effective national policy frameworks. For example, farmers in the dry AEZs of Nigeria were more knowledgeable about the causes of climate change than farmers in the humid AEZs. Due to different climatic conditions and varying gaps in knowledge, a standardized policy intervention on a national level would hardly allow an approach tailored to the specific needs of farmers in different regions.

Another critical success factor in the face of climate change adaptation in agriculture is a closer interaction among all involved stakeholders. Particularly in LDCs, farmers are often unaware of current policy action plans. For instance, case study 1 showed that most tea farmers in Nepal were unaware of the government's ambitious plans to strengthen the domestic tea sector. Clear communication between farmers and policymakers is thus a precondition for realizing the goals set in agricultural climate change action plans. Again, this undertaking also requires the selection of appropriate information channels.

6.2 Suggestions for future studies

This dissertation used current scientific debates on climate change as the research basis. The three included case studies aimed to fill knowledge gaps particularly connected to factors affecting climate change knowledge and adaptive capacities in the agricultural sector. Future studies with a multi-country approach could unify their research layout to undermine factors further positively influencing climate change adaptation. The standardized survey layouts and analysis methods for several research areas would make the results more comparable.

Due to climate change's wide range of impacts on various agricultural fields, research on specific farming systems could be particularly insightful. This is also due to climate change's varying effects, even according to a particular crop. Climate change adaptation studies possibly provide the most accurate results if the research areas are defined within small geographical boundaries. The reason is the significant climatic variations even within one country. Smaller research areas, for example, a municipality instead of a state, would allow drawing a more precise image of the current situation and create a more homogenous sample in terms of farm location.

In addition, future research in this field could be extended to more randomized experiments in which behavioral drivers should also be subject to analysis. It is essential to understand why farmers adapt to climate change and how they can be motivated to increase their adaptive capabilities. Incorporating more qualitative data could enhance further research on climate change adaptation in agriculture. To this point, there seems to be a lack of studies with a qualitative approach. Qualitative data approaches, for example, focus groups or expert interviews, would add valuable and complementary insights to a merely quantitative survey layout.

A time series approach instead of longitudinal data would allow researchers to identify differences between the responses over a more extended period. The accelerating pace of climatic shifts requires capturing momentary perceptions and analyzing how climate change knowledge and application rates of adaptation measures change over time.

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8. Author´s scientific contributions

This study consists of three research studies that were individually conducted. The structure of each case study was based on the specific journal requirements and submitted to suitable journals. The status of each manuscript is as follows:

1. Muench S, Bavorova M, Pradhan P. 2021. Climate Change Adaptation by Smallholder Tea Farmers: a Case Study of Nepal. Environmental Science & Policy (116): 136-146. https://doi.org/10.1016/j.envsci.2020.10.012

2. Muench S, Cechura L, Bavorova M. 2024. Climate Change Adaptation in European Agriculture – Insights from the Czech Republic. Submitted to: Mitigation and Adaptation Strategies for Global Change (Springer Nature); (Under Review)

3. Madaki MY, Muench S, Bavorova M, Kaechele H. 2023. Climate Change Knowledge and Perception among Farming Households in Nigeria. Climate 11 (115). https://doi.org/10.3390/cli11060115

In addition to the case studies conducted for this thesis, the author was involved in the following scientific work:

1. Pilařová T, Muench S, Bavorova M, Huml J. 2023. Exploring the motivations behind food self-provisioning in the Czech Republic. Agric. Econ. – Czech 69 (6): 234-245. doi: 10.17221/117/2023-AGRICECON.

2. Muench S, Bavorova M, Verner V. 2022. Effect of institutional factors and farm location on tea farm gate price: A case study of Ilam district in Nepal. (In preparation)

9. Conference contributions and projects

Conferences:

1. Muench S, Bavorova M. 2020. Factors Influencing the Selling Price of Unprocessed Tea among Smallholder Farmers in Ilam, Nepal. Tropentag 2020. 9-11 September 2020. Virtual Conference.

2. Muench S, Cechura L, Bavorova M. 2021. Climate Change Adaptation in Agriculture - Insights from the Czech Republic. CAAEES Annual Seminar 2021. 18 May 2021. Prague, Czech Republic

3. Muench S, Bavorova M. 2021. Factors Influencing the Adaptation towards Climate Change among Smallholder Tea Farmers in Ilam, Nepal. XVI EAAE Congress. “Raising the impact of Agricultural Economics: Multidisciplinary, Stakeholder Engagement and Novel Approaches”. 20–23 July 2021, Prague, Czech Republic.

4. Muench S, Bavorova M, Verner V. 2022. How do institutional characteristics and farm location affect tea farm gate prices in Ilam, Nepal. Tropentag 2022 - Can agroecological farming feed the world? Farmers' and academia's views. 14-16 September 2022. Prague, Czech Republic

Projects:

Technology needs assessment for the implementation of Azerbaijan´s NDC (National Determined Contributions) targets in the Agriculture, Land Use, Land Use Change and Forestry Sector (LULUCF).

Commissioned by the Food and Agricultural Organization of the UN (FAO) and financed by the Green Climate Fund (GCF). (Duration: March 2021 – December 2021)

Responsibilities: Literature review, development of questionnaire, data analysis, composition of reports, presentation of findings in various work group meetings

10. Appendix

Appendix A

Appendix A1: Questionnaire used for data collection – Case Study 1

1.Did you hear about the term "CC" before?	
Yes	No

2.If yes, how often do you hear about this topic?		
Rarely	Sometimes	Frequently

3. Considering the following changes in weather, what is the perceived impact on your economic performance as tea farmer?					
No impact at all – 0 1 2 3 4 – Very high impact					
High amount of rainfall in a short period	0	1	2	3	4
Higher variation and unpredictability of rainfall patterns	0	1	2	3	4
Increase in temperature average	0	1	2	3	4
Increased drought periods	0	1	2	3	4
More annual rainfall	0	1	2	3	4
Unevenly spread rains	0	1	2	3	4

4.Please indicate to which extend you agree:					
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
CC in Nepal is an ongoing problem					
Tea plantations can decrease biodiversity					

through loss of plants and animals					
Extreme weather destroys my livelihood					
Droughts will occur more frequently					
Usage of banned or severely restricted chemicals is high in Nepal					
Tea production causes soil erosion					
Chemicals, such as pesticides and fertilizers pollute water					

5.Please indicate how important the following strategies would be for your tea plantation in terms of adopting to a changing climate in the future:	
Unimportant – 0 1 2 3 4 – Very important	
Crop diversification (e.g. different cultivars)	0 1 2 3 4
Reduced soil cultivation	0 1 2 3 4
Agroforestry (Shade and wind protection)	0 1 2 3 4
Switch to less climate sensitive cultivars	0 1 2 3 4
Making use of water from rain storage, pumps or dams	0 1 2 3 4
Water conservation and storage through rain water harvesting using ponds	0 1 2 3 4
Other:	0 1 2 3 4

6.Which of these adaptation strategies do you already make use of?		
Crop diversification (e.g. different cultivars)	Yes	No
Soil conservation	Yes	No
Shade management	Yes	No
Switch to less climate sensitive cultivars	Yes	No

Making use of water from rain storage, pumps or dams	Yes	No
Water conservation and storage through rain water harvesting using ponds	Yes	No
Other:	Yes	No

7.Do you consider switching to other, less climate sensitive crops in the future? (e.g. food crops such as rice)		
Yes	I do not know/ maybe	No
If yes, please indicate which crops:		

8.While thinking about the changing climate, are you concerned about your future as tea farmer?		
Not concerned	Somewhat concerned	Highly concerned

9.How high is the impact of the following factors on your tea yield? (terroir concept: all environmental factors having an influence on the crop):					
No impact at all – 0 1 2 3 4 – Very high impact					
Temperature	0	1	2	3	4
Amount of annual rainfall	0	1	2	3	4
Distribution of annual rainfall	0	1	2	3	4
Soil quality	0	1	2	3	4
Topography (physical features of the farmland)	0	1	2	3	4
Cultivar (Strain/Type of tea tree)	0	1	2	3	4

10.Which constraints do make it particularly difficult for you as tea farmer to appropriately adopt to CC?					
Not relevant-0 1 2 3 4- Very relevant					
Lack of financial capital	0	1	2	3	4
Not enough information	0	1	2	3	4
Insufficient governmental support	0	1	2	3	4

2.Financing and information access

11.Did you make use of a credit or loan to support your farm within the past 5 years?	
yes	no

12.How often do you make use of the following information channels regarding weather information?						
Never – 0 1 2 3 4 – Frequently						
Internet		0	1	2	3	4
Television (e.g. weather forecast)		0	1	2	3	4
Other tea farmers		0	1	2	3	4
Print media (e.g. newspaper)		0	1	2	3	4
Mobile phone		0	1	2	3	4
Other (please indicate):		0	1	2	3	4

13.How often do you make use of the following information channels regarding tea cultivation?						
Never – 0 1 2 3 4 – Frequently						
Internet		0	1	2	3	4
Television		0	1	2	3	4
Other tea farmers		0	1	2	3	4
Print media (e.g. newspaper)		0	1	2	3	4
Participation in trainings		0	1	2	3	4
Mobile phone		0	1	2	3	4
Other (please indicate):		0	1	2	3	4

14.Have you participated in trainings and workshops regarding tea farming?				
Very often (several times per year)	Frequently (around once per year)	Occasionally (around once every 2-3 years)	Seldomly (less than once in 5 years)	Never

15.Are you aware of the "National Tea Export Strategy 2017-2021" commissioned by the Nepalese government and the international trade centre?		
Never heard	Heard about it but do not know details	Aware about the content

16.Do you believe, that you are well informed about current trends in the tea cultivation practises in Nepal?		
Not well informed	Somewhat informed	Very well informed

17.How many tea farmer cooperative(s) are you currently a member of?
Number:
Please mention which cooperative(s):

18.Please evaluate the importance of the following types of information for you as tea farmer:	
Least important- 0 1 2 3 4 -Most important	
Loans/credits	0 1 2 3 4
Market information (e.g. tea prices)	0 1 2 3 4
Fertilizers and pesticides usage	0 1 2 3 4
Farming techniques	0 1 2 3 4
Storage of the harvested tea	0 1 2 3 4
Processing techniques	0 1 2 3 4
Other:	0 1 2 3 4

19.Please estimate the quantity (in kg) of all your harvested tea in the past 3 years for each year individually:	
Year:	**Tea harvest (kg):**
2015	
2016	
2017	

20.Please estimate the average price you sold your tea for (per kg) for the past 3 years:	
Year:	**Selling price in NPR (per kg):**
2015	
2016	
2017	

21.How would you evaluate the profitability of your tea farm in the past 3 years?
1=No profit at all; 2=Low Profit; 3=Average Profit; 4= High Profit; 5= Very High Profit

2015	
2016	
2017	

22.Considering your economic performance in the past 5 years, which of the following statements would you most agree with?
1. Positive economic development
2.No significant changes
3. Making money by producing tea is increasingly difficult

23.How often did you make use of fertilizers within the last 12 months?		
Never	Sometimes (less than 5 times)	Frequently (more than 5 times)
If yes, please indicate which fertilizers:		
24.How often did you make use pesticides within the last 12 months?		
Never	Sometimes (less than 5 times)	Frequently (more than 5 times)
If yes, please indicate which pesticides:		

25.Is your tea farm currently certified according to international organic standards?	
Yes	No
If yes, please indicate which certifications:	

26.Is your tea farm currently certified according to Nepalese organic standards?	
Yes	No
If yes, please indicate which certifications	

27.Please indicate where further processing of your harvested tea takes places?
At my own farm
Processed by a small private processing factory
Processed by a cooperative, larger processing unit

28.Please estimate how much of your average annual tea harvest (in %) is lost (not usable) because of issues such as mould and insufficient quality

29.Do you know for which type of tea processing your harvested leaves are used?		
CTC (Crush Tear Curl)	Orthodox Tea	I do not know

30.Please indicate your gender:	
Male	Female

31.Please indicate your current age:

32.How long have you been working as a tea farmer? (years)

33.Would you consider yourself to be…?	
Able to write and read (literate)	Unable to write and read (illiterate)

34.Please indicate the number of years of your education:

35.What is your marital status?			
Single	Married	Divorced	Widow

36.How many people do live in your household?		
Children (-15 years):	Adults (16-59 years):	Elderly (60+ years):

37.Please indicate how many people are working on your farm and which gender they have:		
Total number:	Number of male workers:	Number of female workers:
Family members:	Male:	Female:
Paid workers:	Male:	Female:

38.Please indicate the size of your farm (in ha):

39. What is the share (in %) of your farmland size used for tea production only?

40.What is the elevation (altitude) of your tea plantation plots? (in meter)

41.Do you currently grow only tea or other crops (e.g. rice) too? If yes, please indicate which crops	
Yes	No
Other crops:	

Table A2: Farm and institutional characteristics of the sample

Variable	Total (in %)	Min.	Max.	Mean
Farm features				
Size (Hectar)	-	0,2	10	1,2
Size (Ropani)	-	4	200	23,7
Share used for tea production (%)	-	30	95	75,4
Elevation (meter)	-	1100	1900	1554
Farm employment				
Total	-	2	34	7
Farming experience (years)	-	7	40	18,9
Usage of loan (credit)				
Yes	24 (26,4%)	-	-	-
No	67 (73,6%)	-	-	-
Cooperative member				
Yes	47 (51,6%)	-	-	-
No	44 (48,4%)	-	-	-
Training participation				
Never	5 (5.5%)	-	-	-
Seldomly (<once every 5 years)	9 (9.9%)	-	-	-
Occasionally (once every 2-3 years)	17 (18.7%)	-	-	-
Frequently (around once per year)	25 (27.5%)	-	-	-
Very often (several times a year)	35 (38.5%)	-	-	-
Aware about CC				
Yes	79 (86.8%)	-	-	-
No	12 (13.2%)	-	-	-

Appendix B

Appendix B1: Questionnaire used for data collection – Case Study 2

A. SOIL DEGRADATION AND CLIMATE CHANGE

A1. In your opinion, does climate change exist or not?

Definitely exists	1
More likely exists	2
More likely does not exist	3
Definitely does not exist	4
Do not know, cannot judge	5

A2. In your opinion, is climate change caused by human activity or not?

Definitely is	1
More likely is	2
More likely is not	3
Definitely is not	4
Do not know, cannot judge	5

A3. If your agricultural business (your farm) has experienced the following changes in the last roughly 5-10 years, please specify the degree of their seriousness.

		Degree of seriousness					
		Not serious at all				**Very serious**	**No experience of this problem**
A)	Increasing temperature during growing season	0	1	2	3	4	5
B)	Changes in precipitation distribution during growing season	0	1	2	3	4	5

C)	Increasing variability of temperature and precipitation	0	1	2	3	4	5
D)	More frequent extreme events (such as drought, extreme temperatures or precipitation/floods)	0	1	2	3	4	5
E)	Reduced water availability	0	1	2	3	4	5
F)	Shorter growing season	0	1	2	3	4	5
G)	Changes in sowing/planting dates	0	1	2	3	4	5
H)	Changes in harvest dates	0	1	2	3	4	5

A4. Based on your agricultural experience, to what extent do you agree/disagree with the following statements?

		Degree of (dis)agreement				
		I definitely agree	**I agree**	**I neither agree nor disagree**	**I disagree**	**I definitely disagree**
A)	Changing climate conditions are a serious problem affecting crop production in our business.	1	2	3	4	5
B)	Changes in precipitation affect crop production.	1	2	3	4	5
C)	Water erosion has been seen more often than before in recent years.	1	2	3	4	5
D)	Wind erosion has been seen more often than before in recent years.	1	2	3	4	5
E)	Drought is a greater problem than it was five years ago.	1	2	3	4	5
F)	Climate change impacts on crop production can be reduced with agrotechnical measures.	1	2	3	4	5

B. MEASURES FOR MITIGATION OF SOIL DEGRADATION AND CLIMATE CHANGE IMPACTS ON AGRICULTURAL PRODUCTION

B1. Which of these agrotechnical measures do you apply or plan to apply in near future, within say three years' time?

B1.1 Please specify on what percentage of your arable land you apply each measure.

		B1. Application			B1.1
	Measure	Applied	Not applied, but planned within say 3 years' time	Not applied, planned for later	**% of arable land on which the measure is applied**
A)	Minimal tillage	1	2	3	
B)	No tillage	1	2	3	
C)	Mulching	1	2	3	
D)	Cultivation of crop mixtures	1	2	3	
E)	Cultures between rows	1	2	3	
F)	Cultivation of cover crops	1	2	3	
G)	Cultivation of leguminous plants	1	2	3	
H)	Irrigation	1	2	3	
I)	Cultivation of new varieties	1	2	3	
J)	Cultivation of new crops	1	2	3	

K)	Woody plants on arable land (agroforestry)	1	2	3	
L)	Woody plants on pastures (agroforestry)	1	2	3	
M)	Provision of constant soil cover	1	2	3	
N)	Crop rotation	1	2	3	
O)	Precision agriculture	1	2	3	

B2. For measures that you apply or plan to apply in near future, please specify how important these measures are for achieving the following goals.

A) Climate change impact mitigation

		Not important at all		**Neither important nor unimportant**		**Very important**
A)	Minimal tillage	1	2	3	4	5
B)	No tillage	1	2	3	4	5
C)	Mulching	1	2	3	4	5
D)	Cultivation of crop mixtures	1	2	3	4	5
E)	Cultures between rows	1	2	3	4	5
F)	Cultivation of cover crops	1	2	3	4	5
G)	Cultivation of leguminous plants	1	2	3	4	5
H)	Irrigation	1	2	3	4	5
I)	Cultivation of new varieties	1	2	3	4	5
J)	Cultivation of new crops	1	2	3	4	5
K)	Woody plants on arable land (agroforestry)	1	2	3	4	5
L)	Woody plants on pastures (agroforestry)	1	2	3	4	5
M)	Provision of constant soil cover	1	2	3	4	5
N)	Crop rotation	1	2	3	4	5
O)	Precision agriculture	1	2	3	4	5

B3. What other measures (not listed above) do you apply or plan to apply for mitigating <u>negative impacts of climate change</u>?

Please specify:

1) ……
2) ……
3) ……
4) ……

B4. What other measures (not listed above) do you apply or plan to apply for <u>soil protection</u>?

Please specify:

1) ……
2) ……
3) ……
4) ……

C. BARRIERS TO APPLICATION OF AGROTECHNICAL MEASURES

C1. Why do you neither apply nor plan to apply the following measures? You can quote more reasons for each measure.

		Reasons					
		Will not pay/Economic	effect not sufficient (to mitigate climate	Agrotechnically too complex	Lack of information	Lack of funds for investment	Other reasons
A)	Minimal tillage	1	1	1	1	1	1
B)	No tillage	1	1	1	1	1	1
C)	Mulching	1	1	1	1	1	1
D)	Cultivation of crop mixtures	1	1	1	1	1	1

E)	Cultures between rows	1	1	1	1	1	1
F)	Cultivation of cover crops	1	1	1	1	1	1
G)	Cultivation of leguminous plants	1	1	1	1	1	1
H)	Irrigation	1	1	1	1	1	1
I)	Cultivation of new varieties	1	1	1	1	1	1
J)	Cultivation of new crops	1	1	1	1	1	1
K)	Woody plants on arable land (agroforestry)	1	1	1	1	1	1
L)	Woody plants on pastures (agroforestry)	1	1	1	1	1	1
M)	Provision of constant soil cover	1	1	1	1	1	1
N)	Crop rotation	1	1	1	1	1	1
O)	Precision agriculture	1	1	1	1	1	1

C2. What factors might positively influence your decision to adopt sustainable agrotechnical measures in future? You can quote more factors for each measure.

		Factors					
		Better information about economics	**Better information about technology**	**Financial support by the State**	**Better access to loans**	**Higher employee qualifications (e.g., tractor drivers)**	**Other factors**
A)	Minimal tillage	1	1	1	1	1	1
B)	No tillage	1	1	1	1	1	1
C)	Mulching	1	1	1	1	1	1
D)	Cultivation of crop mixtures	1	1	1	1	1	1

E)	Cultures between rows	1	1	1	1	1	1
F)	Cultivation of cover crops	1	1	1	1	1	1
G)	Cultivation of leguminous plants	1	1	1	1	1	1
H)	Irrigation	1	1	1	1	1	1
I)	Cultivation of new varieties	1	1	1	1	1	1
J)	Cultivation of new crops	1	1	1	1	1	1
K)	Woody plants on arable land (agroforestry)	1	1	1	1	1	1
L)	Woody plants on pastures (agroforestry)	1	1	1	1	1	1
M)	Provision of constant soil cover	1	1	1	1	1	1
N)	Crop rotation	1	1	1	1	1	1
O)	Precision agriculture	1	1	1	1	1	1

C3. Are there any other factors that might positively influence your decision to adopt sustainable agrotechnical measures in future? If yes, please write them down.

Please specify:

1) …… ………………………………………..
2) …… ………………………………………..
3) …… ………………………………………..

D. USE OF INFORMATION SOURCES

D1. How often do you use the following information sources and channels to obtain information related to agricultural production?

	Not at all			Very often

A)	Agricultural associations (non-governmental organisations)	1	2	3	4
B)	Ministry of Agriculture/SAIF (governmental organisations)	1	1	1	1
C)	Research institutes/universities	1	1	1	1
D)	Other farmers	1	1	1	1
E)	Information from commercial companies (equipment, seed, fertiliser vendors, etc.)	1	1	1	1
F)	Farmers' magazines	1	1	1	1
G)	Mass media (television, radio)	1	1	1	1
H)	Internet	1	1	1	1
I)	Field days	1	1	1	1
J)	Training, courses, etc.	1	1	1	1
K)	Other, please specify: :……………………………………………………………………… ………	1	1	1	1

D2. Which of the following information sources and channels do you consider most important for getting important information about measures for mitigating climate change impacts and soil protection? You can specify more options.

		Very important information sources
A)	Agricultural associations (non-governmental organisations)	1
B)	Ministry of Agriculture/SAIF (governmental organisations)	1
C)	Research institutes/universities	1
D)	Other farmers	1
E)	Information from commercial companies (equipment, seed, fertiliser vendors, etc.)	1
F)	Farmers' magazines	1
G)	Mass media (television, radio)	1
H)	Internet	1
I)	Field days	1
J)	Training, courses, etc.	1

K)	Other, please specify: :…………………………………………………………………………………	1

E. MANAGER (FARMER) CHARACTERISTICS

E1. Are you?

Male	1
Female	2

E2. How old are you?

Under 30	1
30-40	2
41-50	3
51-60	4
Over 60	5

E3. What is your highest achieved education?

Primary	1
Secondary, without leaving exams	2
Secondary, with leaving exams	3
University	4

F. BUSINESS (FARM) CHARACTERISTICS

F1. In which district(s) do you farm?

Please specify: …………………………………………………………………………………………………….

F2. What is your soil quality (i.e., average official price of your land)?

Average official price of your land (CZK)	

F3. What is the current legal form of your business?

Farming cooperative	1
Limited liability company	2
Joint stock company	3
Self-employed person	4

Other, please specify: ______________________________	5

F4. What type of production generated the greatest part of your business income in 2019?

Crop production	1
Animal husbandry	2
Both crop and animal about the same	3
Other, please specify: …………………………………………………………………………………………	4

F5. Now please complete the main economic characteristics of your business.

	2015 (approximately)	**2019**
F6.1 Total production (thousand CZK)		
within that:		
A) Crop production		
- cereals		
- oil crops		
B) Animal husbandry		
within that:		
- milk production		

F6.2 Size of land	**2015**	**2019**
A) Farmland area, ha		
B) Arable land, ha		
C) Leased land, % of total area (or ha)		

F6. What priority do the following objectives have in your business?

		Not important at all				Very important
A)	Profit making	0	1	2	3	4
B)	Rural employment	0	1	2	3	4
C)	Soil protection and fertility support	0	1	2	3	4
D)	Other objectives, please specify: …………………………………………………	0	1	2	3	4

Table B2: Average marginal effects (AME) of independent variables on selected climate change adaptation

Variable/Adapt. strategy	Minimal soil cultivation			Mixed crops			Climate-resilient varieties			New crops			Permanent soil cover			Crop rotation		
	AME	SE	P-Val	AME	SE	P-Val	AME	SE	P-Val	AME	SE	P-Val	AME	SE	P-Val	AME	SE	P-Val
CC awareness	**-0.057**	**0.033**	**0.086**	-0.047	0.037	0.204	**-0.068**	**0041**	**0.096**	-0.036	0.039	0.361	-0.036	0.039	0.366	-0.022	0.023	0.338
Gender	0.046	0.051	0.369	-0.017	0.054	0.751	0.049	0.,062	0.435	0.037	0.062	0.549	0.047	0.062	0.452	-0.020	0.043	0.638
Age	**0.027**	**0.014**	**0.063**	0.015	0.015	0.318	0.014	0.017	0.424	**-0.032**	**0.016**	**0.041**	0.013	0.017	0.416	-0.004	0.010	0.694
Education	-0.023	0.021	0.261	0.010	0.024	0.675	-0.005	0.025	0.839	0.008	0.024	0.730	0.017	0.026	0.514	-0.005	0.014	0.737
Land area	0.000	0.000	0.100	0.000	0.000	0.818	**0.000**	**0.000**	**0.032**	0.000	0.000	0.366	0.000	0.000	0.593	0.000	0.000	0.607
OSVC	0.046	0.054	0.394	-0.014	0.053	0.799	0.012	0.063	0.851	-0.039	0.054	0.468	-0.062	0.054	0.246	**0.062**	**0.031**	**0.042**
Rented Land (Ratio)	-0.009	0.017	0.605	-0.005	0.018	0.772	0.005	0.015	0.736	**-0.050**	**0.022**	**0.020**	0.016	0.015	0.291	-0.002	0.008	0.789
Farm target-profit	0.004	0.019	0.824	0.014	0.022	0.536	-0.017	0.025	0.483	0.008	0.026	0.762	-0.025	0.024	0.307	0.009	0.012	0.458
Farm target-rural employment	0.003	0.012	0.778	0.020	0.015	0.177	**0.035**	**0.015**	**0.022**	0.011	0.016	0.476	-0.001	0.016	0.968	0.011	0.009	0.233
Farm target-soil protection	-0.016	0.024	0.494	-0.018	0.028	0.522	-0.023	0.031	0.468	0.005	0.032	0.887	**0.058**	**0.032**	**0.071**	-0.017	0.016	0.285
Wheat production	-0.014	0.036	0.703	**-0.088**	**0.043**	**0.041**	**0.074**	**0.043**	**0.087**	-0.068	0.043	0.113	-0.024	0.045	0.590	**0.054**	**0.023**	**0.019**
Agricultural associations	-0.007	0.016	0.676	0.017	0.018	0.336	-0.018	0.019	0.341	-0.028	0.020	0.160	-0.002	0.019	0.908	0.004	0.011	0.727
Min. of agriculture	0.004	0.020	0.854	-0.017	0.022	0.437	0.026	0.024	0.291	0.005	0.026	0.846	0.005	0.026	0.837	0.007	0.013	0.567
Research institutions	-0.001	0.019	0.967	-0.033	0.021	0.120	**0.056**	**0.023**	**0.016**	**0.040**	**0.021**	**0.053**	-0.016	0.022	0.467	0.004	0.014	0.800
Other farmers	-0.026	0.021	0.225	0.023	0.023	0.313	-0.004	0.026	0.888	-0.014	0.025	0.575	0.014	0.026	0.572	**-0.027**	**0.015**	**0.082**
Commercial companies	-0.036	0.024	0.134	**-0.054**	**0.026**	**0.035**	-0.001	0.029	0.984	0.007	0.028	0.801	-0.019	0.026	0.476	0.012	0.016	0.444
Agricultural journals	0.019	0.019	0.321	**-0.044**	**0.023**	**0.051**	-0.001	0.023	0.957	-0.012	0.023	0.593	**0.042**	**0.023**	**0.062**	-0.020	0.013	0.132
Mass media	**-0.043**	**0.021**	**0.041**	-0.024	0.023	0.301	**-0.060**	**0.026**	**0.020**	-0.035	0.025	0.164	-0.029	0.024	0.216	-0.011	0.014	0.426
Internet	**0.037**	**0.021**	**0.085**	0.026	0.025	0.303	0.034	0.026	0.183	-0.004	0.027	0.879	-0.008	0.027	0.764	0.005	0.015	0.757
Field days	-0.013	0.021	0.544	0.015	0.024	0.531	**0.049**	**0.025**	**0.050**	0.017	0.026	0.515	-0.011	0.025	0.665	**0.029**	**0.016**	**0.073**
Trainings	0.030	0.020	0.138	0.009	0.023	0.700	-0.002	0.025	0.929	0.004	0.024	0.863	0.006	0.024	0.807	-0.002	0.014	0.888
Importance for climate change	**0.056**	**0.017**	**0.001**	**0.063**	**0.019**	**0.001**	**0.053**	**0.020**	**0.007**	**0.057**	**0.023**	**0.012**	**0.105**	**0.018**	**0.000**	**0.023**	**0.011**	**0.035**
Importance for profitability	**0.067**	**0.016**	**0.000**	**0.072**	**0.021**	**0.001**	**0.069**	**0.019**	**0.000**	**0.053**	**0.022**	**0.014**	0.027	0.020	0.170	**0.024**	**0.011**	**0.030**

Table B3: Results of variance inflation factor (VIF) calculation for the BLMs

Variable	Min.Soil Cult.	Mixed crops	Climate-res. varieties	New crops	Perm. soil cover	Crop rotation
Gender	1.057	1.060	1.058	1.057	1.060	1.070
Age	1.083	1.087	1.081	1.081	1.092	1.084
Education	1.162	1.180	1.162	1.160	1.193	1.163
Land area	1.315	1.302	1.300	1.300	1.302	1.300
OSVC	1.304	1.304	1.304	1.308	1.305	1.306
Rented Land (Ratio)	1.139	1.112	1.111	1.111	1.111	1.111
Farm target-profit	1.258	1.256	1.257	1.252	1.290	1.257
Farm target-rural employment	1.204	1.207	1.204	1.218	1.205	1.205
Farm target-soil protection	1.308	1.305	1.303	1.305	1.342	1.304
Wheat production	1.094	1.084	1.089	1.087	1.093	1.145
Agricultural associations	1.363	1.364	1.377	1.363	1.372	1.364
Min. of agriculture	1.290	1.290	1.284	1.291	1.292	1.283
Research institutions	1.441	1.458	1.501	1.479	1.439	1.427
Other farmers	1.151	1.159	1.152	1.159	1.161	1.160
Commercial companies	1.475	1.475	1.481	1.507	1.476	1.475

Agricultural journals	1.469	1.443	1.443	1.465	1.445	1.445
Mass media	1.315	1.281	1.283	1.293	1.290	1.289
Internet	1.256	1.254	1.264	1.255	1.271	1.,263
Field days	1.653	1.648	1.668	1.646	1.647	1.679
Trainings	1.355	1.367	1.349	1.375	1.373	1.357
Importance for climate change	7.181	7.781	5.195	8.977	7.518	2.407
Importance for profitability	7.077	7.850	5.094	9.106	7.519	2.447

Table B4: Application rates of specified adaptation strategies

Adaptation strategies	Applying this strategy? (Share of respondents in %)		
	Yes (already using it)	No (planning to use within 3 years)	No (no intention to use)
Minimal soil cultivation	48.3	8.38	43.30
No-tillage	4.47	5.31	90.22
Mulch	38.83	9.22	51.96
Mixed crops	38.27	15.36	46.37
Inter-cropping	5.03	12.57	82.40
Cover crops	67.04	9.78	23.18
Legumes cropping	23.18	10.06	66.76
Irrigation	8.10	4.75	87.15
Climate resilient varieties	56.15	20.95	22.91
New crops	24.02	28.77	47.21
Timber on arable land	2.79	3.35	93.85
Timber on pastures	2.51	3.91	93.58
Permanent soil cover	34.64	21.23	44.13

Crop rotation	91.62	3.63	4.75
Precision agriculture	26.54	31.28	42.18

Table B5: Perceived severity of specific climate change impacts

Climate change effects	**Perceived severity (share of respondents in %)**					
	No severity	**Low severity**	**Moderate severity**	**High severity**	**Very high severity**	**Not experienced**
Increasing temperature (vegetation period)	4.2	12.6	23.2	31.6	27.4	0.0
Changes in precipitation (vegetation period)	0.0	2.8	12.3	31.8	52.8	0.0
Increasing variability in temperatures and precipitation	0.3	4.5	26.5	38.0	29.6	0.0
Frequent extreme events (e.g. droughts)	0.3	2.2	9.8	32.4	54.5	0.0
Lower water accesibility	0.8	4.5	16.5	33.0	43.9	0.0
Shorter vegetation period	12.3	24.0	34.4	22.6	3.9	0.0
Change in seeding date	16.5	30.2	37.4	12.0	2.2	0.0
Change in harvesting date	16.2	28.2	36.3	15.9	2.0	0.0

Table B6: Degree of agreement on statements towards climate change

Climate change statements	Agreement on statements towards climate change (share of respondents in %)				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Climate change is affecting crop production in our farm	20.9	50.6	21.8	6.4	0.3
Changes in precipitation distribution affect crop production	40.8	50.8	7.5	0.8	0.0
Water erosion is more frequent in the last years	7.3	23.2	43.6	20.1	5.9
Wind erosion is more frequent in the last years	7.3	31.0	41.3	17.0	3.4
Drought has become a serious problem in the last 5 years	52.8	40.5	4.7	1.1	0.8
Climate change impact on crops might be decreased by agrotechnical measures	8.4	51.7	29.1	10.3	0.6